Michigan at a Climate Crossroads: Strategies for Guiding the State in a Carbon-Constrained World

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A project submitted in partial fulfillment of requirements
for the degree of Master of Science
(Natural Resources and Environment)

University of Michigan
Ann Arbor

April 2007

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A report of the Center for Sustainable Systems

Report No. CSS07-02

Abstract

The *Michigan at a Climate Crossroads: Strategies for Guiding the State in a Carbon-Constrained World Project* (MCCP) team developed state-level greenhouse gas (GHG) emission reduction policies for the State of Michigan to consider as it faces an emerging carbon-constrained world. The MCCP builds upon the results of the *Michigan Greenhouse Gas Inventory 1990 and 2002*, conducted by the Center for Sustainable Systems at the University of Michigan.

Approximately 180 regional stakeholders representing the industrial, commercial, higher education, government, and non-profit sectors provided the MCCP team with input and feedback throughout the duration of the project. The MCCP team used the US Environmental Protection Agency's (EPA) State Inventory Tool, the Energy 2020 model, and the Regional Economic Modeling, Inc. (REMI) Policy Insight Tool to calculate potential GHG emission reductions and economic impacts of state-level policies.

The MCCP demonstrated that enacting policies to reduce GHG emissions can positively affect the state's economy and reduce GHG emissions. Implementing a set of the state-level GHG emission reduction policies has the potential to reduce Michigan GHG emissions by 84 million metric tons of carbon equivalent (MMTCE) by 2025, while increasing both gross state product (GSP) by an average of $380 million per year and state employment by roughly 3,400 full-time jobs. The final policy analysis will be provided to members of the Michigan State Legislature and the Office of the Governor.

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List of Acronyms

21CEP	Michigan's 21st Century Energy Plan
AATA	Ann Arbor Transit Authority
AC	Alternating Current
ACEEE	American Council for an Energy Efficient Economy
AEO	Annual Energy Outlook
AF	Alternative Fuel
AFUE	Annual Fuel Utilization Efficiency
AVT	Alternative Vehicle Technology
B100	100% Biodiesel
B2	Biodiesel-Diesel Mix containing 2% Biodiesel
B20	Biodiesel-Diesel Mix containing 20% Biodiesel
B5	Biodiesel-Diesel Mix containing 5% Biodiesel
BAU	Business-As-Usual
BBTU	Billion British Thermal Units
BCC	Michigan Bureau of Construction Codes and Fire Safety
Bhp-hr	Brake-horsepower hour
BRT	Bus Rapid Transit
Btu	British Thermal Unit
CATA	Capital Area Transit Authority
CBECS	Commercial Building Energy Consumption Survey
CCC	Commodity Credit Corporation
CCX	Chicago Climate Exchange
CE	Carbon Equivalents
CG	Conventional Gasoline
CH4	Methane
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CO	Carbon monoxide
CO2	Carbon dioxide
CRP	Conservation Reserve Program
CRT	Commuter Rail Transit
CSS	Center for Sustainable Systems
DC	Direct Current
DDOT	Detroit Department of Transportation
DEQ	Department of Environmental Quality
DOE	United States Department of Energy
DSM	Demand Side Management
DVD	Digital Video Device
E10	Ethanol-Gasoline Mix containing 10% Ethanol (also referred to as RFG)
E85	Ethanol-Gasoline Mix containing 85% Ethanol
EF	Efficiency Factor
EIA	Energy Information Agency
EOR	Enhanced Oil Recovery
EPA	United States Environmental Protection Agency
EPRI	Electric Power Research Institute
EtOH	Ethanol
FF	Fossil Fuel
FFV	Flex Fuel Vehicle

FHWA	Federal Highway Administration
FLEP	Forest Land Enhancement Program
FRED	Fossil Research Database
FT	Fisher-Tropsch
FTA	Federal Transit Administration
GHG	Greenhouse gas
GJ	Gigajoule
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
GSP	Gross State Product
GWP	Global Warming Potential
HDDV	Heavy Duty Diesel Vehicle
HERS	Home Energy Rating Service
HES	Home Energy Saver Model
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
IECC	International Energy Conservation Code
IGCC	Integrated Gasification Combined-Cycle
Inventory	Michigan Greenhouse Gas Inventory 1990 and 2002
IRC	International Residential Code
ITC	Investment Tax Credit
km	Kilometer
kWh	Kilowatt-hour
LDC	Light Duty Personal Car
LDT	Light Duty Truck
LDV	Light Duty Vehicle
LED	Light Emitting Diode
LEED	Leadership in Energy and Environmental Design
LPG	Liquified Petroleum Gas
LPW	Lumens per Watt
LRT	Light Rail Transit
mmcf	Million Cubic Feet
MAERS	Michigan Air Emissions Reporting System
Magland	Marginal Agricultural Land
MATS	Muskegon Area Transit System
MBtu	Million British Thermal Units
MCCP	Michigan at a Climate Crossroads: Strategies for Guiding the State in a Carbon Constrained World project
MDA	Michigan Department of Agriculture
MDOT	Michigan Department of Transportation
MEA	Monoethanol amine
MEC	United States Model Energy Code
Mgal/yr	Million gallons per Year
mi/gge	Miles per gallon gasoline equivalent
MJ	Megajoule
MMBTUhr	Million British Thermal Units-Hour
MMTCE	Million metric tons of carbon equivalent
MMTCO2	Million metric tons of carbon dioxide
mpg	Miles per gallon
MPSC	Michigan Public Service Commission
MRCSP	Midwest Regional Carbon Sequestration Partnership
mmscf	Million Standard Cubic Feet

MSEC	Michigan Sustainable Energy Coalition
MTA	Flint Mass Transportation Authority
MTC	Metric tons of carbon
MTCE	Metric tons of carbon equivalent
MTCO2	Metric tons of carbon dioxide
Mton	Metric ton
MUEC	Michigan Uniform Energy Code
MW	Megawatt
MWh	Megawatt-hour
N2O	Nitrogen oxide
NAAQS	National ambient air quality standard
NCGA	National Corn Growers Association
NG	Natural Gas
NGCC	Natural gas combined-cycle
NLDC	National Land Cover Dataset
NOx	Nitrogen oxides
NREL	National Renewable Energy Laboratory
NTD	National Transit Database
NYSERDA	New York State Energy Research and Development Authority
O&M	Operations and Maintenance
PC	Pulverized-Coal
PM	Particulate matter
psi	Pounds per square inch
PTC	Production Tax Credit
REC	Renewable Energy Credit
RECS	Residential Energy Consumption Survey
REMI	Regional Economic Modeling, Inc. Policy Insight Tool
RFG	Reformulated Gasoline
RFS	Renewable Motor Fuel Standard
RPS	Renewable Portfolio Standard
RTSP	Ann Arbor to Detroit Rapid Transit Study Project
SB 1333	Senate Bill 1333
scf/bbl water	Standard cubic foot per barrel of water
SEMCOG	Southeast Michigan Council of Governments
SMART	Suburban Mobility Authority for Regional Transportation
SOx	Sulfur oxides
STARS	Saginaw Transit Authority Regional Services
T&D	Transmission and distribution
tC	Metric tons of carbon (see above Mton)
tCO2	Metric tons of CO2 (see above Mton)
TSM	Transportation Systems Management
USDA	United States Department of Agriculture
USGS	United States Geologic Survey
VMT	Vehicle miles traveled
WTP	Well-to-Pump
WTW	Well-to-Wheel

Executive Summary

The *Michigan at a Climate Crossroads: Strategies for Guiding the State in a Carbon-Constrained World Project* (MCCP) analyzed the greenhouse gas (GHG) reduction potential and economic effects of eight state-level strategies. Using standard modeling techniques, the MCCP demonstrates that enacting policies to reduce GHG emissions can positively affect the state's economy. Enacting a set of state-level GHG emission reduction policies has the potential to reduce Michigan GHG emissions by 84 million metric tons of carbon equivalent (MMTCE) by 2025, while increasing gross state product (GSP)[i] by an average of $380 million per year, and increasing state employment by roughly 3,400 full-time jobs. (See Table 2.)

The MCCP builds on the results of the *Michigan Greenhouse Gas Inventory 1990 and 2002* (Inventory) conducted by the Center for Sustainable Systems at the University of Michigan. The Inventory indicates that total statewide GHG emissions increased 9% from 57.4 MMTCE in 1990, to 62.6 MMTCE in 2002. In 2002, 33% of Michigan GHG emissions resulted from the production of electricity in the state, 26% from the transportation sector, and 17% from industrial operations.[ii] Beyond providing a baseline for Michigan GHG emissions, the Inventory highlights opportunities for improvement. Across the United States, state and local governments are leading efforts to develop policy approaches to GHG emissions management. As of September 2006, 29 states had developed State Action Plans (also referred to as Climate Action Plans) specifically targeting GHG emissions reductions; the state of Michigan had not. The MCCP serves to help Michigan legislators understand proactive mechanisms for reducing emissions and to determine their economic impact.

In February 2007, the Intergovernmental Panel on Climate Change reported that the observed increase in global average temperature over the past 50 years is very likely (>90% certainty) due to the observed increase in anthropogenic GHG emissions. The MCCP provides crucial strategies to help the state become the Midwest's leader in climate change policy. These results emphasize that by focusing on energy efficiency, fuel switching, carbon sequestration, and renewable energy, the state can realize economic benefits. Additionally, this report supplements the findings of the Michigan's 21st Century Energy Plan.[iii] A responsible economic development strategy for Michigan should position the state to respond to the impact of impending federal policies intended to reduce GHG emissions. Whether such policies take the form of a mandatory cap-and-trade system, taxes on GHG emissions, or other mechanisms, aggressive action will stimulate and encourage clean energy technology innovations and efficiency improvements that can provide significant economic benefits to the state. By taking immediate action, Michigan could realize the economic benefits generated by GHG reduction policies. In a carbon-constrained world, the economic benefits of greenhouse gas reductions will likely be even greater.

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[i] Gross state product is a measure of the total economic output of a US state.
[ii] Bull, P., McMillan C., and Yamamoto A. (2005). *Michigan Greenhouse Gas Inventory 1990 and 2002*. Master's Thesis, School of Natural Resources and Environment, University of Michigan: Ann Arbor. Retrieved Jan. 2006 from: http://css.snre.umich.edu/css_doc/CSS05-07.pdf
[iii] Michigan Public Service Commission (2007). *Michigan's 21st Century Energy Plan*. Lansing, MI. Retrieved Jan. 2007 from: http://www.dleg.state.mi.us/mpsc/electric/capacity/energyplan/index.htm

The MCCP Team worked with over 150 regional stakeholders in the industrial, commercial, higher education, government, and non-profit sectors to develop policy options and parameters for MCCP modeling. The team constructed GHG models for each policy and utilized the Regional Economic Modeling, Inc. (REMI) Policy Insight Tool, in combination with the Energy 2020 model, to determine the economic effects of each policy. The team analyzed the following eight policies:

1. **Renewable Portfolio Standard (RPS)**: The RPS policy increases production of renewable energy fed into the electric grid and reduces fossil fuel consumption in the electric sector. The team analyzed two RPS policies: one requires regulated utilities to provide 8% from qualifying renewable sources by 2015, the other requires 10% by 2015, and 20% by 2025.[iv]
2. **Appliance Energy Standards**: Appliance efficiency standards reduce the energy consumed by common industrial, commercial, and household appliances. This policy requires appliance efficiency levels above those mandated by federal standards if already covered, and imposes new standards for appliances not already covered. MCCP modeled the effects of Michigan State Bill 1333.
3. **Alternative Fuels**: Alternative fuels policies promote the production, distribution, and use of bio-based renewable fuels for the motor vehicle transportation sector. The team analyzed two policy alternatives: one, a production tax credit for ethanol production, and two, a renewable fuel standard for state motor fuel usage.
4. **Carbon Sequestration**: This policy is intended to capture the carbon sequestration potential of tree plantings on 1% and 10% of marginal agricultural lands. This policy is designed as a cost-share between non-industrial private landowners and the state or federal government.
5. **Building Codes**: To increase energy efficiency in homes, the residential building code policy requires higher R-values for ceiling, walls, floors, windows, and basements in all new single-family homes built in the state. The team analyzed two policies: one roughly equivalent to the International Residential Code (IRC) 2004, and the other a combination of the International Energy Conservation Code (IECC) 2006 and Department of Energy (DOE) insulation recommendations for the state.
6. **Mass Transit Development/Enhancement**: This policy implements a mandatory fuel-switch directed at urban mass transit buses. This policy requires affected entities to switch from diesel to biodiesel (B20).
7. **Alternative Vehicle Technology**: This policy implemented a state-sponsored consumer tax credit for the purchase of alternative vehicle technologies.
8. **Combined Heat and Power (CHP)**: Incentives were designed to increase CHP implementation and utilization in Michigan, in an attempt to introduce more fuel-efficient energy sources, thus reducing the state's GHG emissions. The MCCP assumed Michigan could produce at least 180 MW of electricity by utilizing CHP as a replacement electricity and steam source for appropriate industrial candidates.

[iv] 8% by 2015 refers to the Michigan Sustainable Energy Coalition (MSEC) scenario and 10% by 2015 and 20% by 2025 refers to the MCCP scenario.

For each policy, the MCCP team modeled several scenarios to help understand the different potential effects of the policy. The table below provides a list of scenarios with the greatest GHG reduction potential and their corresponding economic impact.

Table 1. Individual Policy Results:
GHG Reduction Potential and Economic Effects (2007 - 2025)

Policy	Cumulative GHG Savings (MMTCE)[1]	Avg. Annual Δ GSP (2000 $Millions)[2]	Avg. Annual Δ Job-Years[3]
20% Renewable Portfolio Standard	**39.9**	**64.6**	**881**
Renewable Motor Fuel Standard	**13.2**	**283**	**1,700**
Carbon Sequestration	**10.3**	**-46.7**	**- 212**
Ethanol PTC	**8.45**	**504**	**2,970**
Appliance Standards	**7.35**	**38.3**	**437**
Building Codes	**6.83**	**54**	**644**
Combined Heat and Power	**6.09**	**-13.6**	**-81**
Mass Transit Fuel Switching	**0.13**	**4.48**	**31**

1. MMTCE: Million Metric Tons of Carbon Equivalent.
2. GSP: Gross State Product.
3. Job-Years: Average increase in employment over a baseline on a year-by-year basis. For example, 100 job years is equivalent to either 10 jobs lasting 10 years or 100 jobs lasting one year.

Note: Negative numbers are due to large government subsidies.

Table 2. Summary of Results:
Cumulative Impact of MCCP Policies (2007-2025)

	GHG Emissions Reductions	Avg. Annual Δ GSP, $	Total Jobs Created
MCCP Policies[1]	84 MMTCE	380 Million	3,400

1. This table represents an estimate of impact from implementing a subset of the MCCP policies, selected to eliminate potential overlapping impact. The policies included in these cumulative figures are Renewable Portfolio Standard, Appliance Standards, Renewable Motor Fuel Standard, Carbon Sequestration, Building Codes, and Combined Heat and Power.[v]

The MCCP findings show that the modeled policies represent a range of GHG emission reduction potentials. If state GHG emissions continue to grow by 9% every 12 years (consistent with the Inventory's findings), Michigan GHG emissions in 2025 are predicted to be 74.6 MMTCE. By implementing of a set of the MCCP modeled policies, the state could cut emissions to approximately 65.7 MMTCE, reducing projected GHG emission levels by 12%. However, the modeled policies only slow the overall growth rate of the state's GHG emissions, and are not sufficient to reduce emissions below 2002 levels. Thus, these policies represent only a first step. The state will need to take actions more substantial than simply implementing the policies modeled by MCCP to significantly reduce emissions and help avoid the adverse consequences of global climate change.

[v] Specific policy scenarios included in this result include: MCCP RPS (20% renewable by 2025), Renewable Motor Fuel Standard--Cellulose and Corn Based Ethanol Supply (25% RFS by 2025), Carbon Sequestration--10% magland planted with conifers (CRP funding), Appliance Efficiency Standards--SB 1333 (Introduced by Senator Brater), Building Codes--MCCP 2006 (IECC 2006 and DOE Insulation recommendations according to climate zones), and Combined Heat and Power Incentives--180 MW, 6,570 hr/yr ($0.05/ kWh state subsidy).

MCCP modeling indicated that the combined economic effects of these policies are a net positive for the state, with all but two policies resulting in net positive economic effects. As with all policies, the benefits and costs vary within and across sectors. While average annual impacts are mostly positive, some individual policies did have negative annual GSP and employment figures. Additionally, economic modeling did not account for a future price of carbon. Therefore, MCCP considers reported results to be conservative estimates for the economic benefits of these policies in a carbon-constrained world. The Chicago Climate Exchange has operated a voluntary carbon-trading market since 2003, in which carbon prices range from $3.67 -$18.33/MTCE.[vi] Under this price scenario, the cumulative MCCP GHG emission reductions (84 MMTCE) would be roughly valued between $308 million and $1.54 billion by trading the carbon offsets that these policies produce. While it was not possible for the MCCP team to model a price of carbon due to the uncertainty of future climate legislation, various federal climate bills provide some perspective on the range of potential future carbon prices. The US Department of Energy's Energy Information Administration analyzed proposed bills and predicted future (2025-2030) carbon prices ranging from $52-$180/MTCE.[vii]

The following are summary results of the individual policies.

1. **Renewable Portfolio Standard (RPS)**: Both RPS policies modeled by the MCCP team are effective instruments for reducing GHG emissions and stimulating economic development. By 2025, the 8% RPS reduces cumulative GHG emissions in the electric sector by 20.3 MMTCE. By that year, annual emissions reductions reach 1.4 MMTCE. Over the same period, the 20% RPS reduces cumulative GHG emissions by 39.9 MMTCE. Under this more ambitious policy, annual emissions reductions in this period increase from 1.4 MMTCE with the 8% RPS to 4.5 MMTCE. Most emissions reductions are achieved by new renewable electric generation (mostly wind and biomass) displacing the development of future coal and natural gas plants.

   These GHG reductions can be achieved while producing modest, yet positive, economic benefits. Annually, the 8% RPS contributes an average of $144 million to the GSP, while the 20% RPS contributes an average of $64.6 million. (If the modeling period were extended beyond 2025, the 20% RPS would show greater economic benefits.) The construction sector realizes economic benefits by producing new renewable electric generating facilities.

2. **Appliance Energy Standards**: By 2025, Michigan could experience a reduction of 7.35 MMTCE of GHG emissions and an average annual growth in GSP of $38.3 million as a result of implementing SB 1333. This translates roughly into a total cumulative savings of $1.89 billion from reductions in end-use electricity consumption and $14.2 million from reductions in end-use natural gas consumption. Appliance efficiency standards resulted in significant in-state GHG

[vi] Chicago Climate Exchange prices have ranged from $1.00-$5.00/metric ton of CO_2-equivalent since its founding in 2003. Historical prices retrieved Mar. 2007 from: http://www.chicagoclimatex.com/trading/marketData.html.

[vii] Energy Information Administration (2007). *Energy Market and Economic Impact of a Proposal to Reduce Greenhouse Gas Intensity with a Cap and Trade System* (Washington, D.C.) projects an allowance price of $14.18/metric ton of CO_2e in 2030. Energy Information Administration (2006). *Energy Market Impact of Alternative Greenhouse Gas Intensity Reduction Goals* (Washington, D.C.) projects an allowance price of $49/ metric ton of CO_2-e in 2030, for the most aggressive greenhouse gas intensity reduction scenario analyzed.

emissions reductions and job growth and increases in GSP. The majority of the benefits related to GHG emissions reductions are attributed to the reduction in fuel consumption by the utility sector. The majority of the benefits related to economic impact are attributed to the redistribution of consumer spending as a result of savings on fuel and electricity spending.

3. **Alternative Fuels**: The alternative fuels policies, Ethanol Production Tax Credit and Renewable Fuels Standard, present similarly positive effects. Fuel cycle GHG emissions are dramatically reduced from the Michigan transportation sector by shifting a proportion of motor fuel usage from petroleum-based fuels to bio-based fuels. This transition also provides a significant economic benefit, as a state that imports nearly 100% of its conventional gasoline will move to an increasingly locally supplied fuel system. Through the pursuit of in-state bio-fuel production, Michigan can obtain significant GHG emission reductions, realize economic benefits from a more localized fuel system, and take steps to reduce its dependence on foreign oil.

4. **Carbon Sequestration**: By 2025, Michigan can sequester 10.3 MMTCE by planting conifers on 10% of the state's marginal agricultural land. The economic effects of this policy, however, are negative due to the cost of planting trees by participating landowners and government. These costs could be reduced if a price of carbon were factored into the economic model; the MCCP team was unable to include a price of carbon ($/MTCE) due to the uncertainty of future climate legislation. Nevertheless, the Chicago Climate Exchange (CCX) currently operates a carbon trading market and, since 2003, prices have ranged from $3.67/MCTE to $18.33/MTCE. Considering the 10.3 MMTCE sequestered by planting 10% of marginal agricultural land with conifers and the CCX's range of carbon prices, this policy could generate $37.8 million to $189 million through the trading of carbon forestry offsets. While total tree planting costs are approximately $204 million, this revenue would decrease the magnitude of the negative economic effects. Pursing Conservation Reserve Program funds from the federal government would be an additional mechanism to increase the economic benefits. This policy would be better suited under a carbon-constrained world scenario, in which a price of carbon could create the need for mechanisms, such as carbon sequestration projects, to offset GHG emissions.

5. **Building Codes**: The modeled code equivalent to the IRC 2004 demonstrated emission reductions of 6.83 MMTCE, with an average annual GSP contribution of $54 million. Energy conservation achieved through implementation of the code would result in approximately 2.3 million kWh of electricity and 7.8 million therms of natural gas savings by lowering demand for energy needed to heat and cool the new houses. On average each house saves 55.5 kWh and 186 therms per year. The combination of IECC 2006 code and DOE recommendations save 4.87 million kWh and 17.6 million therms per year. On average, this equals 116 kWh and 417 therms of savings per house per year. The per house energy savings translate directly into financial savings for the consumer to spend elsewhere in the economy while reducing the income for the utility sector. These effects, combined with the assumed increased house construction costs of 2%, which were passed directly onto the consumer, yielded a net positive for the state GSP and job-years.

6. **Mass Transit Development/Enhancement**: Fuel-switching in urban mass transit buses demonstrates the potential to reduce GHG emissions, create positive economic effects, and reduce foreign oil consumption. This policy is small in scale (focused only on mass transit buses) and produces the lowest cumulative GHG reductions (0.13 MMTCE) of the analyzed policies. Average annual changes in GSP were $4.74 million and an addition of 33 job-years. A policy with a broader scope, focusing on a larger number of diesel vehicles, could further increase the GHG reduction potential and economic benefits of a fuel-switching policy.

7. **Alternative Vehicle Technology**: Increasing the adoption of alternative vehicles is an important step in weaning the transportation sector off petroleum-based fuels. However, a consumer tax credit is an economically inefficient mechanism to achieve this end.

8. **Combined Heat and Power**: By 2025, Michigan can experience a reduction of 6.09 MMTCE by generating up to 180 MW of power through CHP systems instead of from utilities. Economic modeling for a state subsidy of $0.05/kWh given to CHP adopters to achieve the full 180 MW was a burden on the state, resulting in negative economic impact. Similarly, implementing 180 MW of CHP power in the state without a subsidy resulted in slightly negative impact. Given the uniqueness of Michigan's quasi-unregulated utility sector, the variety of electricity rates, and substantial standby and back-up fees, the state still needs to consider providing incentives for adopting CHP. However, incentives do not need to be as high as $0.05/kWh. Further exploration into variations of state incentives, such as production tax credits and investment tax credits, should be conducted to fully understand potential adoption rates and the range of CHP's potential impact.

Detailed descriptions of the above policies, modeling methods, and results are provided in the full report.

Michigan will need to implement innovative and far-reaching policies to achieve significant reductions in GHG emissions, minimize economic risks, and take advantage of economic opportunities presented by a carbon-constrained world. Starting now can help the state prepare for likely federal action, allow it to assume a leadership position, and stimulate the economy in the process. The policies outlined above can guide the state forward. We have demonstrated that the state can achieve environmental improvements at the same time that it creates positive economic outcomes.

I. Project Overview and Purpose

The Michigan Greenhouse Gas Inventory 1990 and 2002 (Inventory), conducted by the Center for Sustainable Systems (CSS) at the University of Michigan, indicates that total statewide greenhouse gas emissions (GHG) increased 9% from 57.4 million metric tons of carbon equivalent (MMTCE) in 1990, to 62.6 MMTCE in 2002. In 2002, 33% of Michigan GHG emissions resulted from the production of electricity in the state, 26% from the transportation sector, and 17% from industrial operations.[viii] The Inventory highlighted opportunities for action and provided a baseline to measure progress. Following the conclusion of the Inventory project, CSS explored further research through the *Michigan at a Climate Crossroads: Strategies for Guiding the State in a Carbon-Constrained World Project* (MCCP) to determine possible methods to reduce state GHG emissions.

Across the United States, state and local governments are leading efforts to develop policy approaches to GHG emissions management. As of September 2006, 29 states had developed State Action Plans (also referred to as Climate Action Plans) specifically targeting GHG emissions reductions. Michigan has yet to develop a State Action Plan. Additionally, several states, including California and New York, are pursuing more sweeping legislative action to reduce emissions. For example, in 2005 California Governor Arnold Schwarzenegger signed Executive Order S-3-05 calling to reduce GHG emissions 80% below 1990 levels by 2050. Additionally, a range of federal GHG reduction strategy proposals have been introduced to the US Congress, including scenarios for a Cap and Trade System and a Renewable Portfolio Standard.

As Michigan struggles to improve its economy, the state must consider the potential effects of impending federal GHG emission regulations. Whether such policies take the form of a mandatory cap-and-trade system, taxes on GHG emissions, or other mechanisms, aggressive action now could stimulate and encourage clean energy technology innovations and efficiency improvements that will provide significant economic benefits to the state.

Building on legislative and voluntary actions in other states as well as on input from Michigan stakeholders[ix], the MCCP analyzed a set of state-level GHG emissions reduction strategies, in order to inform Michigan policymaking as the state considers strategies and initiatives to capitalize on future federal GHG regulations. MCCP results include an assessment of both the emission reduction potential and economic effects of a set of eight GHG emission reduction strategies.

Specific project goals included:

- identifying potential strategies and initiatives for GHG management in Michigan,
- engaging Michigan stakeholders throughout the MCCP process to ensure the development of highly feasible strategies,
- estimating the GHG emission reductions of the selected strategies, and
- accounting for the potential economic benefits and costs associated with proactive carbon management in Michigan.

[viii] Bull, P., C. McMillan, A. Yamamoto and G. Keoleian (2005). *Michigan Greenhouse Gas Inventory 1990 and 2002*. Master's Thesis, School of Natural Resources and Environment, University of Michigan, Ann Arbor (CSS05-07). http://css.snre.umich.edu/css_doc/CSS05-07.pdf.

[ix] MCCP stakeholders represented the manufacturing, transportation, energy, agriculture, building, non-governmental organization, government, and higher education sectors. In total, the MCCP team contacted 185 individuals to participate in and inform the project.

II. Project Process and Methodology

The MCCP team developed the project according to the following key tasks and formal stakeholder engagement opportunities:

Task 1. Identify and select emission reduction strategies warranting further analysis. Identify stakeholders affected by strategies and invite them to participate in the project.

Forum 1: Convene stakeholders to screen strategies for Tasks 2 and 3.

Task 2. Evaluate emission reduction potential of identified strategies.

Task 3. Assess the economic effects of each identified strategy, in terms of change in gross state product (GSP) and employment.

Forum 2**:** Reconvene stakeholders to review Tasks 2 and 3, assess results, and make recommendations for policy implementation.

Task 4. Report findings and present to Michigan policy-makers and others.

TASK 1. Strategy Identification

In recent response to the challenges presented by climate change, numerous voluntary programs, initiatives, and regulations for GHG emissions reduction have been proposed and implemented by states, including Michigan. These policies and programs offer a range of options to reduce GHGs. With numerous states now pursuing GHG emission reductions, examples of existing programs continue to multiply. Several examples of carbon emission management strategies that can be implemented at the state level include[x]:

- Voluntary industry performance improvement programs, such as the "Green Tier" program in Wisconsin.
- Industry performance improvement loan programs, such as those provided by the Industrial Energy Efficiency Fund in Indiana.
- Transportation fuel standards, such as specific biodiesel requirements in Minnesota.
- Renewable Portfolio Standards, such as the Texas Renewable Energy Mandate Rule.
- Net metering requirements, currently existing in 35 US states. Michigan has a voluntary statewide net metering program.[1]
- Tax incentive programs for renewable energy, such as West Virginia tax code adjustments.
- Carbon cap-and-trade programs supported by organizations, such as the Northeast States for Coordinated Air Use Management. Three California municipalities are trading on the Chicago Climate Exchange.

An example of carbon emission management strategies in Michigan includes the initiatives outlined in Governor Jennifer Granholm's Executive Order 2005-4, focusing on energy efficiency in state facilities and operations, included in the overall list of potential MCCP strategies. These initiatives along with other policies and programs

[x] Rabe, B.G. (2004) *Statehouse and Greenhouse: The Emerging Politics of American Climate Change Policy*. Brookings Institution Press, Washington, D.C.

shaped more than 75 potential GHG emission reduction strategies. The MCCP team then selected strategies with possible applications in Michigan for initial consideration by the stakeholders. Strategy options affecting each major sector of the economy (electricity, buildings, transportation, industry) were considered. In summary, this list of GHG emission reduction strategies drew from three primary sources: similar analyses performed in other states, feedback from a questionnaire distributed to stakeholders, and supplemental research performed by the MCCP team.

Forum I

The MCCP was designed to be stakeholder-driven and included two formal opportunities for stakeholders to be involved in the identification of strategies for consideration in the project scope and through contributions to the project analysis and recommendations of strategies to the state based on project findings.

Forum I was the first formal opportunity for the MCCP team to engage the stakeholders as a whole. As such, the MCCP team convened key stakeholders from the industrial, commercial, higher education, government, and non-profit sectors to facilitate the selection of emissions reduction strategies for further analysis in Tasks 2 and 3. The Forum was held on January 31, 2006, in the Michigan League on the University of Michigan's Central Campus in Ann Arbor.

Forum I Objectives

Forum I was designed to assess and identify a list of GHG emission reduction strategies warranting further analysis. This objective was accomplished by screening a "long list" of strategies to identify those with the most promise of positive economic effects, GHG emission reductions, and overall stakeholder-support.

Forum I Proceedings

- <u>Project Team and Stakeholder Introductions:</u> Forum I began with a roundtable introduction of Forum I participants including approximately 60 stakeholders, Forum speakers, and the MCCP team.
- <u>Project Description and Forum I Guidelines:</u> The MCCP team provided the stakeholders with a detailed description of the project, including the goals and objectives of Forum I. Additionally, guidelines for the Forum I process were discussed and accepted by the stakeholder group.
- <u>Presentation of Potential GHG Emission Reduction Strategies</u>: The MCCP team presented a detailed list of more than 75 GHG emission reduction strategies, grouped in six broad sectors: Transportation, Manufacturing, Agriculture, Energy, Building, and Government/Education. Stakeholders discussed the strategies presented by the MCCP team and proposed additions and clarifications. Throughout the plenary discussions of Forum I, the MCCP team recorded in detail the shareholders' comments and concerns. Stakeholders discussed concerns regarding how strategies would be funded, how to address strategies that have effects that cross the boundaries of economic sectors, and how potential tax incentive programs could be analyzed.

- Indication of Preferences for Specific Strategies: Following the presentation and discussion of the strategies, stakeholders indicated, through an open voting process, their preferred strategies within each sector.
- Discussion of Preferred Strategies: The stakeholders discussed the top three to five strategies in each sector based on the open voting results. This discussion revealed concerns and points for consideration as the MCCP team and stakeholders refined the list of strategies targeted for the detailed analysis. Stakeholders discussed concerns regarding the implementation feasibility of proposed strategies, as well as ways to address concerns regarding the potential negative economic impact associated with some strategies.
- Recommendation of Priority List of Strategies: Stakeholders indicated through a second round of voting a subset of preferred strategies that should be high priority in the analysis phase of the MCCP. Of the top twenty strategies, ten were established as priorities for the MCCP team to analyze. (See Table 1.)

Table II.1. Prioritized GHG Reduction Strategies.

1	Renewable Portfolio Standard/ Clean Energy Portfolio Standard
2	Demand-Side Management
3	Alternative Fuel Infrastructure/ Flex/Biofuels*
4	Carbon Sequestration/ Soil Management
5	Revise Building Codes/LEED or Energy Star
6	Mass Transit Enhancement and Development
7	Production Tax Credit for Renewables/ Net Metering
8	Tax Credit for Alternative Vehicles Technologies Incentives for Production and R&D
9	Tax Incentive Programs

*Note: Biofuels was listed as a stand-alone strategy during Forum I, but was consolidated into strategy 3.

Forum I Follow-up

The next stage of the process utilized the nine identified strategies for developing specific GHG emission reduction policies. The MCCP team worked with stakeholders to narrow and define the policy language, taking into account current state activities, political feasibility, and modeling capabilities. Throughout Tasks 2 and 3 described below, members of the MCCP team contacted stakeholders about modeling assumptions and related research questions.

TASK 2: GHG Emissions Reduction Potential Modeling

Using the policies identified in the last stage of Task 1, the GHG analysis evaluated potential emission reductions relative to emissions resulting from a business-as-usual scenario. The Inventory model follows the standard US EPA Emission Inventory Improvement protocol. Scenarios were designed to reflect variations in technology penetration, changes in demand, and other variables to provide a robust understanding of expected emission reduction benefits for each policy. The EPA's *States Guidance*

Document: Policy Planning to Reduce Greenhouse Gas Emissions was referenced for the purpose of understanding the various scenarios.

Using Microsoft Excel, the MCCP team developed GHG emission reduction models for each policy. Modeled GHG pollutants include: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The MCCP utilized a standard activity-based framework for modeling GHG emissions associated with each policy. Figure 1 presents a simplified form of this framework, illustrating that a specific activity is multiplied by an appropriate GHG emission factor to obtain the associated GHG emissions. For MCCP modeling purposes, activities--for example, vehicle miles traveled in the transportation sector or tons of coal burned in the electricity sector--were identified for each policy.

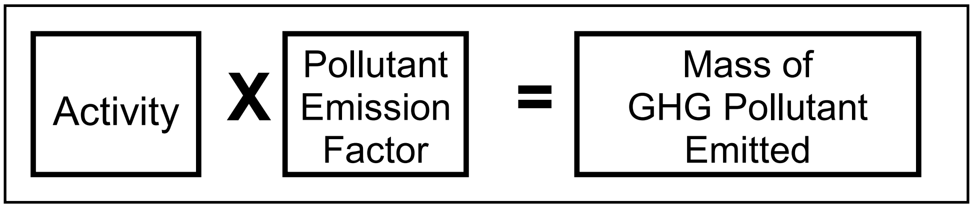

Figure II.1. Activity Based GHG Emission Calculation Framework.

GHG emission factors were obtained from available public sources. For example, the MCCP team used factors from the US EPA for the electricity sector, Chicago Climate Exchange for carbon sequestration, and the Argonne National Laboratory's Greenhouse Gas, Regulated Emissions, and Energy Use in Transportation (GREET) model for the transportation sector.

The MCCP process dictated that GHG emission reductions or increases were measured as a net change from a likely business-as-usual (BAU) case/scenario, allowing two approaches for applying the activity-based framework. The approach determined the level of the activity under BAU and under the policy, then determined the net change in activity level, and multiplied by the emission factor to determine the net effect on emissions. Alternatively, the GHG emissions associated with the BAU activity can be calculated by applying the emission factors and the GHG emissions under the policy scenario. The net change in emissions is then calculated by netting the BAU emissions and the policy emissions.

In all of the GHG policy models, GHG emissions were determined for each of the three listed GHG compounds above. However, it is typical to report GHG emissions as total emissions of either carbon or CO_2. The conversion of individual GHG compound mass emissions to a common base, such as CO_2, is accomplished using Global Warming Potential (GWP) figures. GWP is a widely accepted measure of how much a specific GHG contributes to global climate change in relation to CO_2, the benchmark GHG. The common unit resulting from using the GWP figures is referred to as carbon dioxide equivalents (CO_2-e). Therefore, one unit of CH_4 contributes the same to global climate change as 21 units of CO_2, and one unit of N_2O is equivalent to 310 units of CO_2. The GWP figures are listed below.

- CO_2 GWP = 1
- CH_4 GWP = 21
- N_2O GWP = 310

The MCCP team reported the effects of GHG emissions on a basis of carbon equivalents (CE). GHG emissions are often reported in either CO_2-e, as calculated using the GWP method described above, or CE. The process for determining the CE emissions from the CO_2-e is achieved by determining the contribution of carbon to the carbon dioxide molecule on a molecular weight basis. More specifically, the molecular weight of carbon is 12 grams/mole, and the molecular weight of CO_2 is 44 grams/mole (12 grams from C and 32 grams from O_2). Therefore, one unit of CE is equal to 12/44 units of CO_2-e. This conversion was applied to the units of CO_2-e calculated from the activity-based method and the GWP conversion in order for MCCP team to report GHG emission results in units of carbon equivalents.

Detailed descriptions of the GHG emission reductions modeling are included in subsequent policy-specific chapters of the report.

TASK 3: Economic Impact Modeling

Michigan's economy needs a competitive response to national policies regulating GHG emissions. Given such policies, the state will need to assess the economic impact of business-as-usual relative to a proactive GHG strategy for maximum job growth. GHG management programs can provide economic development opportunities. For example, a recent assessment by the Renewable Energy Policy Project (REPP) found that the development of a strong market for wind power in the US could create 8,549 jobs in Michigan. The REPP assessment also found that Michigan is the second leading state in employment potential in the area of wind power rotor manufacturing.[xi]

Task 3 of the MCCP included an assessment of each strategy's economic effects in terms of changes to the GSP and employment. The MCCP team used two different models--the Energy 2020 model and the REMI model--to determine the impact of the policies on the state of Michigan. In tandem, the GHG and economic results point to policies that best position the state to adapt to national climate change policies while strengthening the state's economy.

Energy 2020 Model

Developed by Systematic Solutions, Inc., the Energy 2020 model is designed specifically for modeling changes to a region or state's energy sector. The model covers electric utilities, transportation, extraction industries, and related regulatory agencies, and was calibrated to the state of Michigan using historical data and REMI's baseline forecast (see below). The future baseline was then modified to match projections developed by the Michigan Public Service Commission's Capacity Need Forum (CNF), which estimated future electric power needs for the state.

REMI Policy Insight Model

The Regional Economic Models, Inc. (REMI) Policy Insight Tool (Version 8.0) is a general equilibrium model designed to inform policy-makers of the potential economic impact of various government activities. The model can cover the entire nation, individual states, groups of states, and sub-state regions (i.e. counties and large cities).

[xi] Sterzinger, G., and M. Svrcek (2004) *Wind Turbine Development: Location of Manufacturing Activity.* Renewable Energy Policy Project, Washington, D.C.

The particular version that the MCCP team utilized treats Michigan as one region and divides the economy into 70 sectors. The model for policy analysis follows four steps:
1) Formulate a policy question.
2) Generate a baseline forecast.
3) Generate an alternative forecast with affected policy variables.
4) Compare the two forecasts.

The baseline forecast used for the MCCP was the regional control developed by REMI for the state of Michigan. REMI uses historical economic data for the various sectors of the state's economy and projects current trends into the future as a prediction of future economic activity. Because the MCCP project was primarily concerned with *changes* in GSP and employment, as opposed to final *absolute* levels of these variables, inaccuracies in the state's predicted future economy are not a significant variable. This forecast was used as a foundation upon which to analyze the impact of changes brought about by the MCCP-modeled policies.

To create the policy case, the MCCP team used the Energy 2020 model to translate policy mandates into the variables used by the REMI model. The MCCP compared the baseline forecast for Energy 2020, matching the CNF projections to a policy case that included changes brought about by the various MCCP policies. Because Energy 2020 is specifically designed to model the energy sector, the MCCP team had a larger and more representative suite of variables available as inputs into REMI. The output data from the Energy 2020 analysis were specifically designed to match the input variables available in the REMI model. The Energy 2020 model allowed us to translate changes in energy variables (such as the mix of renewable-based and fossil fuel-based electricity generation) into changes in economic parameters (such as demand for construction, electrical equipment, and fuel sources). These changes were then compared to the baseline case in REMI to measure the economic impact of the policies. The process involved iterations between the two models, with output from one run serving as input for the next, until the results converged around a final outcome.

The output data from REMI can be displayed as a final level, an absolute change, or a percent change. For instance, the REMI model can show that a policy will result in a total employment level in Michigan of 5,100,000 people, an increase of 100,000, or an increase of 2%. The values are calculated on an annual basis over a user-defined time period, with the model forecasting through the year 2025. While the model gives a large amount of data as output, the MCCP team focused on absolute and percentage changes in state employment and GSP.

Input Variables

The input variables for the model fall into the following six categories, or blocks:

1) *Output Block*: The Output Block includes variables related to industry output and demand, disposable income, consumer and government spending, and investment spending. Consumer spending categories include household operation, housing, transportation and gasoline, durables and non-durables, and general services. Industry output keeps all new purchases within the state. Industry demand opens the state to outside competition and divides any increases based upon existing self-purchase coefficients for the sector.

2) *Labor and Capital Demand Block*: The Labor and Capital Demand Block includes variables related to employment, labor access, and labor productivity. The majority of changes in industry demand and output drive changes in employment.

3) *Population and Labor Supply Block*: The Population and Labor Supply Block includes variables related to migration, birth and survival rates, and other demographic parameters. These variables are further broken down among age and racial categories. These variables were not used in our analysis.

4) *Wage, Price, and Profit Block*: The Wage, Price, and Profit Block includes variables related to production costs, taxes and credits, fuel and capital costs, compensation rates, and consumer prices. The REMI model uses a modified production function to model investments across all sectors. When prices increase for capital, the model shifts spending to labor and resources to optimize production. Given this dynamic, the team grouped changes in capital and production costs under the production costs category to avoid unintentional shifts in the production decisions of firms away from capital investments.

5) *Market Shares Block*: The Market Shares Block includes policy variables related to the region's (i.e. Michigan's) ratio of exports and imports to the rest of the world. Generally, the MCCP team used the distinction between industry output and industry demand to drive intra- versus inter-regional purchase mixes.

6) *Fiscal Calibration Block*: The Fiscal Calibration Block includes variables related to state and local government expenditures and revenues. According to the consultants at REMI, this block is rarely used for most applications.

Within each of these blocks are a number of sub-categories, further divided into policy variables. Specific policy variables can be defined in different ways, primarily by sector (listed below) and by share or amount (i.e. percent changes or absolute dollar changes).

Definition by Sector

The REMI model divides the state of Michigan's economy into 70 different sectors. For some variables, it is possible to define the variable for each sector individually. (For example, we can model the effect of increasing the price of electricity for vehicle manufacturing by 10 %.) The 70 economic sectors are listed below.

Forestry
Agriculture
Oil/gas extraction
Mining (except oil/gas)
Support activities for mining
Utilities
Construction
Wood product mfg.
Nonmetallic mineral production mfg.
Primary metal mfg.
Fabricated metal product mfg.
Machinery mfg.
Computer/electronic product mfg.
Electrical equipment/appliance mfg.
Motor vehicle mfg.
Transportation equip. (motor veh.)
Furniture/related product mfg.
Miscellaneous mfg.
Food mfg.
Beverage/tobacco prod. mfg.
Textile mills
Textile product mfg.
Apparel mfg.
Leather/Allied product mfg.
Paper mfg.
Printing/Related support activity
Petroleum/coal product mfg.
Chemical mfg.
Plastics/rubber mfg.
Wholesale trade
Retail trade
Air transportation
Rail transportation
Farm
State Government
Water transportation
Truck transp./couriers/messsengers
Transit/ground passenger transp.
Pipeline transport
Scenic/sightseeing transp./supply
Warehousing/storage
Publishing (exc. Internet)
Motion picture/sound recording
Internet service/data processing
Broadcasting internet/telecomm
Monetary authority
Security/communication/contracts
Insurance carriers
Real estate
Rental/leasing services
Professional/technical services
Management Companies/Enterprises
Admin/support services
Waste management/remediation
Educational services
Ambulatory health care services
Hospitals
Nursing/Residential care facilities
Social assistance
Performing arts/spectator sports
Museums
Amusement/gambling/recreation
Accommodations
Food services/drinking places
Repair/Maintenance
Personal/laundry services
Membership associations/orgs.
Private households
Local Government
Federal Government

Upon completion of GHG and economic modeling of the MCCP policy strategies, results were presented to the stakeholders in a second public Forum. Based on feedback, some models were revisited and refined. The following section is a description of Task Four of the MCCP process, including the proceedings of Forum II.

TASK 4: Final Presentation of Results to Stakeholders

Forum II

On October 25th, 2006, the Center for Sustainable Systems at the University of Michigan hosted the second of two stakeholder forums, a formal opportunity for the MCCP team to engage with the stakeholders.

Forum II Objectives

Forum II brought stakeholders together to discuss the modeling results of the MCCP team's GHG emission reduction potential and economic analyses. Stakeholders explored the implications of the policies and discussed how the team's work might guide future state policymaking.

Forum II Proceedings

- Project Team and Stakeholder Introductions: Forum II began with a roundtable introduction of Forum II participants including approximately 60 stakeholders, Forum speakers, and the MCCP team.
- Presentation of Policies and Results: The MCCP team presented an overview of the nine strategies and related policies, along with results of the GHG emission reductions and economic modeling for each policy. Stakeholders were provided fact sheets for each policy, describing modeling assumptions and results. Stakeholders also received corresponding PowerPoint slides and a survey to provide feedback to the MCCP team.
- Breakout Sessions: Breakout sessions discussed each of the modeled policies. Throughout the sessions, the MCCP team recorded stakeholder comments and concerns. Those that directly impacted the modeling were considered and, if needed, addressed by revising the models.
- Plenary Session: Plenary discussions of each policy followed the breakout sessions. Through an open voting process, stakeholders indicated their preference for policies. Stakeholders discussed the implementation feasibility of the policies, as well as concerns regarding the potential negative economic impact associated with specific strategies.

The following chapters of this report provide details regarding each of the modeled policies, including related research.

III. MCCP Policy Chapters

1. Renewable Portfolio Standard

1.1 Policy Background

In the 1990 to 2002 interval, greenhouse gas emissions from electricity generation in the state of Michigan increased 9.2%, from 18.15 million metric tons of carbon equivalent (MMTCE) to 19.82 MMTCE.[2] Generating electricity is the largest source of CO_2 emissions in the state and represents 38 percent of such emissions from fossil fuel combustion.[3] Any attempt to reduce greenhouse gas emissions must therefore address the electricity generation sector.

As a result of the stakeholder discussions at Forum I in late January 2006, the renewable portfolio standard (RPS) strategy commanded considerable stakeholder interest, with the largest number of votes received by any potential MCCP strategy. The MCCP team analyzed several aspects of two proposals for an RPS, a policy by which regulated electric utilities, by given dates, are required to provide specified percentages of electricity from qualifying renewable sources. Regulated utilities covered by the proposed Michigan RPS are the nine investor owned utilities and nine cooperatives regulated by the Michigan Public Service Commission. (In 2001, service provided by the two largest investor owned utilities, Detroit Edison and Consumers Energy, generated 81 percent of total electric sales, with the remainder generated from several lower peninsula utilities (12 percent) and upper peninsula utilities (6 percent)).[4] Stakeholder interest in an RPS was attributable to a variety of factors, including its popularity in other states.[xii]

1.1.1 Existing State Programs

As of Forum I, RPS measures had been enacted by 22 states and the District of Columbia.[5] Shortly after Forum II, in November 2006, voters in Washington State approved Initiative 937, requiring the state's largest utilities to obtain 15 percent of their electricity from new renewable sources, including wind and solar, by 2020. I-937 also requires utilities to pursue low-cost opportunities for energy conservation.[6] (See Appendix F.1 for a list of states that enacted an RPS and the specific fuels that qualify as renewable.)

The growth of renewable energy attributable to state RPSs has exceeded the expectations of policymakers, resulting in several states, most prominently Texas and Nevada, increasing their RPS targets over time.

Definitions of what constitutes a renewable resource vary significantly across states. While all current RPS programs accept wind and biomass, and all but Minnesota include solar photovoltaic, variability exists across states. Most states include tidal/ocean power and landfill gas as renewable resources, as well as fuel cells (which are not an energy source themselves but rather a storage mechanism), yet states differ as to whether solar thermal, geothermal, or wave power resources meet the renewable definition.[7]

[xii] An RPS proposal can, if desired, include credit for energy efficiency measures, known as a clean energy portfolio standard. To simplify the analysis and make it most comparable to the majority of existing state RPS provisions, the team decided to analyze RPS proposals without energy efficiency provisions.

Texas

Texas has had much success with its RPS. Established in 1999, the measure required an increase in overall renewable generation capacity from 1,280 MW in January 2003, to 2,880 MW by January 2009. The measure sparked a tremendous amount of wind development, especially in west Texas. By June 2005, 1,322 MW of new wind generation had come online, along with modest additional solar, landfill gas, and small-scale hydro capacity. Since the initial targets established in the 1999 legislation were on track to be exceeded ahead of schedule, the legislature revised the RPS targets in 2005, establishing a new goal for total renewable capacity of 5,880 MW by January 2015.[8] Almost all of Texas' wind resources were developed after passage of the RPS.

Nevada

Nevada's RPS, revised several times, also has achieved positive results. The state's RPS legislation passed in 1997, 2001, and 2003, and the most recent update in 2005 established a 20% renewable by 2015 requirement. Nevada incorporated aspects of Texas' successful RPS, including a system for renewable energy credits (RECs) and a requirement for eligible electricity to be generated in-state or imported through a dedicated transmission line. Yet Nevada adapted its RPS to its circumstances, retaining a solar carve-out but reducing its level to 5 percent. Nevada's renewable resources are not primarily confined to wind and solar, as is the case in Texas, and its RPS is designed to promote a range of renewable technologies including solar, wind, geothermal, and biomass.[9] This approach is relevant to Michigan since, like Nevada, it has a range of renewable resources that could be utilized under an RPS.

Colorado

While most states have enacted RPS by legislative action, Colorado became the first state to pass an RPS with an instrument of direct democracy, by approving Proposition 37 in November 2004. Suppliers are currently required to provide 2 percent of generated electricity from renewable sources. The requirement increases to 3 percent in 2007, and climbs to 10 percent by 2015. Two elements of the Colorado program are noteworthy. First, prior to passage of the RPS, Colorado had been reluctant to address greenhouse gas emissions. Coal and utility interests were instrumental in blocking the passage of the RPS in the state legislature in three consecutive sessions. Second, the RPS includes a cost cap, preventing RPS impact from exceeding 50 cents per residential customer per month.[10]

Across the country, the RPS policy measure promotes an assortment of goals with particular appeal to various constituencies. Proponents of renewable energy as an economic development tool see the benefits of encouraging in-state renewable energy generation. Michigan spends in excess of $18 billion annually to import all of its coal, 96% of its oil and petroleum products, and over 75% of its natural gas. The state could realize economic savings from displacing future fuel imports by increasing renewable generation in the state.[11] RPS can address criteria air pollutants and climate change impacts of fossil fuel use in the electricity sector, depending on which generating plant's emissions gets displaced by new renewable resources. Those who have an interest in stable electricity rates see the potential for a more diverse fuel mix, brought about by an RPS, to act as a hedge against uncertain future costs for fossil fuels. More recently, those concerned with the national security implications of energy security and climate change have helped to create a political dynamic in which policies to reduce GHG emissions are viewed in a more favorable light.

Lessons from other state RPS experiences are relevant as Michigan considers the implications of having an RPS. Tremendous variability exists across state RPS measures with respect to eligible resources, the structure and size of the renewable requirement, and various measures concerning regulatory oversight, compliance verification, and provisions for implementing future changes to the RPS. These provisions affect the degree to which an RPS is an effective, efficient tool for promoting renewable energy development.[12]

Economic impacts are a common concern for utilities subject to an RPS, and existing state experiences also shed light on the likely impacts. While no definitive studies have focused on Michigan, a broad array of analyses of other states suggests the likely economic impacts to be modest. Ryan Wiser's analysis of 28 existing studies shows that 20 studies predict rate increases of one percent or less, while five studies predict rate savings. The median change in retail electric rates is $0.04/month.[13]

1.1.2 Michigan Activity

In the last several years, discussions about an RPS in Michigan have increased. In April 2006, Michigan Governor Jennifer Granholm issued an executive order directing the Michigan Public Service Commission (MPSC) to develop a 21st Century Energy Plan to meet the state's electricity needs in the short- and long-term. Provision 5 of the executive order calls for the creation of a renewable portfolio standard.[14] The order came on the heels of RPS bills proposed in the last two sessions of the Michigan Legislature, and from the support of environmental non-profit organizations for variations of RPS initiatives.

State Rep. Chris Kolb (D-Washtenaw County) and eight colleagues introduced House Bill 4970 in 2003, which proposed a state RPS with an initial target of 7% renewable energy by 2006, and 15% by 2013. Of the renewable energy requirement, 5% is required to come from solar. This bill was referred to the Committee on Energy & Technology, and saw no further action.[15]

In the last legislative session (2005-06), State Rep. Roger Kahn (R-Saginaw County) was the primary sponsor of HB 4608, a less ambitious RPS proposal also referred to the Energy & Technology Committee. Under this bill, the state's electricity providers would have to reach 7% renewable energy by 2013, with intermediate steps of 4% for 2004-06, 5% for 2007-09, 6% for 2010-12, and 7% for 2013 and thereafter. The solar carve-out provision in this bill (percentage of renewable energy required to come from solar photovoltaic) is 1 percent.

The Michigan Sustainable Energy Coalition (MSEC) has consistently promoted an RPS of 8% renewable by 2015. Environment Michigan has advocated for a more ambitious 20% renewable by 2020 RPS. The combination of legislative interest, nonprofit organizational interest, and the proceedings of the 21st Century Energy Plan process have all contributed to the issue's salience.

The 21st Century Energy Plan calls for an RPS requiring all load serving entities in Michigan to provide 10% of electric sales from qualifying renewable sources by 2015.[xiii] This plan would require enabling legislation to be passed this year; its first requirement is 3 percent renewable by 2009, which can include existing renewable sources. The additional 7 percent is required to be obtained from qualifying new sources.[16]

1.2 Two RPS Scenarios

The MCCP team modeled two scenarios: the 8% by 2015 RPS proposed by the Michigan Sustainable Energy Coalition (MSEC), and a 20% by 2025 RPS (MCCP). The MSEC RPS scenario has been in the public discourse and is similar to the Kahn bill considered by the Legislature. The MCCP team opted to build on the work by other organizations to assess the impact of this proposal. The MCCP scenario represents a more ambitious RPS. The team assessed the relative impact of an RPS with a greater renewable requirement, and one that extended beyond 2015 (20% renewable by 2025).

The MCCP team focused only on regulated utilities because their sales data was more readily available and they comprise the majority of electric sector emissions in Michigan. (The MSEC proposal covers all electricity generators, but the team's model assumed it applied only to regulated utilities.) Also, the Kahn bill contained a solar carve-out, which would likely benefit solar cell manufacturing companies in Michigan, including Uni-Solar. The Energy 2020 and REMI models did not adequately model carve-out provisions in an RPS. As a result, the MCCP team modeled the RPS scenarios without such provisions. However, in MCCP's GHG modeling, the team assumed that 1% of all new renewables would be solar, thus the team expects GHG results to be consistent with an RPS with an explicit solar carve-out.

1.3 GHG Modeling Methodology

For the MSEC and MCCP scenarios, the team calculated net GHG emission reductions from a business-as-usual (BAU) case with no RPS. In both RPS cases, 2007 is the first policy implementation year with renewable requirements. In each scenario, existing renewables count toward meeting the RPS requirement, and qualifying new resources include wind, solar, geothermal, biomass, landfill gas, and hydro (no pump storage).

Table 1-1 shows a comparison of the two scenarios relative to BAU. Renewable electric sales were approximately 2.75 percent of the state total in 2004.[17] The team assumed that all existing renewables would continue to operate over the 2007-2025 period. The BAU scenario shows a drop in renewables over time because the projected annual demand growth of 1.1% causes existing renewables to represent a smaller proportion of overall electric sales over time.

[xiii] Load serving entities include all investor-owned utilities, cooperatively owned utilities, municipal utilities, and alternative electric suppliers with retail sales to Michigan customers.

Table 1-1. RPS Renewable Electricity Requirements, by Year.

Year	BAU, %	MSEC RPS, %	MCCP RPS, %
2004	2.8	2.8	2.8
2005	2.7	2.7	2.7
2006	2.7	2.7	2.7
2007	2.7	4.0	4.0
2008	2.7	4.0	4.0
2009	2.6	5.0	5.0
2010	2.6	5.0	5.0
2011	2.6	6.0	6.0
2012	2.6	6.0	6.0
2013	2.5	7.0	8.0
2014	2.5	7.0	8.0
2015	2.5	8.0	10.0
2016	2.5	8.0	11.0
2017	2.4	8.0	12.0
2018	2.4	8.0	13.0
2019	2.4	8.0	14.0
2020	2.4	8.0	15.0
2021	2.4	8.0	16.0
2022	2.3	8.0	17.0
2023	2.3	8.0	18.0
2024	2.3	8.0	19.0
2025	2.3	8.0	20.0

The model used estimated demand growth projections for overall annual electric demand (increasing 1.1% per year). This growth projection is based on the updated Capacity Need Forum Projections from the 21st Century Energy Plan process. Modeling did not assume any power plant retirements beyond those already projected under modeling for the Capacity Need Forum process of the 21st Century Energy Plan process. The MCCP team used MPSC data for electricity sales by regulated utilities in 2004 as the baseline, and obtained fuel mixes for each utility indicating what percentage of its overall electric sales came from which energy source.[18]

For each scenario, the MCCP team modeled three possible ways of meeting the 1.1% annual demand growth:

- Linear growth paths for all fuels projected to grow over time. (Some fuels are predicted to stay constant.)
- A coal scenario in which a 500 MW coal plant comes online in 2013.
- A nuclear scenario in which a 1000 MW nuclear plant comes online in 2013.

In the BAU scenario, projections for annual sales by fuel were calculated using the following assumptions:

- The amount of electricity from nuclear, oil, hydro, landfill gas, and wood remain constant over the modeling period.

- The remaining available renewable fuels (biofuel, non-wood biomass, wind and solar) are projected to grow at 1.10% annually.
- The remaining non-renewable fuels account for the portion of demand not met by existing fuels and new renewables, and non-renewable component is apportioned among coal (88%) and natural gas (12%). (These percentages reflect the relative contributions to load growth in 2004 among coal and natural gas.)

In estimating projected sales under the two RPS cases, MCCP used the following assumptions, in addition to the ones above:

- The new renewables added to the mix were assumed to be allocated among wind (87%), biomass (12%), and solar (1%) based on projections made by MSEC.
- The new renewables were assumed to displace coal and natural gas, according to the same proportions (88% coal and 12% natural gas) noted above.

The MCCP team calculated GHG emissions in a multi-step process, described below and partially depicted in Figure 1-1 below. The team began by obtaining annual differences in electricity sales by fuel between BAU and each of the RPS scenarios. Given that emission factors used by the MCCP team were based on the energy of fuel burned (see Table 1-1), the estimated electricity sales figures were converted into the amount of energy contained in the fuel burned (Mbtu). Therefore, electricity sales were converted to energy (MBtu) sales by fuel type. The next step was to account for transmission and distribution (T&D) losses in the electric system. With approximately 9% of the energy leaving the power plant lost in T&D (a national average),[19] the energy reflected in electric sales to customers was adjusted to account for T&D losses. The MCCP team then focused on the activity at the power plant; the team utilized fuel-specific conversion efficiency figures from EPA data to account for the fraction of electricity produced relative to the energy contained in the fuel burned (coal = 0.322, natural gas = 0.379, oil= 0.362).[20] This allowed the team to ascertain the total amount of energy ultimately burned (Mbtu).

At this point, the MCCP team had converted electricity sales to an energy-burned basis and was ready to assess GHG emissions. The MCCP team then compared energy sources and GHG emissions between the BAU scenario and each of the two proposed RPS scenarios. With the GHG emissions calculations computed at the point of generation (except biomass, for which the team used the full life cycle), the MCCP team assumed zero GHG emissions for all renewable energy sources.[21] For each fossil fuel, the MCCP team utilized three sets of emissions factors, one for each greenhouse gas: CO_2, CH_4, and N_2O.[22] (See Table 1-2) After using the emissions factors (pollutant weight per unit energy) to produce an amount of the GHG emitted, the team utilized IPCC values for Global Warming Potential (GWP) of each GHG to convert into a common metric, million metric tons of carbon equivalent (MMTCE). The last step was simply to sum, for each fuel, the MMTCE produced from each of the three greenhouse gases to arrive at a final figure. See Appendix F.2 for a full explanation of the team's GHG modeling process.

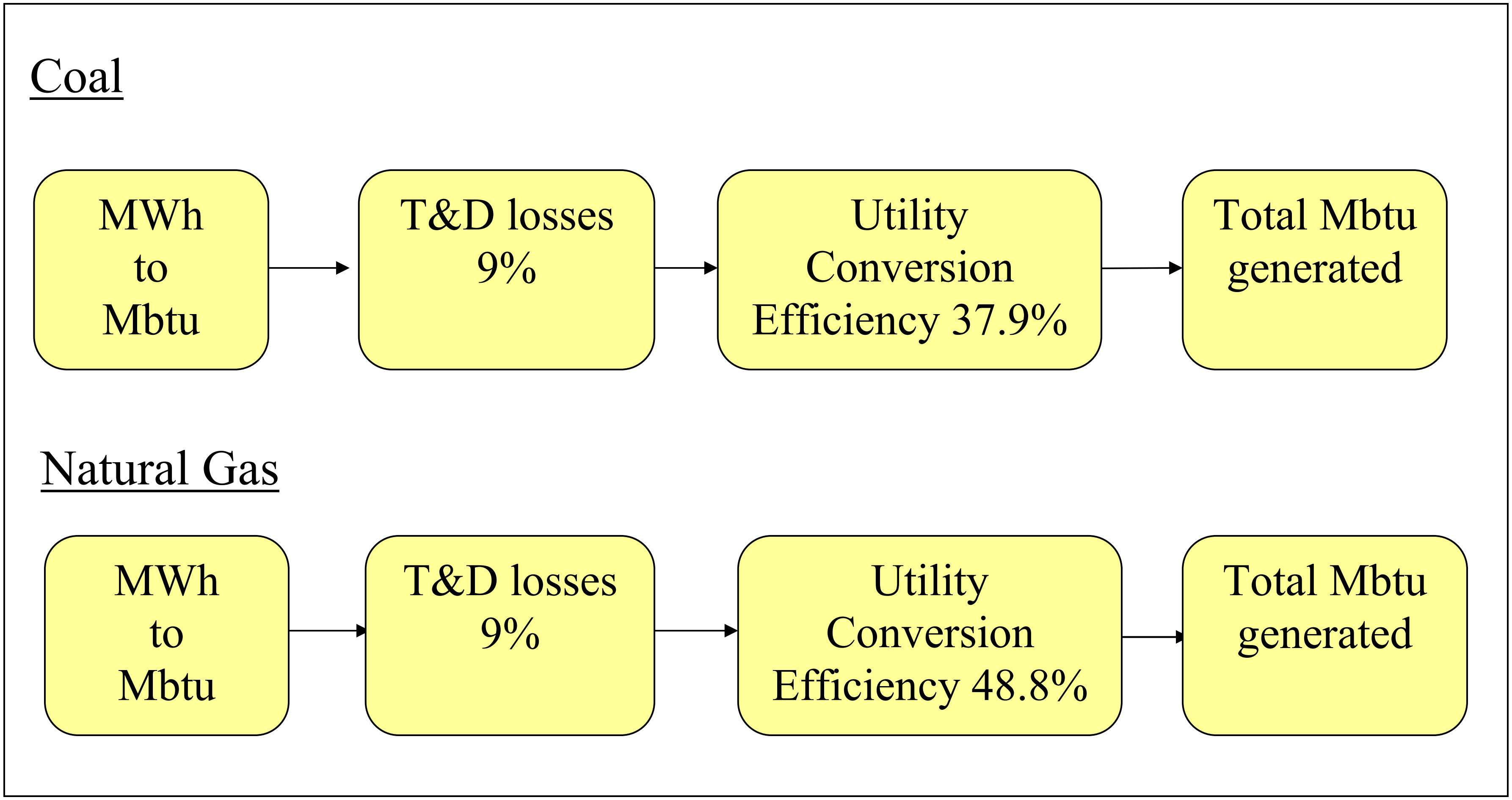

Figure 1-1. GHG Modeling Methodology for Electric Utilities

Table 1-2. Emission Factors.

	CO_2 (lbs C/Mbtu)	CH_4 (Mton CH_4/Bbtu)	N_2O (Mton N_2O/Bbtu)
Coal	57.3	0.001	0.001
Natural Gas	31.9	0.001	9.50x10^-5
Oil	57.6	0.003	6.01x10^-4
GWP	1	21	310

Source: US EPA (2004). *Volume VIII: Estimating Greenhouse Gas Emissions*. US Environmental Protection Agency, State and Local Climate Change Program, Emission Inventory Improvement Program, Washington, D.C.

The MCCP team's calculations showed the RPS proposals not resulting in retirements of existing fossil fuel plants (beyond those already scheduled to retire), but rather having the potential to reduce or eliminate demand for electricity from newer, more efficient fossil fuel plants. Thus, the team's calculations of GHG emissions reductions reflect projections of improved efficiency for new coal and natural gas plants coming online during the 2007-2025 period. That is, the MCCP team assumed the efficiency of new coal plants to increase to 37.9%.[23] The MCCP team also assumed the efficiency of new natural gas plants to increase to 48.975%.[24]

Trajectories are presented in Figures 1-2-1-4. In the MCCP scenario (Figure 1-4), the dramatic increase in wind capacity is the primary factor displacing future growth of coal-generated electricity.

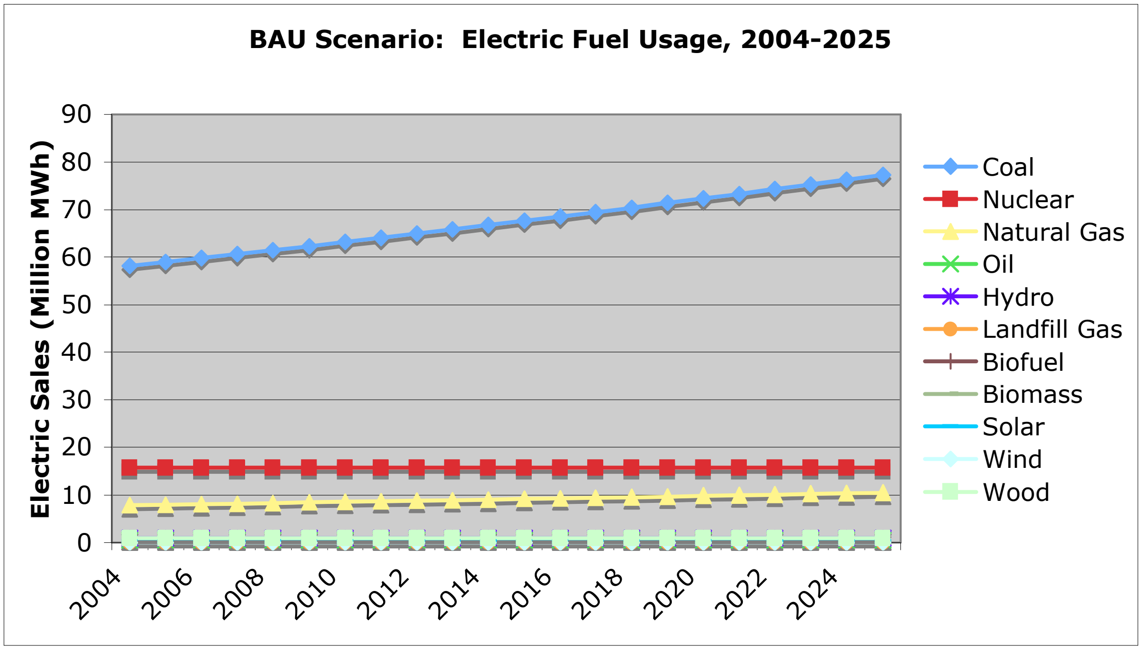

Figure 1-2. BAU Scenario: Electric Fuel Usage.

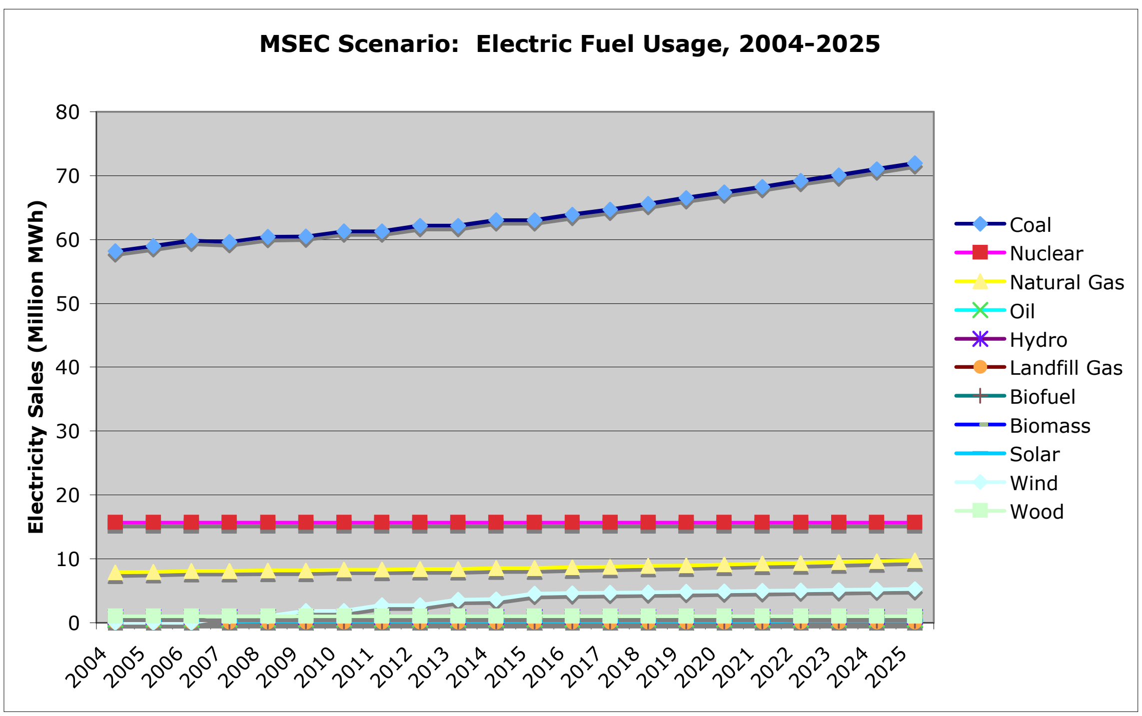

Figure 1-3. MSEC Scenario: Electric Fuel Usage.

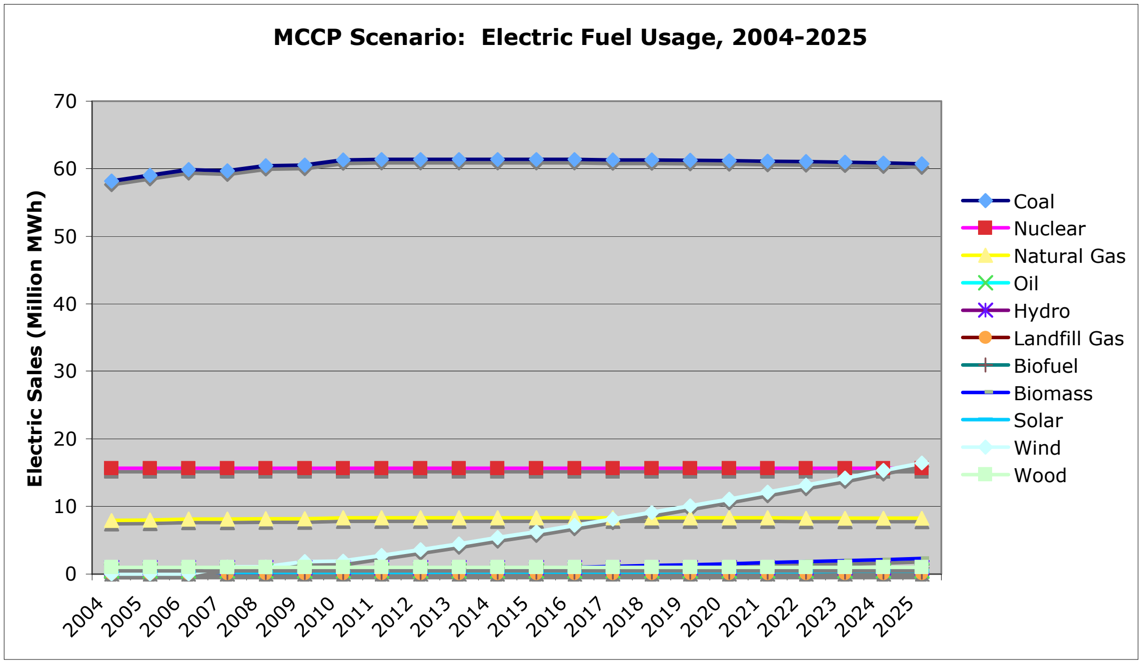

Figure 1-4. MCCP Scenario: Electric Fuel Usage.

1.4 Economic Modeling Methodology

The team modeled two economic scenarios for each of the RPS scenarios. The first assumed that no change occurred in renewable energy industry presence in Michigan. The second assumed that the RPS brings more renewable energy industries into the state. (For example, wind turbine manufacturing or additional solar cell production facilities might opt to locate in Michigan.) The following describes the input variables and assumptions made by the MCCP team, for the Energy 2020 and REMI models to produce useful output. For numerical data, see Appendix F.3.

1.4.1 Input Variables and Rationale

- Energy 2020 showed an increase in the amount of Consumer Spending for Household Operation due to higher electricity prices in the earlier years. Subsequently, as the cost of renewable generation dropped, the model showed consumer prices declined in later years, leading to a decrease in Consumer Spending for Household Operations.
- Energy 2020 showed a decrease in the amount of Consumption Reallocation for All Consumption Sectors by 60%. In later years when electricity prices dropped, the model showed an increase in the amount of Consumption Reallocation for All Consumption Sectors, resulting in the distribution of the savings among all consumer spending categories.

- 40% of consumer spending for household operation goes towards broadcasting industry sales.[xiv] By increasing or decreasing consumer spending on this sector, the model credits or debits the sector. Since broadcasting sales is not likely to be affected by changes in electricity prices attributable to an RPS, the team held the broadcasting component of consumer spending for household operation constant, and allowed the other components to fluctuate.
- The Energy 2020 model showed higher electricity costs and fuel switching caused by the policy, resulting in an increased share of Natural Gas in the electric mix and higher residual fuel costs for Industrial and Commercial sector customers.
- The model showed an increase in the amount of Firm Sales for the Utility Sector, reflecting an overall increase in Net Electricity sales due to higher electricity prices.
- The model showed a change in the amount of Exogenous Final Demand for Petroleum, Coal Product Manufacturing demonstrating the change in fuel usage caused by the policy.
- The model showed initial increases in Production Costs for the Utility Sector to model the initial impact of higher capital costs, due to the high up-front costs of renewables. This variable decreased in later years as the reduced amount of fuel purchases outweigh the higher capital costs. The timing of this changeover depends upon the version of the RPS. The MCCP RPS requires new renewables until the end of the modeling period, and most consumer savings accrue in 2021-2023, whereas the MSEC RPS results in consumer savings realized in 2018-2025.
- The model showed an increased amount of Firm Sales for the Construction Sector reflecting the increased construction due to new renewables.
- The model showed an increase in Exogenous Final Demand for Electrical Equipment Manufacturing, reflecting the equipment costs associated with new capital expenditures for renewables attributable to the policy.
- For the Michigan technology scenario, in which the state makes more of the renewable infrastructure that the policy spurs, the Exogenous Final Demand for Machinery Manufacturing rose instead of the Electrical Equipment Manufacturing because Michigan has a higher self-supply coefficient for this sector (35% versus 17%).

1.4.2 Variable Impacts

(See Appendix F.3 for numerical data.)

- In early years, the change in consumer spending patterns had a negative impact on employment and gross state product. However, in later years, as the price of electricity became cheaper because of the policy, the impact became positive. (See Table 1-4 for consumer spending trajectories, which were reflective of electricity prices.)

[xiv] Broadcasting refers to consumer purchases of cable television, phone, and Internet services.

- The increased amount of Firm Sales for Construction had a positive impact on employment and gross state product.
- The increased amount of Firm Sales (because of the high cost of electricity) for the Utility Sector positively impacted employment and gross state product.
- The increase in Production Costs for the Utility Sector negatively impacted employment and gross state product. However, in later years, when the Production Costs decrease because of the policy, employment and gross state product are positively impacted. The timing of this changeover depends on the aggressiveness of the RPS and on when new renewables are no longer required.
- The increase in Exogenous Final Demand for Electrical Equipment Manufacturing (or Machinery Manufacturing) had positive impact on employment and gross state product.
- When prices increased over certain time periods for Electricity, Natural Gas, and Residual Fuel for the Commercial and Industrial sectors, those higher prices had a negative impact on employment and gross state product.

1.4.3 Economic Sectors Impacted

- The construction and utility sectors, as well as electrical equipment manufacturing, see gains due to the construction and manufacturing of additional renewable electric capacity.
- During the modeling period when electricity prices rise, consumer spending decreases, with temporary negative economic impact in several sectors, including retail trade, services (including health care), accommodations and food service, and educational services. However, these sectors see positive impact in later years as the price of electricity drops.

1.5 Modeling Results

Both RPS proposals result in substantial reductions in emissions of GHGs in the state, with positive economic impact overall, and positive or modestly negative impact in any individual year. The MCCP scenario results in cumulative GHG emissions reductions approximately twice as large as those realized in the MSEC scenario. Table 1-3 presents numerical data for cumulative GHG emissions reductions. Figures 1-5 and 1-6 represent the trajectory of annual emissions reductions. Cumulative emissions reductions are presented in blue.

Table 1-3. Cumulative Greenhouse Gas Emissions Reductions.

	By 2015 (MMTCE)	By 2025 (MMTCE)
MSEC RPS	6.37	20.05
MCCP RPS	7.73	39.86

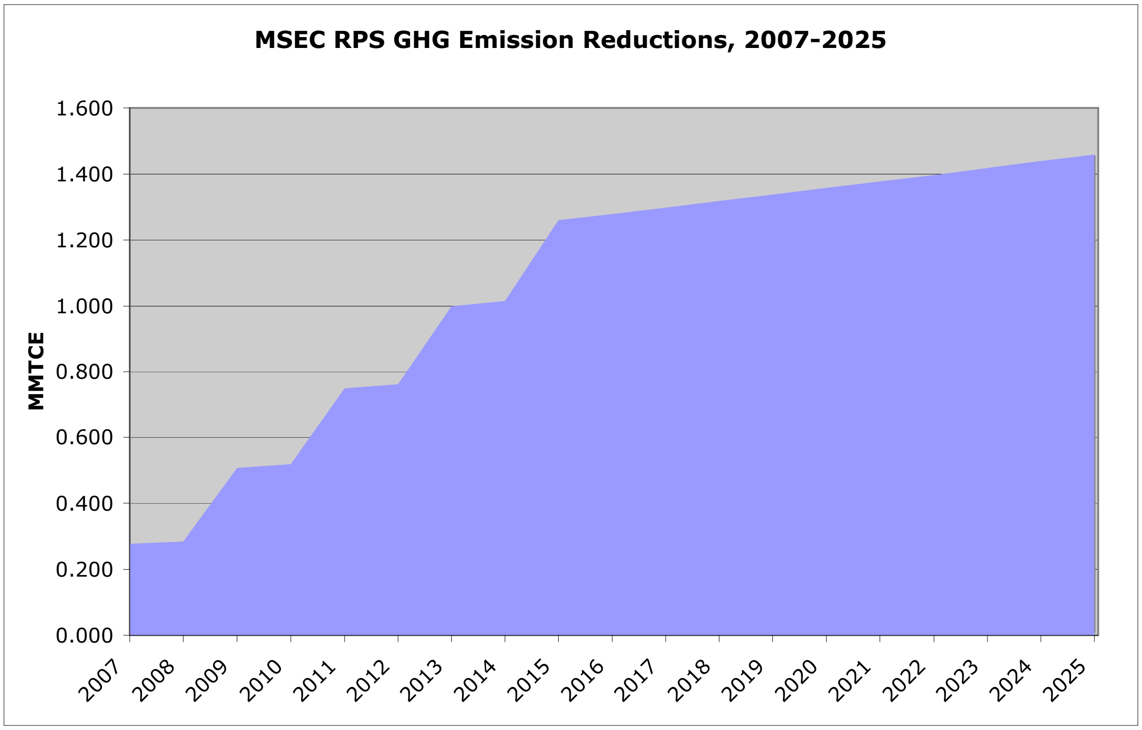

Figure 1-5. MSEC RPS Emission Reductions.

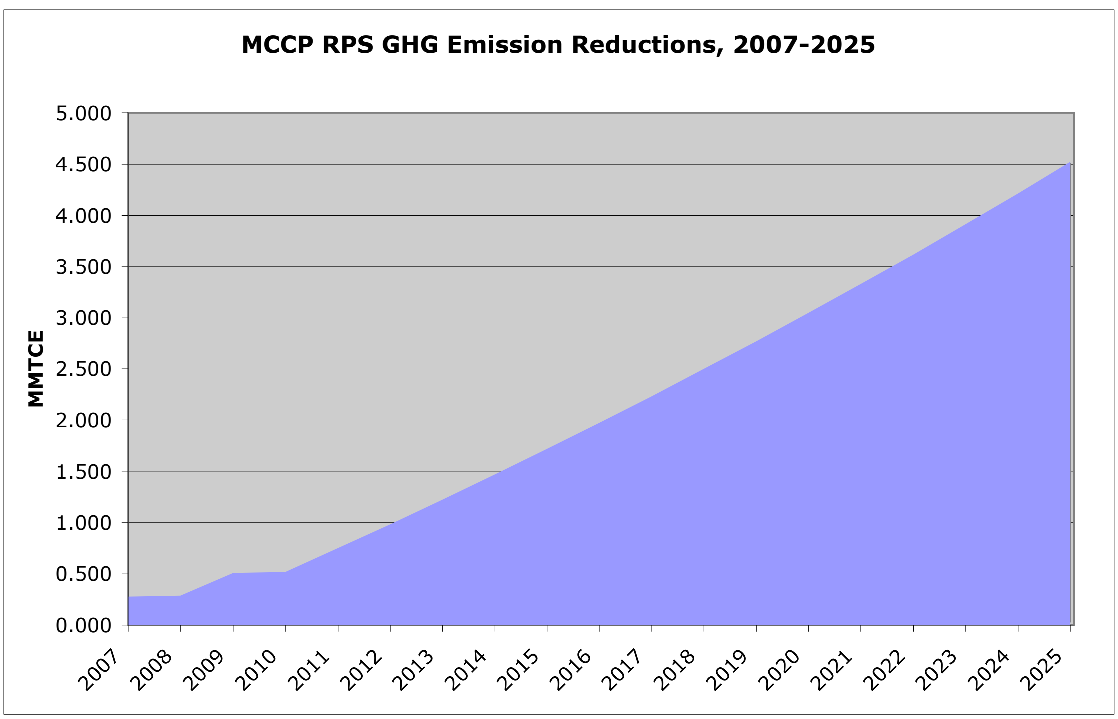

Figure 1-6. MCCP RPS Emission Reductions.

1.6 GHG Results in Context

As noted in the state greenhouse gas inventory, statewide GHG emissions in 2002 were 62.59 MMTCE. The electric utility sector's contribution was 19.82 MMTCE, roughly one-third of the state's total GHG output. Though no definitive data exist, emissions have continued to increase since 2002. The team's calculations focused on regulated utilities, accounting for the vast majority of electricity generation in the state.

Absolute reductions relative to baseline (based on projections of 1.1% annual demand growth) are shown in Table 1-4. However, these numbers do not tell the whole story. As significant as the emissions reductions are, neither RPS scenario results in overall reductions in electric utility GHG emissions over the period studied, given the 1.1% annual demand growth. The MSEC RPS scenario would reduce growth in emissions, but 2015 emissions would be approximately 9% above 2002 levels, and 2025 emissions would be approximately 21% above 2002 levels. The MCCP scenario would eliminate most future growth in emissions from the electric sector, but would not result in an absolute reduction below current GHG emissions levels. Specifically, 2015 emissions would be approximately 7% above 2002 levels. Emissions would have leveled off by 2025, ending up approximately 6% above 2002 levels and showing virtually no increase in the 2012-2025 period. (See Figures 1.2-1.4 above for fuel-specific sales trajectories.)

The MCCP team's modeling assumed all currently operating power plants would continue to operate over the 2007-2025 period, except those projected to retire under modeling done for the Capacity Need Forum process of the 21st Century Energy Plan process.

Annual emissions reductions attributable to each RPS scenario are illustrated in Table 1-3 below. Since both RPS measures have similar ramp-up paths for the first few years, the emissions savings diverge in 2012 and thereafter.

1.7 Economic Results

In both RPS scenarios, electricity production and fuel costs decreased for renewables relative to fossil fuels. At the same time, capital costs were greater, per megawatt of electricity generated, for renewables relative to fossil fuels. Electricity prices increased initially during phases when renewable facility construction was required, then subsequently dropped below baseline. Consumer spending on other goods and services changed as a result of variations in electricity prices. Such spending changes reflect electricity price movements. (See Table 1-5.)

As indicated in Table 1-3, the MSEC RPS results in higher consumer spending in 2007-2017, before realizing significant savings in 2018 and thereafter. The MCCP RPS follows a similar pattern, with consumer spending above baseline in 2007-2020, in some years to a greater extent than the MSEC RPS. Consumer spending levels drop below baseline in 2021-2023, before rising slightly above baseline in the final two years of the modeling period.

Table 1-4. Annual Greenhouse Gas Emissions Reductions (MMTCE).

Year	MSEC	MCCP
2007	0.277	0.277
2008	0.285	0.285
2009	0.508	0.508
2010	0.519	0.519
2011	0.748	0.748
2012	0.762	0.983
2013	0.999	1.22
2014	1.02	1.47
2015	1.26	1.72
2016	1.28	1.97
2017	1.30	2.23
2018	1.32	2.50
2019	1.34	2.77
2020	1.36	3.05
2021	1.38	3.33
2022	1.40	3.62
2023	1.42	3.91
2024	1.44	4.22
2025	1.46	4.52

Table 1-5. Changes in Consumer Spending for Household Consumption (Millions 2000 Fixed $).

Year	MSEC	MCCP
2007	25.8	25.8
2008	76.9	76.9
2009	123.7	123.7
2010	111.0	111.0
2011	92.3	92.3
2012	79.8	79.9
2013	62.2	68.9
2014	52.4	69.2
2015	59.8	95.8
2016	61.4	110.9
2017	37.7	99.6
2018	-15.9	82.6
2019	-72.9	50.9
2020	-118.0	17.5
2021	-172.0	-23.2
2022	-234.4	-71.9
2023	-222.3	-149.2
2024	-145.4	3.4
2025	-127.9	9.4

Both RPS scenarios result in an average annual increase in employment and Gross State Product (GSP). (See Table 1-6.)

Table 1-6. Average Annual Economic Effects.

	Change in GSP (millions 2000 fixed $)	Change in Job-Years
MSEC RPS	144	1,390
MCCP RPS	64.6	881

As illustrated in Tables 1-7 and 1-8, for several individual years, changes in GSP and/or change in job-years are negative despite average annual results being positive because of sequencing of costs and benefits. Specifically, during the years of ramp up where the RPS prompts construction of new renewable facilities (e.g. wind turbines, biomass facilities, solar photovoltaic panels, etc.), data show increases in electricity prices. Increases are to be expected because many renewables have higher capital costs (per MW of electricity generated) than fossil fuel power plants. After completion of construction, when renewable facilities are operational and online, data show that electricity costs decline to below baseline (pre-RPS) levels. At this point the greatest economic benefits are realized, after most new facility construction is completed.

Table 1-7. MSEC RPS Economic Results: Changes in Employment and Gross State Product (GSP).

	MSEC RPS		MSEC RPS (High Local Supply)	
Year	**Employment (1000 Job-Years)**	**GSP (Million fixed 2000 $)**	**Employment (1000 Job-Years)**	**GSP (Million fixed 2000 $)**
2007	0.206	$27.7	0.206	$27.6
2008	2.78	$204	3.64	$271.8
2009	-0.133	$9.4	0.097	$27.7
2010	-0.213	-$4.10	-0.002	$13.3
2011	-0.252	-$15.1	-0.079	-$0.21
2012	-0.257	-$22.7	-0.095	-$8.58
2013	-0.112	-$16.5	0.041	-$2.84
2014	-0.084	-$17.4	0.052	-$4.88
2015	-0.173	-$28.4	-0.010	-$13.1
2016	-0.310	-$43.7	-0.159	-$29.2
2017	-0.655	-$68.8	-0.670	-$70.4
2018	0.207	$6.23	0.170	$2.69
2019	1.22	$103	1.17	$97.8
2020	2.23	$206	2.18	$202
2021	3.43	$337	3.42	$335
2022	4.91	$498	4.95	$502
2023	5.21	$558	5.27	$563
2024	4.36	$503	4.41	$508
2025	4.09	$494	4.14	$499
2005-2015 Avg	0.195	$15.2	0.430	$34.5
2005-2015 Cumulative	1.76	$136	3.85	$310
2005-2025 Avg	1.39	$143	1.51	$153
2005-2025 Cumulative	26.5	$2,730	28.7	$2,920

Table 1-8. MCCP RPS Economic Results: Changes in Employment and Gross State Product (GSP).

	MCCP RPS		MCCP RPS (High Local Supply)	
Year	**Employment (1000 Job-Years)**	**GSP (Million fixed 2000 $)**	**Employment (1000 Job-Years)**	**GSP (Million fixed 2000 $)**
2007	0.206	$27.7	0.206	$27.6
2008	2.78	$204	3.64	$272
2009	-0.133	$9.40	0.097	$27.7
2010	-0.213	-$4.09	-0.002	$13.3
2011	-0.252	-$15.1	-0.079	-$0.210
2012	-0.255	-$22.5	-0.093	-$8.33
2013	0.389	$18.3	0.705	$46.7
2014	0.265	$4.18	0.574	$32.6
2015	-0.157	-$36.6	0.183	-$4.70
2016	-0.570	-$79.0	-0.238	-$47.4
2017	-0.548	-$85.1	-0.225	-$53.2
2018	-0.321	-$71.9	-0.009	-$40.6
2019	0.146	-$33.2	0.425	-$4.40
2020	0.851	$30.8	1.14	$61.6
2021	1.72	$117.1	2.04	$151
2022	2.94	$240.4	3.31	$281
2023	4.50	$406	4.89	$449
2024	2.75	$261	3.15	$307
2025	2.65	$256	3.06	$305
2005-2015 Avg	0.29	$20.5	0.58	$45.1
2005-2015 Cumulative	2.63	$185	5.23	$406
2005-2025 Avg	0.88	$64.6	1.20	$95.8
2005-2025 Cumulative	16.7	$1,230	22.8	$1,820

The economic model used a 19-year (2007-2025) time frame. The MSEC RPS scenario involves increasing renewable mandates through 2015, and the requirement stays constant at 8% through 2015-2025. In the MSEC case, the costs are incurred in the first half of the period studied, and many of the benefits accrue in the second half, reflecting that the greatest economic benefits do not accrue until after most construction of new facilities is complete. By contrast, the MCCP RPS scenario contains increasing renewable mandates through 2025, extending the period of time when new renewable sources are under construction. While overall economic benefits are positive, the largest segment of benefits would be expected to accrue after 2025. Thus, if the economic analysis were continued beyond 2025, the MCCP RPS would likely show even greater economic benefits relative to the MSEC RPS.

1.8 Conclusions

The two renewable portfolio standards modeled by the MCCP team are effective instruments for reducing GHG emissions and stimulating economic development. Most emissions reductions are achieved by new renewable electric generation displacing future coal and natural gas plants from coming online. The MSEC RPS produces annual emissions reductions that rise to 1.4 MMTCE annually by 2025. The MCCP RPS produces annual emissions reductions that rise to 4.5 MMTCE in 2025. This more ambitious RPS could displace all predicted demand growth in the 2002-2025 period, but overall emissions in the electric sector would not see an overall decline. The reductions are significant and can be achieved while contributing modestly to economic development in the state. Yet, they are not large enough to cause an absolute reduction of emissions in the electric sector, which is responsible for one-third of statewide GHG emissions. (Substantial absolute reductions below current levels are necessary for climate stabilization.)

The distribution of costs and benefits resulting from an RPS varies across sectors. Consumers bear increased costs in the first years of the RPS policies due to higher electricity prices, but benefit from overall savings in the long term. The construction and utility sectors, as well as electrical equipment manufacturing, see gains from the RPS due to construction and manufacturing of additional renewable electric capacity. During the modeling period when electricity prices rise, consumer spending has temporary negative economic impact in several sectors, including the retail trade, services (including health care), accommodations and food service, and educational services. However, these sectors see economic gains in later years as the price of electricity drops.

While the state economy currently is losing manufacturing jobs for a variety of reasons, the potential for additional renewable energy firms to locate in Michigan could provide sustainable economic development and manufacturing jobs. In addition, both utilities and consumers stand to benefit from potential reductions in fuel imports associated with increased renewable electric generation in the state. The MSEC RPS adds an average of $140 million annually to gross state product, while the MCCP RPS adds approximately $64 million annually; both scenarios result in net employment gains. (With an annual GSP of approximately $380 billion, these are modest but positive contributions to economic development.)

If a national RPS is enacted, or a series of policy measures are put in place to spur significant amounts of renewable energy development nationally, Michigan will be well positioned to reap the economic benefits. According to a Renewable Energy Policy Project report, if 50,000 MW of new wind capacity came online resulting from federal action, the vast majority of states that would see the greatest benefits are those that have lost the greatest number of manufacturing jobs in the 2001-2004 interval. Michigan would stand to gain over 8,500 new full-time equivalent jobs in industries related to wind, the fourth largest employment increase of any state in the country.[25]

2. Appliance Efficiency Standards

2.1 Background

In June 2006, Michigan Senator Liz Brater introduced SB 1333, designed to establish mandatory energy efficiency standards for 15 appliances, the majority of which are not currently covered by national efficiency standards. With endorsement from Senators Prusi, Clark-Coleman, Basham, Jacobs, and Whitmer, Senator Brater proposed SB 1333 to establish minimum appliance efficiency standards for certain products sold or installed within the state of Michigan. (See Appendix G.1 for a copy of SB 1333.) The bill deliberately parallels recommendations outlined in a March 2006 report by the American Council for an Energy Efficient Economy (ACEEE), *Leading the Way: Continued Opportunities for New State Appliance and Equipment Efficiency Standards*.[26] (See Appendix G.2 for a copy of the report's appendix illustrating appliance efficiency effects in Michigan.)

In response to current efforts in Michigan, the MCCP team sought not only to develop innovative GHG reduction strategies, but also to build upon potential existing strategies in the state. To that end, MCCP modeled the potential impact of implementing SB 1333. During Forum I, stakeholders deemed Demand Side Management (DSM) a high priority strategy. Although the team drew a connection between this policy and DSM, it is not to be confused with more commonly understood DSM strategies. Details of DSM opportunities with great potential in Michigan are discussed in the *Considerations* section of this report.

Appliances covered by SB 1333 are utilized and operated by the residential, commercial, and industrial sectors, all contributors to the main drivers of Michigan's GHG emissions as defined by the Michigan Greenhouse Gas Inventory. The MCCP team built upon the ACEEE study to develop key model assumptions for modeling the impact of this mandatory appliance efficiency standard.

State-enforced appliance efficiency standards are considered to be positive drivers in their respective regions. Another way to induce appliance efficiency is through tax incentives for sellers and operators of high efficiency appliances. For example, sellers and/or purchasers of US EPA Energy Star-rated appliances could be exempted from paying state sales tax on such products.

Several US states have enacted mandatory appliance efficiency standards; other states, including Michigan, are also considering their adoption. The following states have enacted, or are considering enacting, energy efficiency standards for appliances and equipment: Arizona,[27] California,[28] Connecticut, Massachusetts,[29] Maryland, New Jersey, New York,[30] Oregon, Rhode Island, Vermont, and Washington. Appliance efficiency standards can have the following positive impacts:[31]

- Reduced appliance operating costs: This allows for a re-distribution of consumer spending on energy to other forms of consumption. This redistribution affects the state economy by potentially stimulating disposable income dollars into the region while also potentially reducing state energy capacity needs projections.
- Reduced GHG emissions: By reducing onsite and upstream energy consumption, states can reduce the amount of related GHG emissions.
- Preparedness for new federal efficiency updates and standards: Familiarizing demand- and supply-side actors in the production and consumption of energy

efficient appliances enhances public awareness and acceptance of such appliances and induces the technological developments necessary to make energy efficient appliances widely available and cost competitive.

- Flexibility for in-state manufacturers: For example, SB 1333 mandates in-state end-use sales and installations of specific appliances, but does not cover exported products sold or utilized outside the state. This allows flexibility for in-state appliance manufacturers to continue to sell non-compliant appliances out of state, simultaneously generating revenue while adjusting new operations to meet in-state sales requirements.

The MCCP team modeled the potential GHG reductions and economic impact of enacting the proposed legislation, SB 1333. (See Table 2-1 for a list of appliances included in SB 1333).

Table 2-1. Appliances Included in SB 1333.

Appliances Included	
Bottle type water dispensers	Pool heaters (gas)
Commercial boilers (gas)	Portable electric spas
Commercial hot food holding cabinets	Residential furnace (electricity)
Compact audio products	Residential boilers (gas)
DVD Players and recorders	Single voltage external ac-dc power supplies
Liquid immersed distribution transformers	State regulated incandescent reflector lamps
Medium voltage dry type distribution transformers	Walk-in fridges and freezers
Metal halide lamp fixtures	

The US currently mandates appliance efficiency standards for a set of industrial, commercial, and residential appliances and electronics. The first national appliance efficiency standard was enacted in 1987, with passage of the National Appliance Energy Conservation Act. Subsequently, President George H.W. Bush signed the Energy Policy Act of 1992, expanding national efforts to establish efficiency levels for appliances and equipment.[32]

The majority of appliances proposed in SB 1333 are not covered by federal standards. In the case of state standards exceeding federal standards for specific appliances, the state must petition the US Department of Energy (DOE) for the right to enforce different state-specific levels. The DOE is currently updating and developing new standards for certain appliances targeted by the SB 1333. The department is set to issue final rules on residential furnaces and boilers and electric distribution transformers by the fall of 2007.[33]

The following list identifies the status of federal coverage for the SB 1333 appliances and the mandated federal efficiency levels where applicable:

- Bottle type water dispensers: *Not covered by federal standards.*
- Commercial Boilers: *Covered by federal standards.* (For a gas-fired packaged boiler with a capacity (rated maximum input) of 300,000 Btu/hr or more, and an oil-fired packaged boiler with a capacity (rated maximum input) of

300,000 Btu/hr or more, the combustion efficiency at the maximum rated capacity must meet the levels stated above, as in SB 1333.)

- Commercial Hot Food Holding Cabinets: *Not covered by federal standards.*
- Compact Audio Products: *Not covered by federal standards.*
- DVD Players and recorders: *Not covered by federal standards.*
- Liquid-immersed distribution transformers: *Being developed by DOE.*
- Medium voltage dry-type distribution transformers: *Being developed by DOE.*
- Metal halide lamp fixtures: *Not covered by federal standards.*
- Pool Heaters: *Covered by federal standards.*[34] (Including Gas, Oil and Electric Water Heaters)
- Portable electric spas (hot tubs): *Not covered by federal standards.*
- Residential furnaces and residential boilers: *Covered by federal standards.* (71-80% Fuel Efficiency)
- Singe-voltage external AC to DC power supplies: *Not covered by federal standards.*
- State-regulated incandescent reflector lamps: *Covered by federal standards.* (Including categories of lamps with nominal wattage ranging from 40 to 205 watts.)
- Walk-in refrigerators and freezers – *Not covered by federal standards.*

2.2 GHG Model

Calculating the in-state GHG reductions resulting from SB 1333 involved a series of assumptions and estimations. All electricity-utilizing appliances result in GHG reductions occurring upstream at the utility level and all natural gas-consuming appliances result in GHG reductions occurring at the end-use location of the appliance. The following outlines the modeling steps taken:

- Determine reductions of energy consumption by each new energy efficient appliance purchased in the state.
- Translate those savings into reductions in fuel consumption at the utility level (for electric appliances) and at the end-use level (for natural gas appliances).
- Determine emission factors for those fuels.
- Convert all emissions to a common unit. (See Figure 2-1.)

See Appendices G3 and G4 for model calculations and results for years 2015 and 2025.

Table 2-2 presents the percent contribution of each appliance to the total savings experienced by the year 2015.

Table 2-2. Individual Appliance Contributions to Total Savings.

Appliance	*Contribution to Total MWh Savings (2015) %*
Bottle type water dispensers	0.5
Commercial boilers (gas)	0.009
Commercial hot food holding cabinets	0.48
Compact audio products	3.2
DVD Players and recorders	4.7
Liquid immersed distribution transformers	10.54
Medium voltage dry type distribution transformers	0.67
Metal halide lamp fixtures	11.29
Pool heaters (gas)	0.008
Portable electric spas	0.18
Residential boilers (gas)	0.46
Residential furnace (electricity)	45.61
Single voltage external ac-dc power supplies	9.26
State regulated incandescent reflector lamps	10.65
Walk-in fridges and freezers	6.58

Table 2-3 includes targeted appliances and their efficiency standards as stated in SB 1333 and considered for our modeling.

Table 2-3. SB1333 Appliances and Standards.

Appliance	Standard set by SB 1333[35]
Bottle type water dispensers	Standby energy consumption is to be less than or equal to 1.2 kWh per day.
	EPA Energy Star Program Requirements for Bottled Water Dispensers dictates testing methods.
Commercial boilers	Thermal efficiency of 80% for gas fired.
	Thermal efficiency of 82% for oil fired.
Commercial hot food holding cabinets	Maximum idle energy rate of 40 watts per cubic foot of interior volume.
	EPA Energy Star Program Requirements for Commercial Hot Food Holding Cabinets dictates testing methods.
Compact audio products	No more than 2 watts can be used in standby-passive mode for those without a permanently illuminated clock display and 4 watts in standby-passive mode for those with a permanently illuminated clock display.
DVD players and recorders	No more than 3 watts can be used in standby-passive mode.

Table 2-3. SB1333 Appliances and Standards. (continued)

Appliance	Standard set by SB 1333[36]
Liquid-immersed distribution transformers	Minimum efficiency levels 2/10 of a percentage point higher than the class 1 efficiency levels specified in Table 4-1 of the *Guide for Determining Energy Efficiency for Distribution Transformers*, published by the National Electrical Manufacturers Association.
Medium voltage dry-type distribution transformers	Minimum efficiency levels 3/10 of a percentage point higher than the class 1 efficiency levels for medium voltage distribution transformers specified in Table 4-2 of the *Guide for Determining Energy Efficiency for Distribution Transformers,* published by the National Electrical Manufacturers Association.
Metal halide lamp fixtures	If designed to be operated with lamps rated greater than or equal to 150 watts but less than or equal to 500 watts, the fixtures shall not contain a probe-start metal halide ballast.
Pool heaters	Products must be equipped with an intermittent ignition device and the thermal efficiency of pool heaters shall not be less than 80%.
Portable electric spas (hot tubs)	Standby power shall be no greater than $5(V^{2/3})$ watts, where V = the total volume in gallons.

Table 2-3. SB1333 Appliances and Standards. (continued)

Appliance	Standard set by SB 1333[37]		
Residential furnaces and residential boilers	**Product Type**	**Minimum Annual Fuel Utilization Efficiency (AFUE), %**	**Maximum Electricity Ratio, %**
	Natural gas and Propane-fired Furnaces	90	2.00
	Oil-fired furnaces >94,000 Btu/hr in capacity	83	2.00
	Oil-fired furnaces<94,000 Btu/hr in capacity	83	2.30
	Natural gas-, oil-, and propane-fired hot water residential boilers	84	Not Applicable
	Natural gas-, oil-, and propane-fired steam residential boilers	82	Not Applicable
Singe-voltage external AC to DC power supplies	**Nameplate Output Power**	**Minimum Efficiency in Active Mode**	
	0 to <1 watt	0.49* Nameplate Output	
	>1 watt and <49 watts	0.09*Ln(Nameplate Output Power) + 0.49	
	>49 watts	0.84	
		Maximum Energy Consumption in No-Load Mode	
	0 to <10 watts	.5 watts	
	>10 watts and <250 watts	.75 watts	
	EPA Energy Star Program Test Method for calculating the energy efficiency of Single-Voltage External AC-DC and AC-AC Power Supplies is what testing is based on.		
State-regulated incandescent reflector lamps	Enforce federal levels.		

Table 2-3. SB1333 Appliances and Standards. (continued)

Appliance	**Standard set by SB 1333[38]**	
Walk-in refrigerators and freezers	**Motor Type**	**Required Components**
	All	Interior lights. Light sources with an efficacy of 45 lumens per watt or more, including ballast losses (if any). This efficacy standard does not apply to LED light sources until January 1, 2010.
	All	Automatic door closers that firmly close all reach-in doors.
	All	Automatic door closers that firmly close all walk-in doors no wider than 3.9 feet and no higher than 6.9 feet that have been closed to within 1 inch of full closure.
	All	Wall, ceiling, and door insulation at least R-28 for refrigerators and at least R-34 for freezers.
	All	Floor insulation at least R-28 for freezers. (No requirement for refrigerators).
	Condenser fan	Electronically commutated motors, motors permanent split capacitor-type of under 1 motors, or polyphase motors of ½ horsepower.
	Single-phase	Electronically commutated motors evaporator fan motors of under 1 horsepower and less than 460 volts.

To determine the net energy savings from implementing SB1333,[xv] the MCCP team leveraged appliance sales data from ACEEE. As part of the *Leading the Way* report, ACEEE determined per unit electricity savings, affected[xvi] annual sales in Michigan, cost differentials between conventional and more efficient devices, and percent sales of products that currently meet the required efficiency levels as stated in SB 1333. (See Table 2-4.)

To determine the reduction of energy consumption by each new energy efficient appliance absorbed in the state, four common data points are necessary: total annual state sales, percent of state sales already meeting prescribed efficiency levels, average energy savings per product, and product lifetime. These were extracted from the ACEEE

[xv] The MCCP team modeled the effect of all SB 1333 appliances except residential pool pump motors.
[xvi] Affected sales are those sales of appliances not currently meeting the efficiency levels prescribed by SB 1333.

methodology. The following assumptions were made to best determine the total electricity savings for each of these appliances and their new efficiency levels.[xvii]

Table 2-4. SB 1333 Appliances in Michigan: Statistics.

Products	Adjusted Annual State Sales (2001)	% of total state sales that meet the standard	Adjusted per Unit Savings (kWh or *therm*)	Lifetime (years)
Boilers and furnaces				
Boilers (nat. gas)	97,233	38.7	*111.4 therms*	20.3
Furnace fans (heating)	129,204	15.4	794	
Commercial boilers	398	50	*514 therms*	30
Compact audio equipment	236,324	29	52.9	5
Dry type transformers: medium voltage	252,290	10	5.76	30
DVD players	168,822	64	10.7	5
External power supplies	6,110,824	32.5	4.14	7
Hot food holding cabinets	583	40	1815	15
Liquid immersed transformers	3,933,741	10	6.02	30
Pool heaters	3,114	33	58	15
Portable electric spas	1,732	80	250	10
Reflector lamps (BR and R20)	3,551,837	0	61	0.94
Walk-in refrigerators and freezers	1,797,091	5	8220	12
Water dispensers	4,376	41	266	8

The ACEEE methodology for determining state sales figures, individual appliance energy savings, and appliance lifetime factors is as follows:

- State sales figures: Commercial product sales were based on square footage of commercial buildings to total building square footage published for the Michigan region in the 2001 census. Residential product sales were based on the ratio of households in the state to total national households. ACEEE then calculated Michigan-specific saturation and usage rates by using rates found in the Residential Energy Consumption Survey (RECS)[39] and the Commercial Building Energy Consumption Survey (CBECS).[40]
- Increase in efficiency levels: Individual product energy savings estimations were based on DOE publications in the Federal Register; and publications from the Gas Appliance Manufacturers Association, Pacific Gas and Electric, and, in cases where DOE is not currently proposing Advanced Notices of Proposed Rulemakings for specific appliances or other standards, developments, and updates, research conducted for national ACEEE studies.
- Appliance lifetime: Average appliance lifetime was based on national averages as published by DOE, Pacific Gas and Electric, and Oak Ridge National Laboratory.

[xvii] With no accurate way to determine stock efficiency levels of appliances included in SB 1333, MCCP did not include stock appliances in the study. Stock efficiency uncertainty is due to a number of variables including, but not limited to, the status of coverage by federally mandated efficiency standards: if covered, effective date of policy; if not covered, whether intervention programs or market demands have affected efficiency levels, how long such forces have been in place, and average lifetime of product.

The MCCP model shows overall GHG savings from a policy implementation date of 2007, accounting for the saturation levels of each device as it relates to the device's respective lifetime, and showing the incremental change in savings for each year leading up to 2025. The MCCP team calculated each product's annual savings in energy consumption for each year from the policy effective date to 2025.

Annual energy savings calculations accounted for average product lifetime. Equation 1 calculated each year's savings if the product's average lifetime was greater than the difference between the model year and the policy implementation year. This equation also accounts for lag in adoption of practices prescribed by the policy and only counts half of the potential savings in the first year of implementation. Equation 2 calculated each year's savings if the product's average lifetime was the same or less than the difference between the model year and the policy implementation year. As per ACEEE methodology, the following equations converted per unit energy savings to each model year's kWh or therms savings:

> Equation 1: End-use electricity savings = annual sales volume * (years from effective date - .5) * per unit electricity (or natural gas) savings
>
> Equation 2: End-use electricity savings = annual sales volume * average product life * per unit electricity (or natural gas) savings

The MCCP team calculated GHG reductions associated with electricity-consuming appliances based on reducing upstream electricity demand at state-regulated and non-regulated utilities. Utilities consume a mix of fuels to generate electricity which is fed into an electricity grid consisting of transmission and distribution power lines. MCCP calculations account for the conversion efficiencies of utility-consumed fuel and transmission and distribution losses from delivering electricity to end-use location.

The team used two model inputs: cumulative energy savings figures up to and including the year 2015, and cumulative energy savings figures up to and including the year 2025 (See Appendix G.5). For products that consume kWh of energy, the model input was converted to MWh by adjusting the kWh unit factor to represent the MWh equivalent. For products that consume natural gas, the model input was converted from therms to BTU using a factor of 100,000 and from BTU to Million standard cubic feet (or MSCF) equivalent by using a conversion factor of 1020 BTU per cubic foot and then adjusting to equivalent units of MSCF. (See Appendix G.5 for annual savings in MWh, including the conversion calculations from BTU to MSCF.)

Estimated savings associated with each appliance were used as inputs into the model. For electricity and natural gas-consuming appliances, both MWh and MSCF were input into the model and then converted to MBTU. For electric appliances, MCCP used the conversion factor of 1 MWh/3.412 MBTU. For natural gas appliances, MCCP converted MSCF to BBTU by using a heat content of 1.0312 thousand BTU/cubic foot.

The MCCP team calculated GHG emissions reductions from reducing annual electricity sales by fuel type consumed by utilities.[xviii] The team assumed all upstream fuel offsets related to future growth in electric utilities, and apportioned displaced upstream energy generation among two non-renewable fuels at a ratio of 88% for coal and 12% natural gas. These percentages reflect the relative contributions to load growth in 2004, among statewide coal and natural gas generation, and assume that nuclear generation stays

[xviii] Michigan currently imports about 10% of its electricity. However, the team assumed all GHG reduction benefits would remain in the state.

constant over time. The MCCP team assumed no GHG emissions for nuclear sources and therefore did not include nuclear as a displaced electricity source.

MCCP assumed transmission and distribution (T&D) loss factors 9%, based on national averages. Coal-fired utility-operated plant losses were calculated at 37.9% transmission efficiency. Natural gas-fired utility operated plant losses were calculated at 48.8% efficiency. For those devices that consume natural gas, the MCCP team assumed at-source savings and did not include transmission and distribution losses. Table 2-5 illustrates these T&D losses and plant efficiency considerations.

Table 2-5. Transmission and Distribution Losses and Utility Plant Efficiency.

FF	MBTU	T&D Losses, %	Utility Plant Efficiency, %	T&D Loss Factor
Coal	1	9	37.90	2.89
Natural Gas	1	9	48.80	2.25

The MCCP team then converted MBTU to short tons of emissions for each GHG using the assumptions detailed in Table 2-6.

Table 2-6. GHG Emission Factors.

Emission Factor	**CO_2** (lb C/MBTU)	**CH_4** (Mton/BBTU)	**N_2O** (Mton/BBTU)
Coal	57.29	0.001	0.001
Natural Gas	31.91	0.00095	9.49E-05

The GHG emissions savings were estimated by calculating total avoided energy consumption for all the modeled products and translating those energy savings into carbon-equivalent emissions. The MCCP team converted those displaced sales figures (in MWh) to million metric tons of carbon equivalent (MMTCE).

Final model output is represented in MMTCE. Mass emissions of the three main greenhouse gases (CO_2, CH_4, and N_2O) were individually calculated and then converted to MMTCE, given their distinct relationships to carbon, distinct Global Warming Potential (GWP) (CO_2, CH_4, and N_2O = 1, 21, and 310 respectively) and distinct emissions factors per upstream energy sources. (See Figure 2-1 for calculation considerations.) Both MWh and MSCF were converted to BBTU, then to emissions in million metric tons, and then to MMTCE. Table 2-7 represents a sample set of calculations using CO_2 as an example. The following format also was used for CH_4 and N_2O.

Table 2-7. GHG Model Calculations considering CO_2 and Sample Set of Appliances.

GHG	Source	Appliance	Sector	Percent contribution to total FF source	MWh	MBTU	BBTU	Emission Factor (lbsC/MBTU)	Emissions (short tons)	Emissions (MMTCE)
CO2	Coal (utility)	portable electric spa	commercial	0.88	Total * .88	MWh * Transmission and Distribution Loss Factor	MBTU * .001	57.29	BBTU * Emission Factor * 1000/2000	Short tons * 1/1.1023/1000000
CO2	Natural Gas (utility)	portable electric spa	commercial	0.12	Total * .12	MWh * Transmission and Distribution Loss Factor	MBTU * .001	31.91	BBTU * Emission Factor * 1000/2000	Short tons * 1/1.1023/1000000
					Million Standard Cubic Feet	**Heat Content (thousand BTU/Cubic Feet)**				
CO2	Natural Gas (Non-Utility)	pool heater	commercial/residential	N/A	Total	1.03102	MSCF * Heat Content	31.91	BBTU * Emission Factor * 1000/2000	Short tons * 1/1.1023/1000000

2.3 Economic Model

Economic modeling for this Appliance Efficiency Standard explored impacts on the residential, commercial, and industrial sectors of Michigan's economy. Different appliances included in SB 1333 are utilized and operated in varying sectors of the economy. Model results revealed positive net changes to the states economy, though different sectors experienced different impacts.

2.3.1 Energy 2020

Based on average annual energy savings per product, the Energy 2020 model calculated the redistribution of energy consumption savings for both industrial and residential/commercial products. Results of redistributing energy consumption in the state were used to compare a BAU scenario of energy consumption against a new scenario, and were used as inputs into the REMI model. The following identifies each sector, including the specific segment of that sector, affected by each product in the Energy 2020 model:

Industrial	Other Substitutables	Commercial boilers
Industrial	Other Substitutables	Medium voltage dry-type distribution transformers
Industrial	Other Substitutables	Liquid-immersed distribution transformers
Commercial	Lighting	Metal halide lamp fixtures
Commercial	Lighting	State-regulated incandescent reflector lamps
Residential	Other Non-Substitutables	Compact audio products
Residential	Other Non-Substitutables	DVD players and recorders
Residential	Other Non-Substitutables	Pool heaters
Residential	Other Non-Substitutables	Portable electric spas (hot tubs)
Commercial	Other Non-Substitutables	Singe-voltage external AC to DC power supplies
Commercial	Other Non-Substitutables	Bottle type water dispensers
Commercial	Other Non-Substitutables	Commercial hot food holding cabinets
Commercial	Refrigeration	Walk-in refrigerators and freezers
Residential	Space Heating	Residential boilers
Residential	Space Heating	Residential furnaces

2.3.2 REMI

Results from the Energy 2020 model were then input into the REMI model. With model results from the Energy 2020 model, we were able to determine specific adjustments necessary for the REMI to be applied accurately to Michigan. This section explains the Energy 2020-based economic REMI model input variables and rationale, the variable impacts, and the economic sectors impacted by implementing an appliance efficiency standard in Michigan. The following lists REMI inputs determined by the MCCP team as a result of information provided by the Energy 2020 model.

Input Variables and Rationale

- Reduced amount of Consumer Spending for Household Operation to show the decreased spending for electricity due to more efficient appliances.
- Increased amount of Consumption Reallocation for All Consumption Sectors by 60% to redistribute these savings among all consumer spending categories.

- Increased amount of Industry Sales/International Exports for Broadcasting by 40% of the savings in Consumer Spending for Household Operation[xix] to because spending on Broadcasting is a major portion of this Consumer Spending category and is not decreasing because of the policy.[xx]
- Decreased amount of Firm Sales for Construction to account for the reduced capital expansion in the utility sector due to decreased electricity demands. The MCCP team also reduced the amount of Exogenous Final Demand for Electrical Equipment Manufacturing to show the decrease in Machinery purchased by the utility sector.
- Decreased amount of Firm Sales for the Utility Sector to show the overall decrease in Net Electricity sales due to reduced electricity demand from high-efficiency appliances.
- Decreased share of Electricity Fuel Costs for Commercial and Industrial sectors to model the decreased cost of electricity.
- Changed amount of Exogenous Final Demand for Petroleum and Coal Product Manufacturing sector to model the impact of fuel switching by the utilities.
- Decreased amount of Production Costs for Utility sector to model the decreased costs the sector faces due to decreased electricity demand.
- Increased amount of Value Added by Electrical Equipment Manufacturing sector to show the increased consumer value from high-efficiency appliances and products.

Impacts of Model Variables

- Shift in consumer spending positively impacts employment and gross state product.
- Decreased amount of Firm Sales for Utility Sector negatively impacts employment and gross state product.
- Decrease in Production Costs for Utility Sector positively impacts employment and gross state product.
- Decrease in Exogenous Final Demand for Electrical Equipment Manufacturing negatively impacts employment and gross state product.
- Decreased amount of Firm Sales for Construction negatively impacts employment and gross state product.
- Decrease in the share of Electricity Fuel costs for Commercial and Industrial sectors positively impacts employment and gross state product.
- Increase in Value Added by the Electrical Equipment sector positively impacts gross state product but does not affect employment.

[xix] Consumer spending for Household Operations is broken into the following categories: 40% Broadcasting, 30% Utilities, 12% State and Local Government, and less than 2% from each other category.

[xx] Broadcasting currently makes up 40% of household consumption, and includes among others household telecommunications and internet systems. When overall household consumption decreases (in this case due to reductions in electricity spending), 40% of that total reduction amount is not realistically apportioned to Broadcasting. Thus, the team re-spent 40% of the savings back to Broadcasting and then allocated that amount across the non-broadcasting-related household consumption categories.

Economic Sectors Impacted

- Sectors positively impacted by the policy include the Construction Sector, Retail Trade, services such as Health Care, Accommodations and Food Services, and Educational Services (due to increased consumer spending in these areas).
- Primary sector negatively impacted by the policy is the Utility sector.

See Appendix G.6 for annual impact on GSP and job year in the REMI model.

2.4 Results

By 2025, Michigan can experience a reduction of 7.35 Million Metric Tons of GHG emissions and average annual growth in GSP of $38.3 mil as a result of implementing SB 1333. By 2025, total potential savings in MWh of electricity and MSCF of Natural Gas savings equaled 19,526,000 MWh and 177,500 MSCF. This translates roughly to a total cumulative savings of $1.9 trillion from reductions in electricity consumption and $14.2 million[xxi] from reductions in Natural Gas consumption.

Appliance Efficiency standards resulted in significantly positive impacts on in-state GHG emissions, job growth, and gross state product. Relative to the other policies considered by this study, Appliance Efficiency ranked second best with regard to GHG emissions reduction potential. The majority of the benefits related to GHG emissions reductions are attributed to the reduction in utility fuel consumption by the utility sector. Disproportionate growth in cumulative GHG savings between year 2015 totals and year 2025 totals are attributable to products with long life-spans contributing larger proportions to in-state sales and stocks of targeted products. The majority of the benefits related to economic impacts are attributed to the redistribution of consumer spending as a result of savings on fuel and electricity spending.

See Tables 2-8 and 2-9 for GHG and Economic modeling generated for the Appliance Efficiency Standard. Cumulative economic figures represent net change (in all cases positive) to both job-years and gross state product in Michigan.

Table 2-8. GHG Model Results.

	2005-2015 Cumulative	2005-2025 Cumulative
Total GHG reductions from savings (MMTCE)	1.75	7.35

Table 2-9. Economic Model Results.

	2005-2015 Average	2005-2025 Average
Employment (Thousands)	0.233	0.437
Gross State Product (Million Fixed 2000$)	16.0	383

During Forum I, MCCP stakeholders rated Demand Side Management strategies as a very high priority for this project. The MCCP team values existing in-state efforts to

[xxi] This assumed an average natural gas rate of $0.08 per Ccf.

address GHG emission related issues, specifically with respect to reducing energy consumption. Thus, the MCCP team related SB 1333 to the Demand Side Management issues MCCP stakeholders are interested in. Despite addressing demand-side factors that contribute to energy consumption, Appliance Efficiency Standards are not necessarily considered Demand Side Management programs.

Examples of the economic and GHG-reducing potential of demand-side management from utility-based energy efficiency programs can be found in California, New Jersey, and Vermont. California has attempted regulatory decoupling to disassociate a utility's profits from its electricity. This assists in the development of energy efficiency programs given the utility does not stand to lose profit if less electricity is sold. In addition, Vermont employs utility performance incentive mechanisms when, for example, a reward is given for reaching energy efficiency targets, cost savings, or market penetration of energy efficient technologies.[41] To support these and other energy efficiency mechanisms, many states use a systems benefit charge, in which utilities provide a portion of revenues to a third party energy efficiency programs administrator, or rate payers are charged based on energy consumed from utilities. In general, utility-based energy efficiency programs prove to be highly successful improving the penetration of energy efficient technologies as well as reducing the electricity demanded of utilities by the end consumer.

2.4.1 Summary of Findings and Considerations

By 2025, as a result of implementing SB 1333, Michigan can experience a reduction of 7.35 MMTCE of GHG emissions and average annual growth in GSP of $38.3 million. This translates roughly into a total cumulative savings of $1.89 billion from reductions in end-use electricity consumption and $14.2 million from reductions in end-use natural gas consumption. Appliance efficiency standards resulted in significant in-state GHG emissions reductions and job growth and increases in GSP. The majority of the benefits related to GHG emissions reductions are attributed to the reduction in fuel consumption by the utility sector. As a result of savings on fuel and electricity spending, the majority of benefits related to economic impacts are attributed to the redistribution of consumer spending.

SB 1333 considers a variety of products with life-span longer than the study period considered by this project. Products with life-spans greater than twenty years were unable to fully contribute to study results given that full-saturation levels for these products were not yet achieved according to the team's scope. Table 2-10 lists products with life-spans longer than or equal to 20 years.

Table 2-10. Products with Long Life-Spans.[42]

Product	Life-Span, yrs.
Commercial boilers	30
Liquid-immersed distribution transformers	30
Medium voltage dry-type distribution transformers	30
Metal halide lamp fixtures	20
Residential furnaces and boilers	20.3

This study does not reveal any major changes to manufacturing levels related to appliance manufacturing given that efficiency level restrictions are placed on products consumed, but not necessarily produced, in Michigan. In addition, the model does not distinguish appliance manufacturing, but adjusts for the entire manufacturing sector in the state. The bill also represents an opportunity for both demand and supply-side actors in the appliance market to develop technology, awareness, and efficient-use practices, potentially positioning Michigan with a first mover advantage to meet potential federal regulations covering some or all of the appliances listed in SB 1333.

3. Alternative Fuels Production and Infrastructure and Alternative Vehicle Technologies

3.1 Introduction

As reported in the Center for Sustainable Systems' (CSS) *2005 Michigan Greenhouse Gas Inventory 1990 and 2002*, the transportation sector produces approximately one quarter of the state's greenhouse gas (GHG) emissions. Specifically, the transportation sector accounted for 24% of the GHG emissions in 1990, and 26% of the emissions in 2002, amounting to approximately 13.70 and 16.24 million metric tons of carbon equivalent (MMTCE), respectively.[43] Given this contribution to the state's GHG emissions, the transportation sector becomes a strategic opportunity for GHG emission reductions.

Table 1 below summarizes transportation fuel usage used in establishing the GHG inventory.[44] Table 2 displays annual vehicle miles traveled (VMT) data from the last ten years in Michigan, provided by the Federal Highway Administration.[45]

Table 3-1. GHG Inventory Fuel Usage Data.

Transportation Fuel	1990	2002	Unit
Gasoline	98,167	121,587	Thousand Barrels
Diesel	13,207	21,222	Thousand Barrels
Natural Gas	17,930	27,236	Million Cubic Feet
Liquefied Petroleum Gas	283	355	Thousand Barrels
Ethanol	1,205	1,223	Thousand Barrels

Table 3-2. Michigan VMT Trends.

Year	VMT (millions)	Percentage Increase
1995	85,705	--
2000	97,792	14.1%
2004	103,326	5.7%

The Michigan at a Climate Crossroads Project (MCCP) team recognized the opportunity for GHG reductions in this sector and proposed 26 potential GHG emission reduction strategies affecting GHG emissions from the transportation sector to the stakeholders. In Forum I, stakeholders were most interested in two transportation sector strategies for the MCCP team to analyze for GHG emissions reductions and impact to the state's economy. Also listed in the Introduction, these strategies were:

- Alternative Fuel Infrastructure/Flex/Bio Fuels; and
- Tax Credit for Alternative Vehicles Technologies/Incentives for Production and R&D.

These two strategies were broad in scope and impacted numerous aspects of the transportation sector. Therefore, an initial step for the team was to narrow these strategies to specific policies that could then be analyzed for assessments of GHG emission reduction potential and economic effects.

To facilitate the process the MCCP team found it helpful to categorize this sector. The transportation sector can be broken into sub-sectors, including, but not limited to, mass transit, aviation, freight and cargo, urban planning and infrastructure development, and personal on- road mobility. (Note: mass transit also was identified as a high-priority strategy and is addressed in its own section within this document.)

Based on the two prioritized strategies, the MCCP team identified the transportation sub-sector of interest as the personal on-road mobility. This system comprises individual consumers utilizing light-duty vehicles (LDVs: automobiles, light trucks, minivans, and sports utility vehicles) as its primary means of mobility. This system can be refined into three areas of influence: automobile technologies, fuels, and driver decisions and preferences. All three are important leverage points for addressing GHG emissions from the transportation sector.

When evaluating the two strategies against these criteria, the MCCP team focused on the fuels and automobile technology segments, and recognized that these strategies can potentially indirectly influence drivers' decisions by supporting and making available alternative fuels (AF) and alternative vehicle technologies (AVT).

The World Business Council for Sustainable Development listed available AVTs and AFs in their *Mobility 2030* report (2004). Table 3-3 summarizes the listing.[46]

Table 3-3. Alternative Vehicle Technologies and Alternative Fuels.

Alternative Vehicle Technologies	Alternative Fuels
Advanced Internal Combustion Engine	Fischer-Tropsch Diesel
Homogeneous Charge (HCCI) Diesel Engine	Ethanol – blends (E85 and E10)
Flexible Fuel ICE/Diesel	Methanol
Hybrid Electric Vehicle--ICE	Bio-diesel (B5 through B100)
Hybrid Electric Vehicle--Diesel	Compressed Natural Gas
Fuel Cell	Liquefied Petroleum Gas
	Hydrogen

Finally, when evaluating policies for the promotion of new technologies, it is important to consider where AVTS and AFs are on the technology development curve. The Pew Center on Global Climate Change provides a simple framework for classifying new technologies.[47] A technology starts at invention, moves to innovation which translates to commercialization when the technology is adopted through consumer and end-user education. State-level policies can be instituted to assist in each of these phases, taking the form of support for research and development (R&D) in the invention, innovation, and commercialization phases, incentives that promote adoption, and programs that facilitate education. Technology development does not occur in a linear fashion and relies heavily on feedback during the steps requiring moving a technology up and down the development curve.

With this framework, the above-listed AVTs and their accompanying AFs can be placed along the technology curve, helping to shape the structure of the policies and the timeline of expected impact on GHG emission reduction and economic development in the state. In general, flexible fuel vehicles (FFVs), hybrid electric vehicles (HEVs), advanced internal combustion engines (A-ICE), and Homogenous Charge HCCI diesel engines are considered more near- and middle- term alternatives to the traditional internal combustion engine (ICE).

The fuels available for use in these vehicles, such as Fisher-Tropsch (FT) diesel, ethanol blends, methanol blends, and bio-diesel, typically rely on the existing fuel infrastructure, facilitating their use as near term alternatives. Ethanol derived from corn is currently moving from the commercialization phase to the adoption phase, while the next generation of ethanol, cellulosic-derived ethanol, is still in the innovation and commercialization phase. Given their relatively underdeveloped refueling infrastructure, compressed natural gas (CNG) and liquefied petroleum gas (LPG) fuels are likely to exist only as niche alternatives to gasoline and diesel.

The hydrogen and fuel cell vehicle alternatives are still in the early phases of the technology development curve. The infrastructure for hydrogen refueling is extremely underdeveloped, if not non-existent. Additionally, the lack of commercial availability of fuel cell vehicles is a significant barrier to short-term adoption of this technology. As such, when FFV and HEV alternatives are more near-term solutions, hydrogen and fuel cell vehicles are considered more long-term alternatives. Significant debates surround the likelihood of hydrogen as the fuel system of the future.

As a result, the MCCP team engaged key stakeholders in developing (or in some cases modifying existing) policy language that would meet the goals of the two preferred strategies. Appendix H.1 provides a summary of the policies identified by MCCP as potentially applicable to the two transportation strategies. The MCCP team, along with the stakeholders, quickly realized the limitations associated with certain policies for inclusion in the proposed analysis. Therefore, the team chose to focus on policies that would potentially impact the modeling time frame (2007-2025), could reasonably be modeled from a GHG and economic perspective, and potentially affect Michigan's GHG emissions.

These criteria were significant in deciding not to develop a policy specifically geared to state incentives for alternative automobile production and R&D. While the stakeholders contended that these types of policies would represent a strong economic signal for manufacturing and R&D to remain or come to the state, the MCCP team struggled to develop an adequate method to model the downstream GHG emission reduction benefits from the policy. This limitation primarily manifested itself in the limited ability to create a flexible policy to support alternative technologies and predictive of the ultimate commercial success of a set of technologies that would produce meaningful GHG emission reductions. The stakeholders agreed that, although the economic analysis for such a policy would likely be strong, the inability to adequately model GHG emissions reductions meant such policies were outside the scope of this project.

Utilizing the key criteria to develop policies for inclusion in the analysis, the MCCP team and stakeholders defined three policies to support these two strategies. These policies promoted the production of alternative fuels in the state, the availability and distribution of alternative fuels at the consumer level, and the availability of alternative vehicles at the consumer level. These three policies:

1. *Provide production tax credit (PTC) for in-state ethanol (both corn and cellulosic).*

- $0.05 per gallon of ethanol, up to 15 -million gallons per year, produced at a **corn-**based biorefinery, with an annual capacity of less than 60 million gallons. The PTC is limited to three years of operations.[xxii]
- $0.125 per gallon of ethanol, up to 15 -million gallons per year, produced at a **cellulosic** biorefinery. There is no limit on the size of the facility and the PTC is limited to ten years of operations.

2. *Renewable Motor Fuel Standard (RFS): Mandate a 25% renewable fuels standard for in-state motor fuel sales.*

- RFS will begin by requiring 10% of motor fuels sold (on a volume basis) in Michigan to come from renewable resources in 2010.
- RFS will increase 1% per year until 2025, resulting in 25% of motor fuels sold in the state supplied from a renewable resource by 2025.
- Eligible fuels:
    - E85: ethanol used in a 85% volumetric blend of ethanol and conventional gasoline (CG).
    - RFG/E10: ethanol used as a oxygenate in CG.
    - Biodiesel: blended in any proportion with conventional diesel from 20% (B20) to 100% (B100).

3. *Alternative Vehicle Technology Incentive.*

- State-funded automobile consumer tax credit for alternative vehicle technologies.
- Tax credits ranging from $500 up to $10,000.
- Five year program running from 2007 to 2011.
- Eligible vehicles including alternative light duty cars and trucks, are listed in Table 3-4.

[xxii] The US Energy Policy Act 2005 (EPACT) redefined a small ethanol producer from 30 million gallons per year capacity to 60 million gallons per year. This proposed policy provides a tax incentive to this same population of ethanol producers.

Table 3-4. AVT Incentive Eligible Technologies.

Alternative Technology	Alternative Technology
Compressed Natural Gas Bi-fuel	Electric-Gasoline Hybrid*
Compressed Natural Gas ICE	Fuel Cell Hydrogen*
Electric-Diesel Hybrid*	Liquefied Petroleum Gas Bi-fuel
Ethanol-Flex Fuel ICE*	Liquefied Petroleum Gas ICE
Ethanol ICE	Fuel Cell Methanol
Electric Vehicle*	Methanol-Flex Fuel ICE
Fuel Cell Gasoline*	Methanol ICE

The remainder of this section describes the modeling methodologies and results for each of these three policies.

3.A. Michigan Ethanol Production Tax Credit

The Ethanol PTC is a specific policy measure that could be used to spur additional ethanol production in the state.

The MCCP team modeled four Ethanol PTC GHG emission reduction scenarios and one overall economic impact scenario. The primary driver for multiple GHG emissions scenarios was the rapid growth of the corn ethanol industry in the US during the summer of 2006. At the onset of the MCCP (January 2006), Michigan had a baseline capacity for corn ethanol of 250 million gallons per year (Mgal/yr) from five facilities.[xxiii] The ethanol PTC was believed to spur an additional four to five corn ethanol plants with a total capacity of approximately 240-250 Mgal/yr. However, during the project period, the MCCP team learned that four new corn ethanol facilities were either announced or being planned in Michigan and had a total new capacity of approximately 275 Mgal/yr (i.e., potentially increasing total instate capacity to 525 Mgal/yr). In this case, an incentive in the form of a PTC was not necessary to attract new corn ethanol plants or facilities to the state; therefore, the MCCP team recognized that a PTC for corn ethanol production became less meaningful.

However, the GHG model developed was well suited to quantify the GHG reduction potential from the baseline capacity (250 Mgal/yr) along with the proposed new corn ethanol capacity (525 Mgal/yr). Therefore, the following four GHG Ethanol PTC scenarios were modeled:

- Corn Baseline I: production capacity of 250 Mgal/yr.
- Corn Baseline II: production capacity of 525 Mgal/yr.
- Original PTC: induced production capacity of 240 Mgal/yr above Baseline I.
- Cellulosic: production capacity of 100 Mgal/yr from an herbaceous feedstock.

Recognizing that financial incentives were no longer a primary driver of future development of corn ethanol production, MCCP modeled only one economic scenario. This scenario accounted for the benefits of a 525 Mgal/yr corn ethanol supply (Baseline II) along with a 100 Mgal/yr cellulosic ethanol facility.

[xxiii] The 250 million gallons per year capacity was reflective of existing and planned corn ethanol production in the state.

The following sections present the modeling methodology for both GHG reductions and economic effects, the results of the modeling, and the results in the context of overall GHG emission reductions in the state.

3.A.1 PTC GHG Model

3.A.1.1 Introduction

The MCCP's GHG model assesses the GHG emission reduction potential from in-state ethanol production with the end use as a motor fuel. The model evaluated the Well-to-Pump (WTP) emissions associated with ethanol production and the associated reduction of WTP emissions from displacing an energy equivalent of conventional gasoline.[xxiv] "Well-to-Pump," a motor fuel lifecycle analysis term, refers to the complete accounting of emissions from the point of origin of the fuel (well) to the point of delivery (pump). The Ethanol PTC GHG model accounted for GHG emissions from 2005 through 2025, with the policy taking effect in 2007, and emission savings beginning in 2009.

The MCCP team used the federal definition of small ethanol refinery to establish an eligible facility under the proposed corn Ethanol PTC.[48] The team assumed that four additional facilities, resulting in a doubling of in-state corn ethanol capacity, would result from the corn Ethanol PTC. The modeled 100-Mgal/yr cellulosic facility was selected as a probable commercial demonstration facility for this emerging technology.

The Ethanol PTC GHG model functioned primarily to determine the net GHG benefit of additional ethanol capacity in the state. The model accounted for an existing baseline capacity and allowed for the staged introduction of new ethanol capacity across the modeling period (2007-2010). The model accounted for the impact of new ethanol capacity on the biomass feedstock production system. The biomass feedstock for cellulosic ethanol production was assumed to be an herbaceous agricultural product.[xxv] Finally, the model accounted for the displacement of GHG emissions associated with an energy equivalent amount of petroleum motor fuel. Results are reported as MMTCE reduced.

WTP GHG emission factors (grams of pollutant per million British Thermal Unit of motor fuel) are generated using the Argonne National Lab's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model.[xxvi] This model did not address the end form of ethanol at the pump. Ethanol is typically mixed with conventional gasoline, either in an 85% volumetric blend (E85) or as an oxygenate (7%-10% by volume) in reformulated gasoline (RFG). However, for the purposes of a WTP analysis, the end use of the produced ethanol is not a critical factor. Table H.2-3 in Appendix H.2 presents the annual WTP emission rates for the corn and cellulosic models.

[xxiv] Energy Equivalent, refers to the fact that ethanol has a heat rate of approximately 84,250 Btu/gal, whereas petroleum gasoline has a heat rate of 125,000 Btu/gal. Therefore, when operating a vehicle with an ethanol-based fuel, a driver needs more gallons of fuel to drive an equivalent distance with petroleum motor fuel.

[xxv] Two primary feedstocks are often considered for cellulosic ethanol production. Woody biomass typically refers to fast growing trees (such as Hybrid Poplar) and herbaceous biomass typically refers to fast growing grasses (such as switch grass or miscanthus).

[xxvi] Carbon Dioxide (CO_2), Nitrous Oxide (N_2O), and Methane (CH_4) emission factors were generated for conventional gasoline and denatured ethanol (E100). The E100 would be blended with various amounts of conventional gas (CG) to make either E85 or a 10% blend (reformulated gasoline--RFG). These blended fuels are sold to consumers at the pump.

Figure 3.A-1 displays a simplified process flow of the PTC GHG model.

3.A.1.2 Corn Ethanol Model Inputs and Assumptions

Several key pieces of data from the corn industry, the corn ethanol industry, and the GREET model are required as inputs to the Corn Ethanol PTC GHG model. Table 3.A-1 provides these input parameters and the values that the model used to calculate GHG reductions, as well as the assumptions and parameters necessary to create both the Corn Baseline I and Corn Baseline II scenarios.

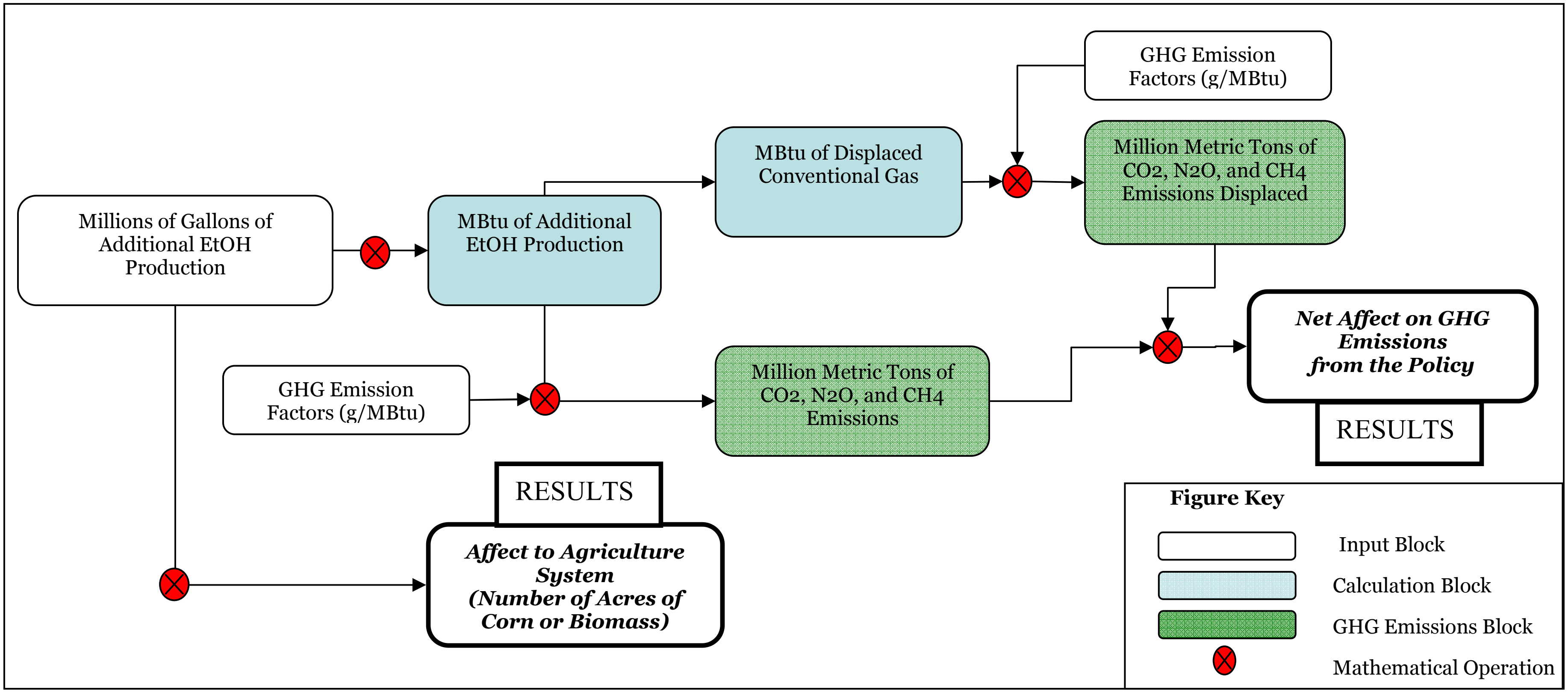

Figure 3.A-1. Corn and Cellulosic Ethanol Production GHG Model Flow Diagram.

Table 3.A-1 is followed by a brief description of sources and methodologies for determining these input values.

Table 3.A-1. Corn Ethanol PTC GHG Model.

Sector	Model Parameter	Source	Value	Unit
Corn Production and Use Sector				
	2005 Acres Planted	USDA[49]	2,250	Thousand acres
	2005 Acres Harvested	USDA[50]	2,020	Thousand acres
	2005 Corn Yield (see Note 1)	USDA[51]	143	bushels/acre
	2005 Corn to In-state Feed	USDA[52]	101,000	Thousand bushels
	2005 Corn Carry-in from 2004	USDA[53]	36,500	Thousand bushels
	2005-2025 Harvest Rate		See Note 2	
	2005-2025 In-state Feed Growth Rate		See Note 3	
	2005-2025 Export Fraction		See Note 4	
	2005-2025 Carryover Fraction		See Note 5	
Ethanol Production				
	2005 Conversion Rate	NCGA	2.8	gallons/bushel
	2005-2025 Conversion Rate Improvement Rate		See Note 6	
	Baseline Capacity (5-plant)	Stakeholders	250 (by 2008)	million gallons
	Baseline Capacity (9-plant)	Stakeholders	525 (by 2010)	million gallons
	PTC Spurred Capacity			
GHG Emission Factors				
	2005-2025 E100 WTP CO2, N2O, and CH4 Emission Factors	GREET	See Appendix H.2	grams/MBtu
	2005-2025 CG WTP CO2, N2O, and CH4 Emission Factors	GREET	See Appendix H.2	grams/MBtu

Corn Sector Input Notes

1. Corn Yields for 2006-2025 are estimated based on historical yield data. The MCCP team looked at actual corn yields from 1995 through 2005 and fit a linear equation to the data. This equation estimated corn yields in 2006 through 2025, resulting in an average annual corn yield improvement of about 1.8%.
2. The Harvest Rate is calculated for 2005 by dividing the number of harvested acres by the number of planted acres. This ratio (85%) is applied in each of the subsequent modeled years.
3. Stakeholder feedback has indicated that corn usage for in-state feed (animal and human) is not expected to grow over the modeled time frame.[54] A baseline 1% annual growth is used to project corn usage for in-state feed.
4. 2005 corn exports accounted for nearly 40% of the supply. However, stakeholder feedback indicated this would be reduced as the demand from the ethanol industry grew. Corn export is not expected to drop to zero, and, therefore, a baseline of 20% export is used for model years 2006-2025.
5. Carryover represents the amount of bushels remaining in-state and available to supplement the next year's supply. 2005 had a carryover fraction of approximately 12%. By anticipating peak production in both the 5-plant and 9-

plant scenarios, carryover ramps up to 28% of production in years 2006 and 2007. To satisfy peak production the carryover fraction is modeled as 0% in years 2010 -2011, and then begins to grow again as corn yields improve, reaching a steady state of 20% by 2016. Note that in the 9-plant scenario an additional 700,000 acres of corn are required to supply the ethanol industry with in-state corn.[xxvii]

Ethanol Sector Input Notes

1. The National Corn Growers Associations (NCGA) has estimated that ethanol conversion rates will increase from 2.8 gallons/bushel in 2005, to 3.36 gallons/bushel in 2016.[55] The GHG model has input annual improvement rates to reach this level by 2016, and then reduces the annual improvement rate to 0%.

3.A.1.3 Cellulosic Ethanol Model Inputs and Assumptions

Michigan, and the entire United States, does not currently have any commercial level Cellulosic Ethanol production capacity. The cellulosic ethanol production process is still an emerging technology, and therefore, the BAU production level is set to zero. It is unclear what effect a PTC, as defined in MCCP, will have on stimulating a cellulosic facility in the state. Based on stakeholder recommendations, the MCCP Team decided to model a single 100-million gallon herbaceous cellulosic biorefinery. The operational start date for this facility is estimated for 2010. Table 3.A-2 provides the key input parameters and the values the model used to calculate GHG impacts. Table 3.A-2 is followed by a description of the sources and methodologies to determine these input parameters.

Note that whereas the Corn Ethanol GHG model assessed the impact on the existing acres of corn agriculture by modeled ethanol demand, the Cellulosic Ethanol GHG model predicts the number of acres required to be planted per year to meet the ethanol demand.

[xxvii] The MCCP team has received feedback from stakeholders concerned with the availability of agricultural land of the quality to tolerate an additional 700,000 acres of corn. Additionally, stakeholders were concerned with implications of soil quality to crop switching to corn to meet the increased demand.

Table 3.A-2. Cellulosic Ethanol PTC GHG Model.

Sector	Model Parameter	Source	Value	Unit
Herbaceous Biomass Production				
	Initial Biomass Yield	McCarl/Schnieder[56]	4.22	dry tons/acre
	2005-2025 Yield Improvement Rate		See Note 1	
	2005-2025 Harvest Rate		See Note 2	
Ethanol Production				
	2005 Conversion Rate	GREET	95	gallons/dton
	2005-2025 Conversion Rate Improvement Rate		See Note 3	
	PTC Spurred Capacity	Estimated	100 (by 2010)	million gals
GHG Emission Factors				
	2005-2025 E100 WTP CO2, N2O, and CH4 Emission Factors	GREET	Appendix H.2	grams/MBtu
	2005-2025 CG WTP CO2, N2O, and CH4 Emission Factors	GREET	Appendix H.2	grams/MBtu

Herbaceous Biomass Sector Input Notes

1. The MCCP team estimated biomass yield improvement as a 2% improvement each year from 2006 through 2025. Modeled yield rates ranged from 4.22 to 6.27.[xxviii]
2. An 85% harvest rate, as estimated in the Corn Ethanol GHG Model, is also used in the Corn model.

Ethanol Sector Input Notes

3. The MCCP team estimated cellulosic conversion rate improvement as a 2% improvement each year from 2010 through 2020. Modeled conversion rates ranged from 95 to approximately 116 gallons per dry ton.[xxix]

3.A.2 PTC Economic Modeling

The modeling of the economic impacts of the ethanol industry in Michigan was intended to capture the benefits and costs of increasing in-state ethanol production. As discussed in the Introduction of this report, to accomplish the economic modeling, the MCCP utilized the REMI model in conjunction with Energy 2020. The model was designed to capture the benefits from growing a manufacturing- and processing- based industry. The benefits and costs associated with increasing the demand for agricultural products such as corn and herbaceous biomass were not able to be captured using these tools. For the Ethanol PTC modeling, the MCCP accounted for consumer spending at the pump for ethanol-based motor fuels versus petroleum-based motor fuels.

[xxviii]The MCCP team estimated an annual biomass yield increase based on projected corn yield increases during the modeled period. This was considered the best available data at the time of modeling
[xxix]The MCCP team estimated an annual ethanol conversion rate increase based on projections of improvements in corn ethanol conversion over the modeled period. Given that cellulosic ethanol is an emerging technology, it is a conservative estimate that process efficiency improvements will be on par with a more developed technology.

The following are modeled variables and their impacts on the economic modeling. For ease of identification, model variable names are highlighted. Appendix H.3 provides detailed input data for each of the presented variables.

Input Variables and Rationale

- MCCP decreased the overall statewide demand for petroleum gasoline (REMI Variable Name: *Exogenous Final Demand for Petroleum, Coal Product Manufacturing*), accounting for the fact that, due to policy, ethanol was displacing gasoline as a motor fuel.
- MCCP increased the amount of chemical processing in the state (REMI Variable Name: *Firm Sales for Chemical Manufacturing*) to model the production and sale of ethanol. This variable was increased at a higher volumetric amount when compared to the amount of petroleum displaced. This accounts for the energy equivalent cost to consumers associated with ethanol having a lower higher heating value than petroleum. While the MCCP team assumed the reduced demand for petroleum will come from both in-state and out-of-state supply, the team also assumed that all of the new ethanol production will be within the state.
- MCCP increased the amount of consumer spending for gasoline (REMI Variable: *Consumer Spending for Gasoline and Oil*) by an amount equal to the extra cost for using ethanol to drive the same distances. To capture this effect, MCCP conservatively assumed that all in-state ethanol production was sold in the form of E85. Note that RFG and conventional gasoline have no price difference and, therefore, ethanol used in this way would result in no increase to baseline Consumer Spending.
- MCCP decreased the amount of consumer spending in other economic sectors (REMI Variable Name: *Consumption Reallocation to All Consumption Sectors*) to show consumers decreased spending on other areas to pay for the higher transportation fuel costs. Overall total consumer spending stays constant.
- MCCP increased the amount of construction activity in the state (REMI Variable Names: *Firm Sales for Construction* and *Firm Sales for Electrical Equipment*) to model the capital spending in labor and equipment to build the new ethanol bio-refineries.
- MCCP decreased the amount of government spending (REMI Variable Name: *Government Spending at the State Level*) to account for the existing state subsidy for sales of ethanol blended motor fuels above 70% by volume.[xxx]

Variable Impacts

Appendix H.3 illustrates the behavior of the modeled variables for this policy.

- The decrease in the demand for petroleum gasoline has negative impacts on both employment and gross state product.
- The increase in the amount of chemical manufacturing capacity has positive impacts on employment and gross state product. These positive impacts are greater than the negative impacts from the decrease in petroleum demand.

[xxx]SB1074 was signed into law in September 2006, and reduces motor fuel taxes on ethanol-blended motor fuels (greater than 70% by volume) by $0.07 per gallon.

- The increase in the amount of construction activity has positive impacts on employment and gross state product.
- The change in consumer spending patterns has negative impacts on employment and gross state product.
- The decrease in the amount of government spending at the state level has negative impacts on employment and gross state product.

Economic Sectors Impacted

- The sectors positively impacted include Chemical Manufacturing, Construction, Electrical Equipment Manufacturing, State and Local Government, Wholesale and Retail Trade, and General Service Sectors.
- The primary sector negatively impacted is the Petroleum Product Manufacturing sector.

3.A.3 PTC Results and Discussion

The following section presents the results of modeling an Ethanol PTC in the state along with a discussion of the implications of pursuing such a policy. This section includes comments from stakeholders during Forum II regarding the modeling results. Tables 3.A-3 and 3.A-4 summarize the cumulative GHG and economic modeling through 2015 and 2025.

Table 3.A-3. Corn and Cellulosic Ethanol PTC GHG Modeling Summary 2015 and 2025.

Scenario	MMTCE by 2015	MMTCE by 2025
Corn Baseline I	1.27	2.67
Corn Baseline II	2.27	5.21
Original PTC	0.78	2.13
Cellulosic	1.22	3.24

Table 3.A-4. Corn and Cellulosic Ethanol PTC Average Annual Economic Effects.

Scenario	2015	2025
Change in Gross State Product (millions of 2000 dollars)	447	504
Change in Employment (job-years)	3,050	2,970

3.A.3.1 Ethanol PTC GHG Modeling Results and Discussion

The GHG benefits of an ethanol PTC were modeled in the context of displacing conventional petroleum gasoline from the transportation system in Michigan.[xxxi] As a first step in the analysis, the MCCP team determined the BAU conventional fuel usage for the state and calculated the associated WTP GHG emissions (Figure 3.A-2). The slopes of the two data series in Figure 3.A-2 do not remain constant across the modeling period because WTP GHG emission factors for conventional gasoline are changing throughout the modeled period. As a result, there is a steeper increase in predicted emissions compared to the predicted increase in motor fuel usage for the period of 2015-2020.

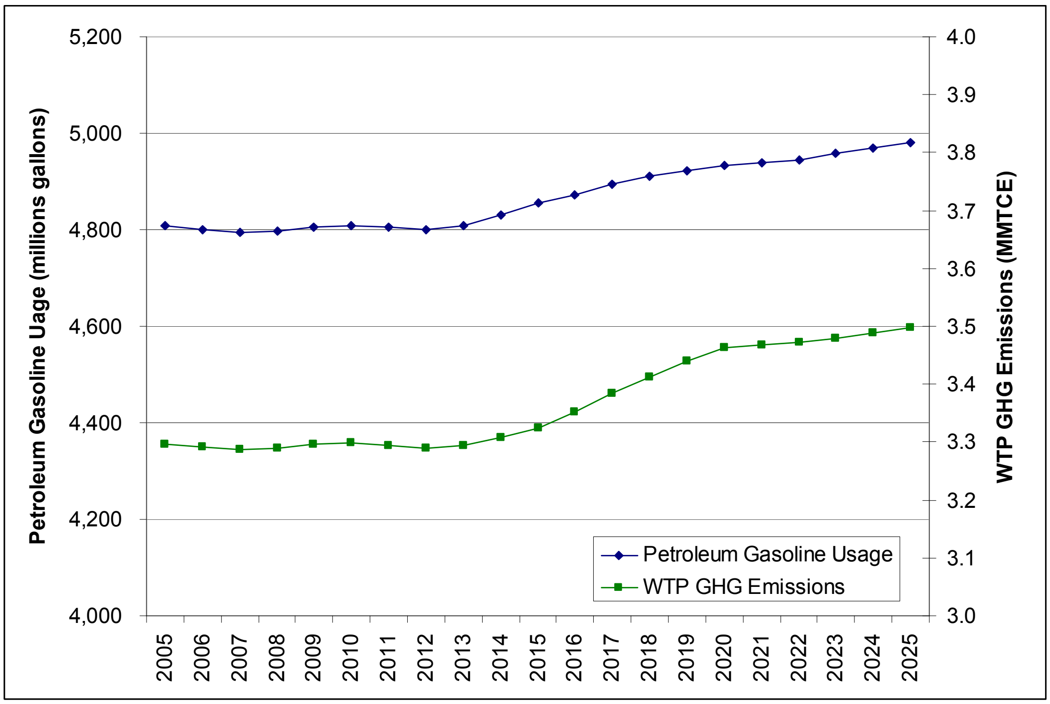

Figure 3.A-2. Baseline Michigan Conventional Gasoline Usage and WTP GHG Emissions (2005-2025).

Figure 3.A-3 through Figure 3.A-6 present the effect each of the four modeled ethanol production scenarios have on BAU WTP emissions from conventional gas usage.

[xxxi]Table H.4-1 in Appendix H.4 presents all motor fuel usage in the state for the modeled timeframe BAU scenario.

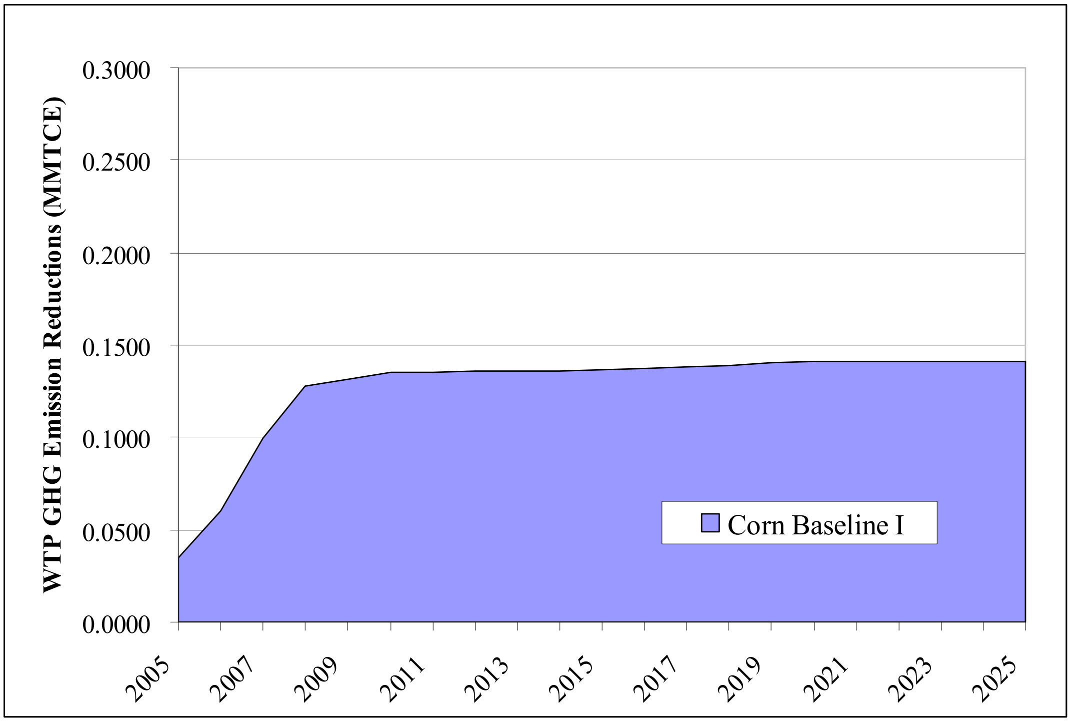

Figure 3.A-3. Corn Baseline I WTP GHG Emissions (2005-2025).

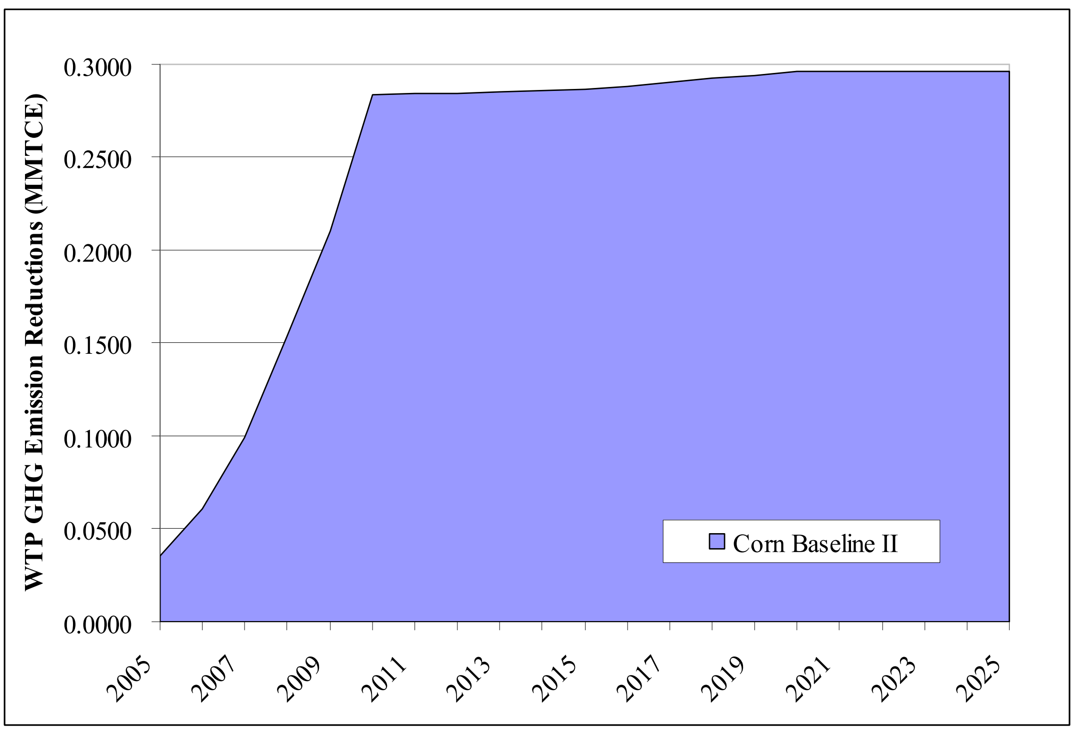

Figure 3.A-4. Corn Baseline II WTP GHG Emissions (2005- 2025).

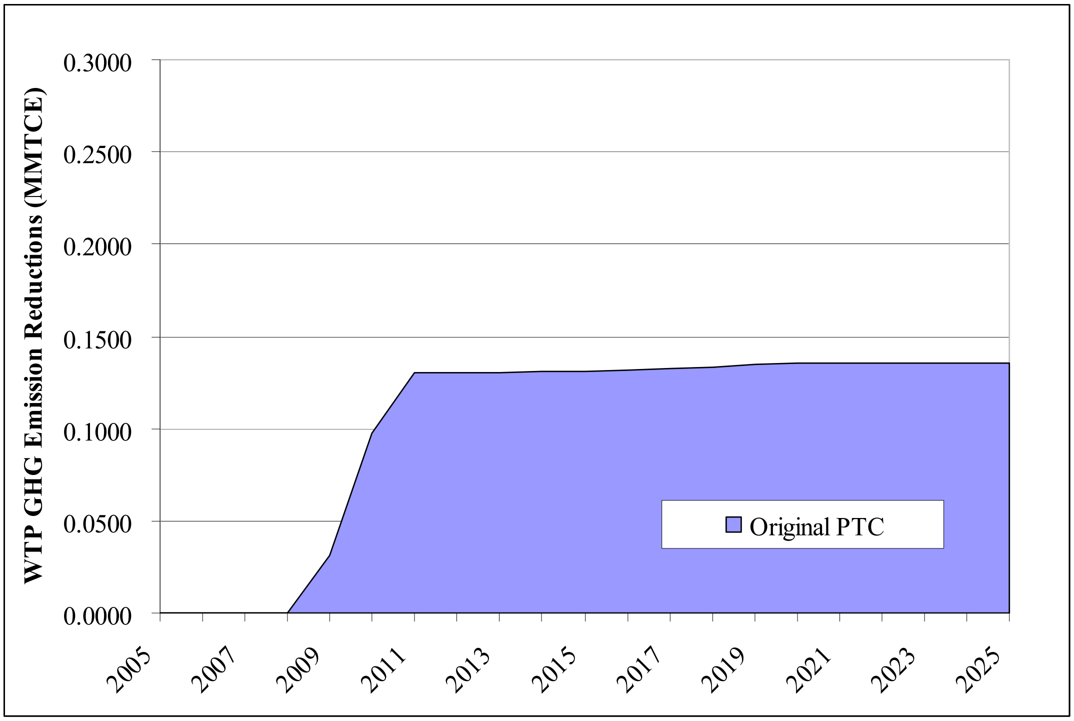

Figure 3.A-5. Original PTC WTP GHG Emissions (2005-2025).

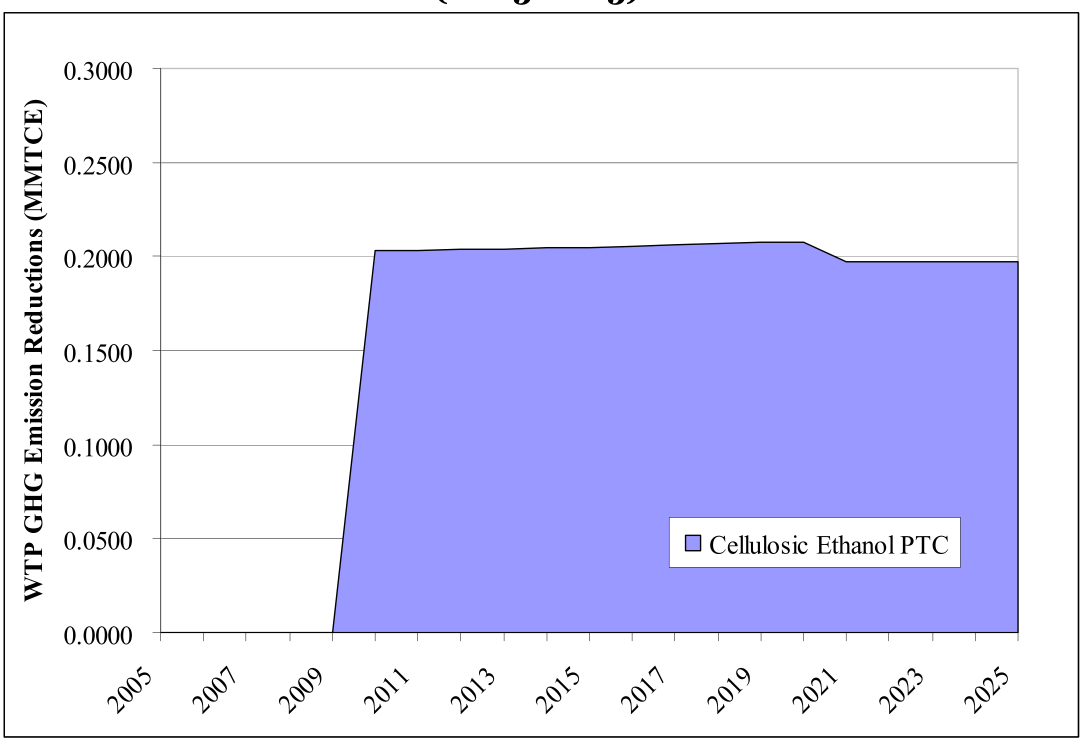

Figure 3.A-6. Cellulosic Ethanol WTP GHG Emissions (2005-2025).

Figures 3.A-3 through 3.A-6 represent various degrees of GHG emission reduction from the BAU scenario. The projected baseline capacity of corn ethanol in the state (Baseline II) represents an average 7.3% reduction per year of WTP GHG emissions from petroleum gasoline usage. A single cellulosic ethanol refinery with an annual capacity of 100 million gallons has the potential to reduce another 4.6% per year of WTP GHG emissions.

These results point to the superiority of cellulosic ethanol feedstocks in terms of GHG emissions. At 100-gallons capacity, cellulosic ethanol has almost two-thirds the cumulative GHG benefit in 2025 as 525-gallons of corn-based ethanol. This result is largely based on the reduction of GHG emissions associated with the production of the feedstocks for cellulosic ethanol compared to corn. Corn requires significantly more nitrogen-based fertilizers, leading to additional terrestrial N_2O emissions. As such, by using a cellulosic-based feedstock, WTP GHG emissions are greatly reduced.

However, GHG emissions are only one aspect of corn ethanol production that ultimately favors cellulosic ethanol production. Several stakeholders were concerned that corn production for ethanol required more Michigan agricultural land compared to cellulosic ethanol production. The modeling associated with this project supports this conclusion. Figure 3.A-7 presents the land usage (in acres) to produce the various amounts of ethanol in the modeled scenario.[xxxii]

Figure 3.A-7 provides two key insights. The first is that to meet a 525 million gallons production capacity for corn ethanol, an additional 700,000 acres of corn will need to be planted.[xxxiii] This represents a 27% increase in corn acreage in the state. The second insight is that for each acre of corn, 433 gallons of ethanol can be produced, and for each acre of cellulosic feedstock, 500 gallons of ethanol can be produced. Corn is typically only grown on high quality agricultural land, whereas most cellulosic feedstock materials (herbaceous and woody) can be grown on marginal agricultural land.

[xxxii] Given gains in the conversion of feedstock to ethanol expected in cellulosic ethanol production, the 200,000 acres needed to supply this demonstration facility in its early years will produce enough feedstock to supply a second 100-gallon facility in the state by 2017. The additional acres required to supply the Baseline II Corn scenario, while maintaining base levels of export and human/animal food consumption, will only allow for incremental gains in ethanol production by the end of the modeling period.

[xxxiii] MCCP assumed that base levels of human and animal feed consumption are maintained and a base level of corn export is maintained.

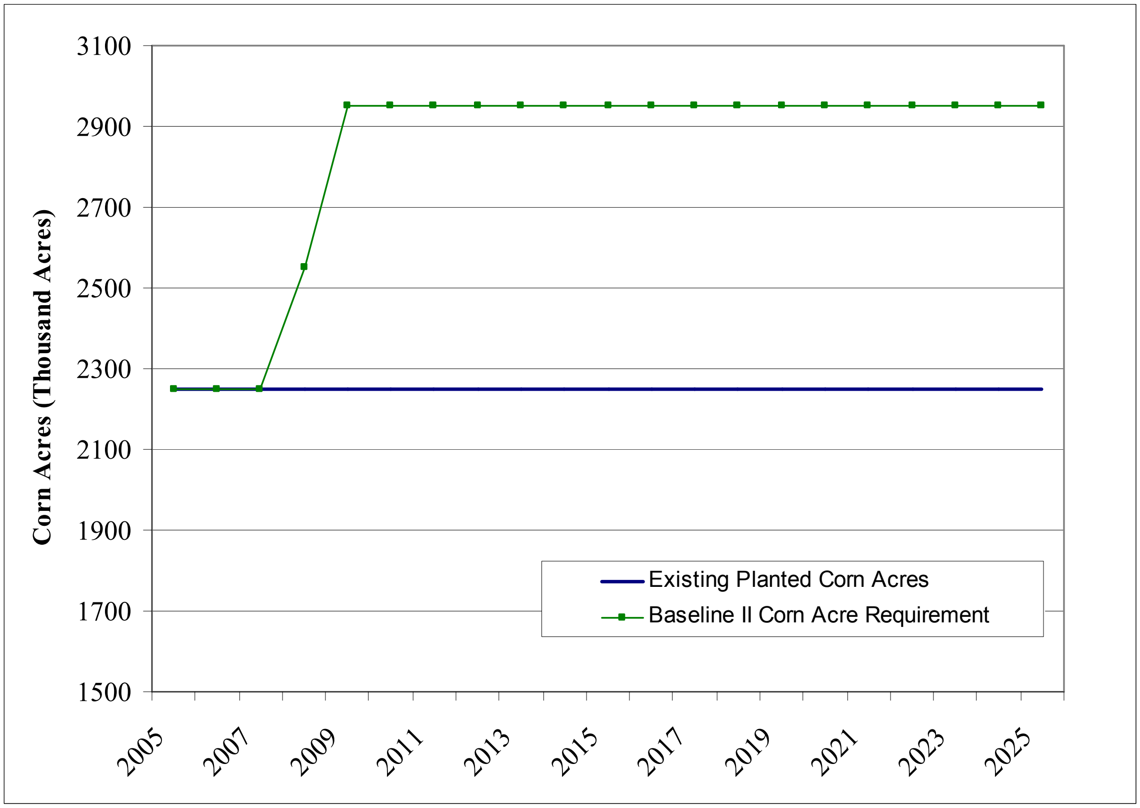

Figure 3.A-7. Michigan Ethanol Production Land Use (2005-2025).

3.A.3.2 Ethanol PTC Economic Modeling Results and Discussion

Figures 3.A-8 and 3.A-9 present the impacts to state GSP and annual job-years through the modeling period for the modeled Ethanol PTC scenario. The production of ethanol in-state as an alternative to conventional gasoline proved to be very positive for the economy as demonstrated by the average annual increase to the state GSP of $532 million and annual average job-year increase of 3,140. This positive effect is explained by the cumulative changes to both the demand for petroleum products and the increase in chemical processing.

These two REMI variables most accurately account for the production and distribution of petroleum based conventional gasoline and ethanol, respectively. These two variables were selected by the MCCP team following conversations with both REMI modeling specialists and other institutions engaged in modeling the economic effects of ethanol production using the REMI tool.[57] By using the Chemical Manufacturing REMI variable, the MCCP team is able to capture the conversion of a product largely imported into the state to a product that has increased reliance on in-state resources. The switch accounts for shifting reliance on a product that keeps $0.18 for every dollar spent in state to a product that keeps $0.36 for every dollar spent in state. Ultimately, even though the 625 million gallons per year of ethanol represents only a fraction of the total Michigan motor fuel usage (approximately 6.0 billion gallons in 2005), the impact of increased reliance on in-state fuel sources has very positive benefits to the economy.

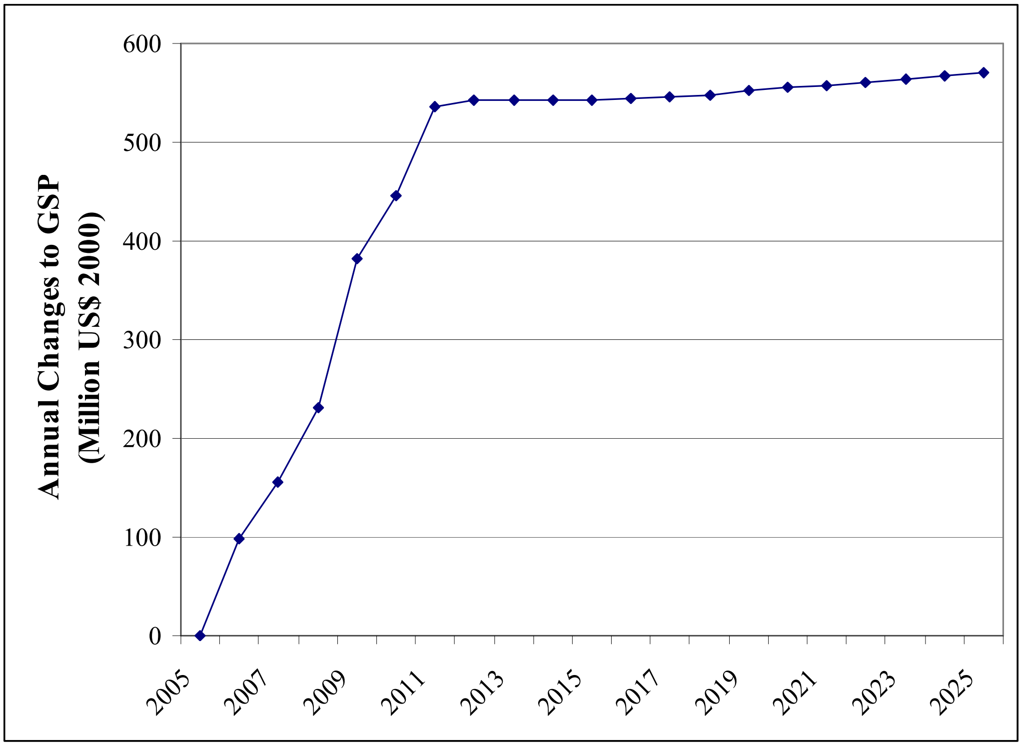

Figure 3.A-8. Changes to the Michigan GSP with 625 Million Gallons of Ethanol Production (2005-2025).

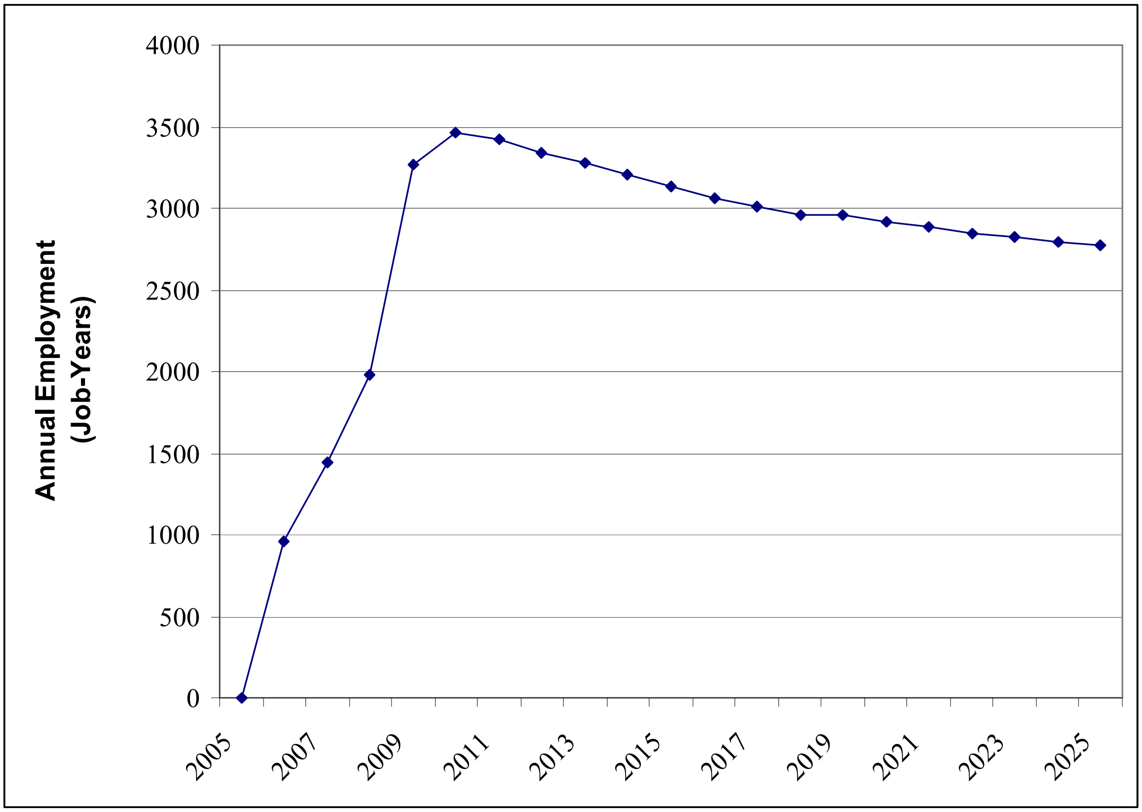

Figure 3.A-9. Changes in Michigan Employment (Job-Years) with 625 Million Gallons of Ethanol Production (2005-2025).

The economic modeling had two primary limitations. The first was its inability to predict the level of ethanol production spurred by the proposed PTC. The modeling was able to capture the cost of such a program, in terms of dollars of state funding per gallon of eligible ethanol capacity, but given the immaturity of the ethanol production market, the MCCP team was unable to determine if the PTC as defined would be sufficient to attract the cellulosic ethanol refinery modeled.

The second limitation is inherent to REMI given its treatment of the agricultural sector. The increase in corn ethanol production over the next five years is sure to have an effect on the price of corn as well as implications for the broader agricultural sector. However, REMI treats the agricultural sector as a "black box" within the defined region. All effects to the regional agriculture sector are treated as 100% import/export. That is, any demand from the agriculture sector is assumed to be imported, and any supply is assumed to be exported. Therefore, the MCCP team was unable to accurately capture the effects to the Michigan corn market with an increase in demand from the ethanol sector.

The MCCP team did not include any treatment for ethanol feedstock by-products. In general, the ethanol process uses only a portion of the biomass feedstock (whether its corn or some form of cellulosic material) and the remainder is sold as a separate product, used for process energy generation, or discarded. The

MCCP team did not analyze Michigan's limitations or potential in handling these by-product streams.

3.A.4 Conclusions

The MCCP's modeling failed to predict the levels of production that would be spurred by the proposed level of ethanol PTC. The project, the team learned that the state did not require a PTC to promote additional corn ethanol production in the state. However, it is unclear if a PTC at the proposed level would be sufficient to attract a demonstration cellulosic ethanol production facility.

The modeling results show both positive GHG and economic benefits from promoting a cellulosic ethanol industry in the state. Considering the limitations on agricultural land, the modeled strain on corn supply, and the projected in-state corn ethanol capacity of 525 million gallons, the MCCP team concludes that reservation is required when pursing additional corn ethanol capacity in the state. However, the existing proposed corn ethanol capacity provides a net GHG benefit and an economic benefit for the state.

3.B. Michigan Renewable Fuel Standard.

The Motor Fuel RFS policy is intended to promote the availability and purchase of renewable motor fuel alternatives. The RFS can both reduce GHG emissions from the transportation sector and reduce the state's dependence on foreign oil. On June 22, 2006, Governor Granholm placed her support behind the 25X25 movement, a national grassroots effort that wants 25% of the country's energy demand to be met by renewable resources by 2025.[58]

Guided by this commitment, the MCCP team designed and modeled the RFS. The proposed RFS comes into effect in 2010, with a mandate that 10% of the state's motor fuel usage will be supplied by renewable resources. The RFS will increase by 1% a year for the following 15 years, thereby reaching the 25% goal by 2025. The MCCP team did not define the policy such that a specific proportion of the renewable fuel was supplied by Michigan-based biomass sources. As described in the discussion of the economic modeling, all renewable fuel used to meet the standard is assumed to come from a national market, in which Michigan is a participant.

3.B.1 RFS GHG Model

3.B.1.1 Introduction

The RFS GHG model is designed to assess the GHG emission reduction potential from meeting the proposed RFS. The model evaluated the Well-to-Wheel (WTW) GHG emissions associated with increasing state-wide vehicle miles traveled (VMT) using renewable fuels and the associated reduction in WTW GHG emissions from displaced VMT using conventional motor fuels. "Well-to-Wheel," a motor fuel lifecycle analysis term, refers to the accounting of emissions from the point of origin of the fuel (Well) through the operation of the vehicle using that fuel (Wheel). The RFS GHG model accounts for the years 2005 through 2025.

The RFS GHG model compared a projected BAU statewide motorfuel mix against a motor-fuel mix that meets the requirements of the proposed RFS. In establishing the baseline motor fuel mix, the MCCP team used data from the US Department of Energy and the US Federal Highway Association.[xxxiv] Figure 3.B-1 presents the modeled motor fuel usage. Renewable fuel usage ranges from 2.70% in 2005, to 7.25% in 2025.

[xxxiv] US DOE, Energy Information Association. Annual Energy Outlook 2006. Additional Tables 3 and 17. US FHWA, Motor Fuel Usage Report 2004, Table 21.

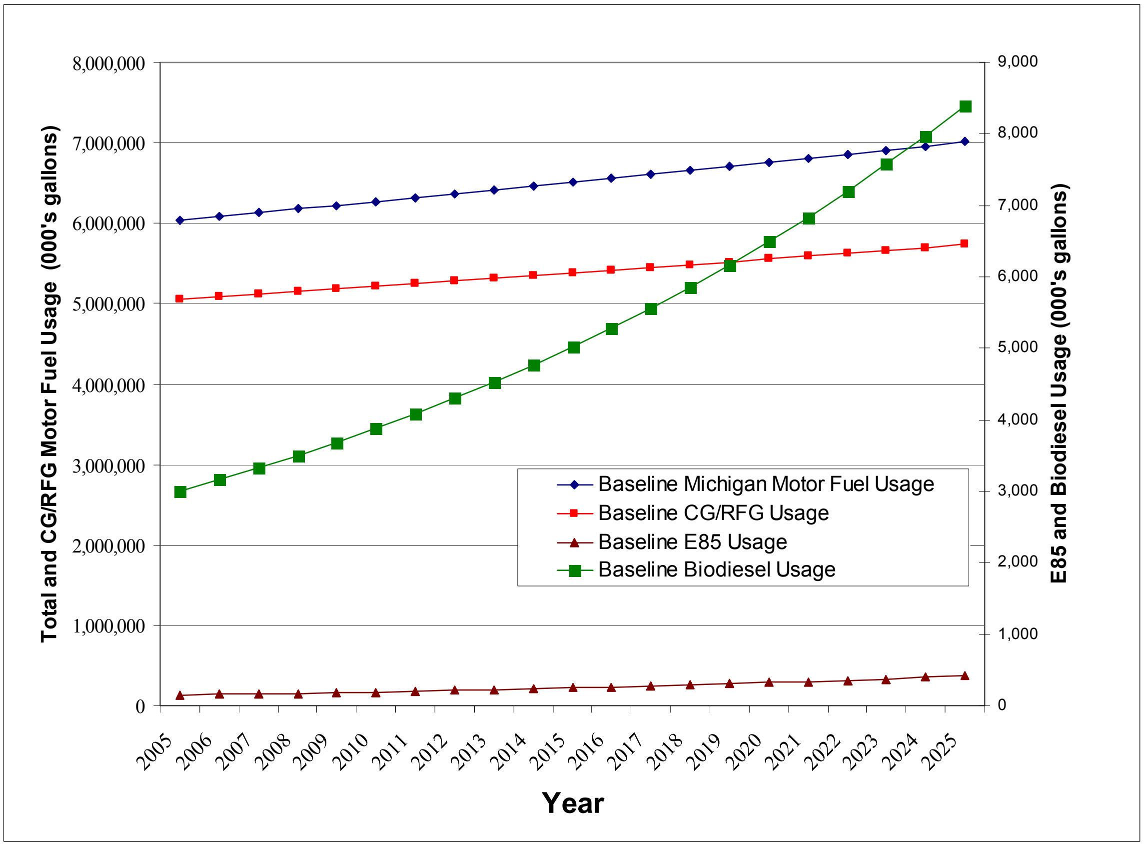

Figure 3.B-1. Michigan Motor Fuel Usage 2005-2025.

Three types of renewable fuels were considered by the model: ethanol as an oxygenate in reformulated gasoline (RFG) (7% - 10% by volume), ethanol as an 85% by volume blend with conventional gasoline (E85), and biodiesel (modeled as B20, a 20% volumetric blend). Although other fuels are considered renewable, quantities of these fuel types are typically much smaller when compared to ethanol and biodiesel. Therefore, for ease of modeling, the MCCP team focused on the two most popular and available renewable fuel sources.

When modeling the GHG emission benefits associated with a RFS, the MCCP team looked at two scenarios:

1. Corn-Based Ethanol Supply: In this scenario, 100% of the ethanol used to meet the modeled RFS was assumed to come from a corn feedstock.
2. Cellulose and Corn-Based Ethanol Supply: In this scenario, the ethanol used to meet the RFS was assumed to come from a mix of cellulosic and corn feedstocks. Table 3.B-1 presents the market adoption of cellulosic material assumed under this scenario.

Table 3.B-1. Ethanol Market Share by Feedstock Type (2005-2025).[59]

Year	Cellulosic EtOH (%)	Corn EtOH (%)
2005	0.0	100.0
2006	0.0	100.0
2007	0.0	100.0
2008	1.8	98.2
2009	3.2	96.8
2010	7.1	92.9
2011	18.4	81.6
2012	26.9	73.1
2013	35.2	64.8
2014	41.6	58.4
2015	50.0	50.0
2016	57.1	42.9
2017	63.0	37.0
2018	68.1	31.9
2019	72.4	27.6
2020	76.0	24.0
2021	79.0	21.0
2022	81.4	18.6
2023	83.4	16.6
2024	85.2	14.8
2025	86.8	13.2

To calculate the GHG impact of the RFS, the model determines the amount of renewable fuels (E85 and biodiesel) used above the BAU, and the associated quantity of conventional fuels (CG, RFG, and petroleum diesel) displaced.[xxxv] To complete the WTW analysis, the gallons of fuels used and displaced are translated into VMT, using a set of fuel economies for various light-duty vehicles (LDVs), which are expected to be the primary consumers of the fuel. WTW GHG emission factors (grams of GHG pollutant per mile traveled) are applied to the miles traveled on the alternative fuels used and the conventional fuels displaced. The model then calculates the net affect of the proposed RFS.

WTW GHG emission factors are generated using the Argonne National Lab's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model.[xxxvi]

Figure 3.B-2 provides a simplified process flow of the RFS GHG model.

[xxxv]To meet the RFS, a certain portion of RFG containing ethanol, is displaced in favor of E85, a blended fuel with a higher renewable content.
[xxxvi] Modeled GHG pollutants include: Carbon Dioxide (CO2), Nitrous Oxide (N2O), and Methane (CH4).

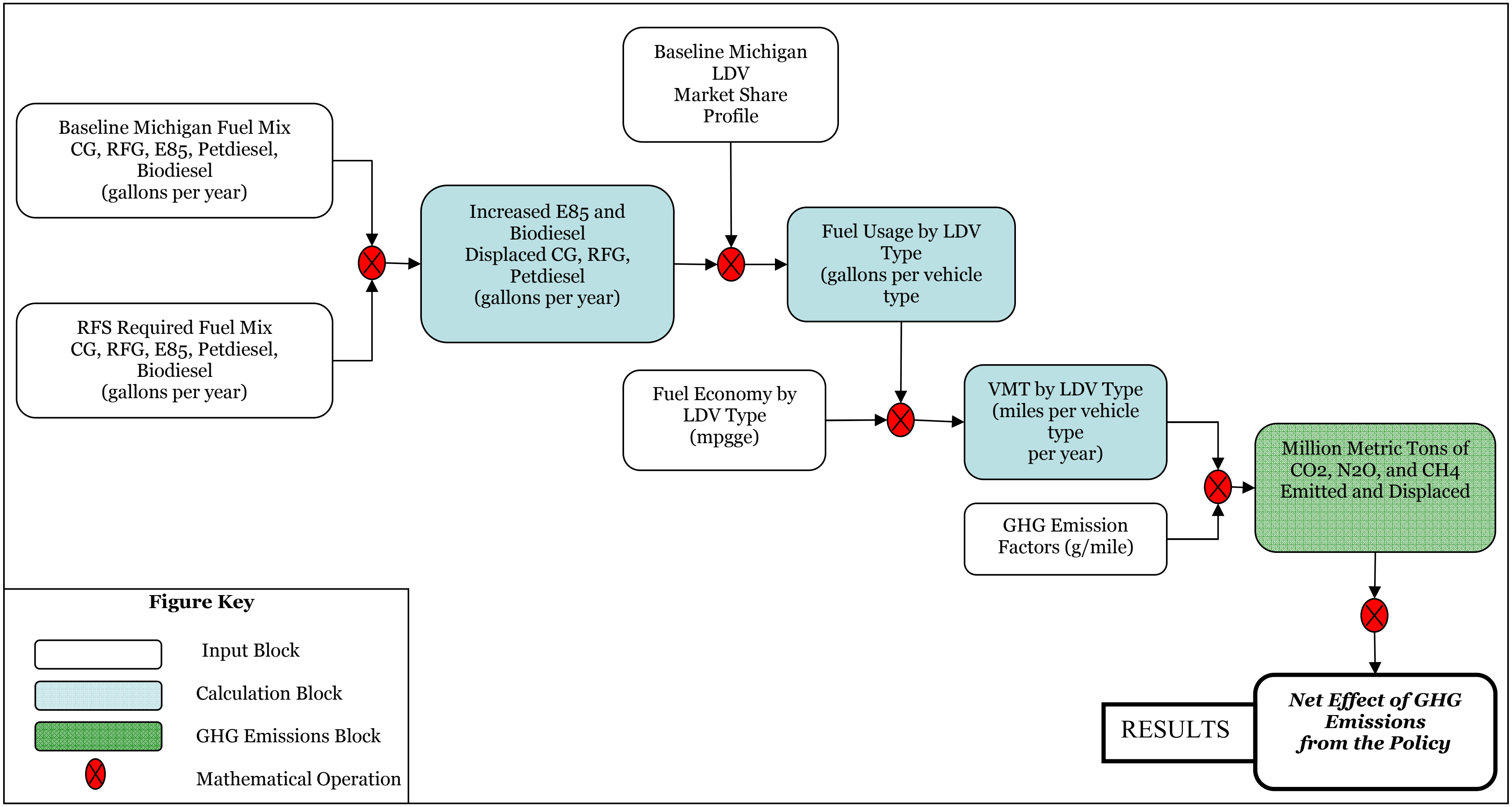

Figure 3.B-2. RFS GHG Model Flow Diagram.

3.B.1.2 RFS GHG Model Inputs and Assumptions

The five yellow blocks presented in Figure 3.B-2 represent the primary inputs required for the RFS GHG Model.

BAU Michigan Motor Fuel Mix

The MCCP team used two primary data sets to estimate and project a BAU fuel mix for Michigan. The FHWA provides annual reports on national and state-wide fuel usage for conventional gasoline, gasohol (E10 or RFG), and diesel.[60] The US DOE *EIA Annual Energy Outlook* (AEO) reports national and regional fuel usage with projections to 2030.[61] With this data, MCCP calculated Michigan's share of the regional fuel usage in 2004. This distribution was applied to the DOE EIA projections of regional fuel usage for model years 2005-2025. Appendix H.4 Table H.4-1, presents this baseline fuel usage.

RFS Compliant Michigan Motor Fuel Mix

For each effected year (2010-2025), the total motor fuel usage in the state is redistributed so that the mandated renewable fuel standard for that year is met. As E85 motor fuel blend does not have the same energy content as conventional or reformulated gasoline, the RFS model accounts for the additional gallons of E85 required to supply the state with an equal amount of motor fuel energy under the BAU. This insures that projected VMT in the state are maintained and GHG emissions are accurately accounted for. As biodiesel and petroleum diesel have similar energy contents, no such accounting is necessary, for the additional biodiesel usage under the RFS is a direct replacement for petroleum diesel. Appendix H.4 Table H.4-2 presents the fuel usage under the proposed RFS.

Baseline Michigan LDV Stock and Market Share

To model the RFS on a WTW basis, the GHG model calculates the VMT from the renewable fuel spurred by the RFS in a set of light-duty vehicle (LDV) technologies capable of operating on the fuels. The volume of renewable motor fuel supplied by the RFS is converted to VMT using fuel economies (as described below) for each of the selected vehicle technologies. Additionally, the VMTs from using the conventional motor fuels displaced by the RFS are estimated for a set of similar conventional LDVs. Table 3.B-2 presents the LDV technologies used to estimate the VMT associated with the renewable fuels used under the RFS and the conventional fuels displaced by the RFS.

Table 3.B-2. Modeled Vehicle Types under the RFS.

Vehicle Model ID	Vehicle Type
LDC-G-ICE	Light Duty Personal Car Gasoline ICE
LDT-G-ICE	Light Duty Truck Gasoline ICE
LDC-E-FF	Light Duty Personal Car Ethanol Flexible Fuel
LDT-E-FF	Light Duty Truck Ethanol Flexible Fuel
LDC-D-ICE	Light Duty Personal Car Diesel ICE
LDT-D-ICE	Light Duty Truck Diesel ICE

The MCCP team utilized US DOE EIA AEO and FHWA data on current vehicle stock and projected vehicle stock by vehicle type to estimate a Michigan LDV market share profile for conventional and alternative vehicles during the modeled time frame. Table H.4-3 of Appendix H.4 presents this vehicle market share profile. From this profile, the MCCP team estimated the types of vehicles that would use the various renewable fuels and would have used the displaced conventional fuels. For example, the profile indicates for model year 2010, 47% of the flex fuel vehicle stock will be LD personal cars (LDC), and 53% will be LD trucks (LDT). Therefore, the GHG model estimates that 47% of the additional E85 created by the RFS will be burned in LDCs and 53% will be burned in LDTs.

LDV Fuel Economy

Vehicle type-specific fuel economy profiles for the modeled time frame were obtained from the GREET model and from US DOE EIA projections. Vehicle-specific fuel economies were calculated on a miles per gasoline equivalent basis. The GREET model was used to establish 2005 vehicle-type specific fuel economies, presented in Table 3.B-3. EIA's AEO 2006 data was used to calculate an annual improvement rate for LDC and LDT fuel economies, which were applied to the 2005 base fuel economies provided by GREET.[xxxvii] From the EIA data, LDC fuel economy improved by 0.5% per year and LDT fuel economy improved by 0.7% per year.

Table 3-B.3. Base Year Fuel Economy Data.

Vehicle Model ID	Vehicle Type	2005 Fuel Economy
		(mi/gge)
LDC-G-ICE	Light Duty Personal Car Gasoline ICE	24.80
LDT-G-ICE	Light Duty Truck Gasoline ICE	19.40
LDC-E-FF	Light Duty Personal Car Ethanol Flexible Fuel	26.04
LDT-E-FF	Light Duty Truck Ethanol Flexible Fuel	20.37
LDC-D-ICE	Light Duty Personal Car Diesel ICE	33.73
LDT-D-ICE	Light Duty Truck Diesel ICE	26.38

[xxxvii]Table 3.B-3 indicates that on a gasoline equivalent basis LD Flex Fuel cars have a slightly better fuel economy compared to their conventional counterparts, resulting in additional VMT by FFV on the same amount of energy as conventional fuels. The RFS GHG model does not correct for this discrepancy and, therefore, overestimates the VMT and associate WTW GHG emissions from this fuel source.

WTW GHG Emission Factors

With a basis of VMT calculated, the model can estimate the end impact to GHG emissions on a WTW basis using grams of pollutant per VMT emission factors. The GREET model was used to estimate vehicle type GHG emission factors for the modeled time period.[xxxviii] The MCCP team used GREET default parameters for fuel production, fuel distribution, and vehicle technology operation. Appendix H.4 provides an input summary from the GREET model for both LDCs and LDTs.

The MCCP team has modeled two RFS scenarios with regard to GHG emission factors. The first scenario assumes that all ethanol used to meet the RFS was produced from a corn feedstock. The second accounts for an increasing contribution of ethanol produced from herbaceous cellulosic material, as detailed in Table 3.B-1.

3.B.2 RFS Economic Modeling

The RFS model was intended to capture the benefits and costs of increasing in-state alternative fuel usage. As discussed in the Introduction of this report, the MCCP utilized REMI Inc.'s Policy Insight model, in conjunction with Energy 2020, to accomplish the economic modeling. The model was designed to capture the costs to end consumers for purchasing alternative fuels at the pump, the benefits of having a portion of the required alternative fuels met by Michigan suppliers, the cost of expanding the alternative fuel distribution systems, and the benefit of reduced demand for petroleum products.

The MCCP team modeled two scenarios for the economic modeling. Understanding that ethanol, primarily E85, played a significant role in meeting the RFS objectives and that E85 does not have the same energy content as conventional fuel, the MCCP team modeled the following two scenarios:

1. CG/E85 Price Equilibrium: A situation where the consumer pays the same amount for CG and E85 on a dollar per mile basis. This scenario accounts for the reduced embodied energy of E85 and the associated reduction in miles per gallon. E85 is priced lower per gallon compared to conventional fuel to compensate for the energy imbalance. Note that petroleum diesel and biodiesel do not have an energy imbalance and biodiesel is price competitive with petroleum diesel. Therefore no special treatment of biodiesel is necessary in the economic modeling. Additionally, no price difference exists between CG and RFG.

2. Uncompetitive E85 Price: Summer 2006 was indicative of a period when prices of E85 were typically $0.10-$0.12 cheaper than CG on a per gallon basis.[62] This difference (at a $2.50 per gallon of CG) was not sufficient to compensate for the reduced energy from an E85 blend. The MCCP team modeled a scenario similar to this where the consumer paid more on a per mile basis for the E85 needed to meet the RFS.

Within the economic model, MCCP accounted for the source of the renewable fuels. The team assumed that all ethanol and biodiesel used to meet the requirements of the RFS would come from the national renewable fuels market,

[xxxviii] GREET is limited to model year 2020 and, therefore, the MCCP team utilized the GHG emission factors calculated for 2020 in each of the subsequent years (2021-2025).

of which Michigan is a part. As such, the MCCP modeled Michigan as having 4.5% of the renewable fuels national market.[xxxix] This affects the economic modeling; for each consumer dollar spent on renewable motor fuels, 4.5% of that dollar is assumed to support the in-state renewable fuels industry and the remaining 95.5% is modeled as an imported fuel.

The following discusses the modeled variables and their impacts on the economic modeling. Appendix H.5 provides detailed input data for each of the presented variables.

Input Variables and Rationale

- MCCP reduced the amount of demand for petroleum gasoline (REMI Variable Name: *Exogenous Final Demand for Petroleum, Coal Product Manufacturing*) to represent the drop in petroleum consumed because of the increased use of renewable fuels. The Final Demand variable, within REMI, is used because the reduction will be distributed across both in-state and out-of-state suppliers within the model.
- MCCP increased the amount of chemical manufacturing (REMI Variable Name: *Exogenous Final Demand for Chemical Manufacturing*) to account for the increased use of ethanol that will come about because of the policy. This increased demand for ethanol will draw from both in-state and out-of-state suppliers.
- For one set of policy runs, MCCP assumed that the price of ethanol will be at equilibrium with gasoline on a miles-driven basis such that consumers will spend the same amount to drive the same distance they would with petroleum motor fuel. This was intended to account for the energy imbalance between ethanol-based fuels and conventional gasoline. In this case, the decreased *Demand for Petroleum* is exactly equal to the increased demand for *Chemical Manufacturing*.
- For another set of policy runs, MCCP assumed that consumers will have to spend more to drive the same distance using ethanol. In this case, the increased demand for *Chemical Manufacturing* is greater than the decreased *Demand for Petroleum***.**
- To model the impact on consumer spending for the non-equilibrium case, MCCP increased the amount consumers spend on transportation fuel (REMI Variable Name: *Consumer Spending for Gasoline and Oil)* in proportion to the energy imbalance between ethanol-derived fuels and petroleum-based fuels. MCCP then decreased the amount of consumer spending in other economic sectors (REMI Variable Name: *Consumption Reallocation for All Consumption Sectors)* by this same amount to keep total consumer spending constant.
- For this policy, MCCP included the cost to upgrade pumps for renewable fuels. To do this, MCCP increased the amount of spending on construction and equipment (REMI Variable Name: *Exogenous Final Demand for Construction and Machinery*) to represent the labor and capital costs for these upgrades.
- MCCP then increased the cost of supplying motor fuels (REMI Variable Name: *Production Costs for the Petroleum, Coal Product Manufacturing*)

[xxxix] RFA data during summer 2006 representing ethanol. Michigan biodiesel production capacity was relatively small at the time of modeling and, therefore, only ethanol was considered in terms of market share.

by the total amount of these upgrade costs to model the spending for these upgrades.

Variable Impacts

- The decrease in demand for Petroleum Products has a negative impact on employment and gross state product.
- The increase in demand for Chemical Manufacturing, Construction, and Machinery Manufacturing all have positive impacts on employment and gross state product.
- The shift in consumer spending has a negative impact on employment and gross state product.
- The increase in production costs for the Petroleum, Coal Product Manufacturing sector has positive impacts on employment and gross state product.

Economic Sectors Impacted

- Sectors positively impacted by the policy include the Construction Sector, Chemical Manufacturing, Wholesale and Retail Trade, Transportation and Warehousing, Professional and Technical Services, and State and Local Governments.
- Sectors negatively impacted include Petroleum Manufacturing and Services such as Health Care, Accommodations and Food, Educational, and Other Services (due to decrease in consumer spending on all other consumption sectors).

3.B.3 RFS Results and Discussion

This section presents the results of modeling a 25% by 2025 RFS in the state, along with a discussion of the implication of pursuing such a policy. Relevant comments are included from stakeholders regarding the modeling results, as obtained during Forum II. Tables 3.B-4 and 3.B-5 summarize the cumulative GHG and economic modeling through the years 2015 and 2025.

Table 3.B-4. Michigan RFS GHG Modeling Summary 2015 and 2025.

Scenario	MMTCE by 2015	MMTCE by 2025
Corn Based Ethanol Supply	1.28	6.51
Cellulosic and Corn Based Ethanol Supply	0.78	13.19

Table 3.B-5. Michigan RFS Average Annual Economic Effects.

Scenario	2015	2025
Change in Gross State Product (millions of 2000 dollars)		
CG/E85 Price Equilibrium	133	283
Uncompetitive E85 Price	165	361
Change in Employment		
CG/E85 Price Equilibrium	920	1,700
Uncompetitive E85 Price	722	1,230

3.B.3.1 RFS GHG Model Results

The GHG benefits of a state-wide RFS were modeled in the context of displacing BAU VMT by conventional motor vehicles by VMT of vehicles powered by renewable fuel sources. Figures 3.B-3 and 3.B-4 present the annual and cumulative WTW GHG reductions from the two modeled RFS scenarios for the entire model period (2005-2025). From a GHG emission reduction standpoint, dramatically increasing the state's usage of renewable motor fuels results in substantial reductions in BAU GHG emissions. Note that in the utilization of increased cellulosic based ethanol (Figure 3.B-4), there is a short-term increase in GHG emissions, largely due to short-term ethanol production inefficiencies as the cellulosic ethanol biorefineries enter the market space.

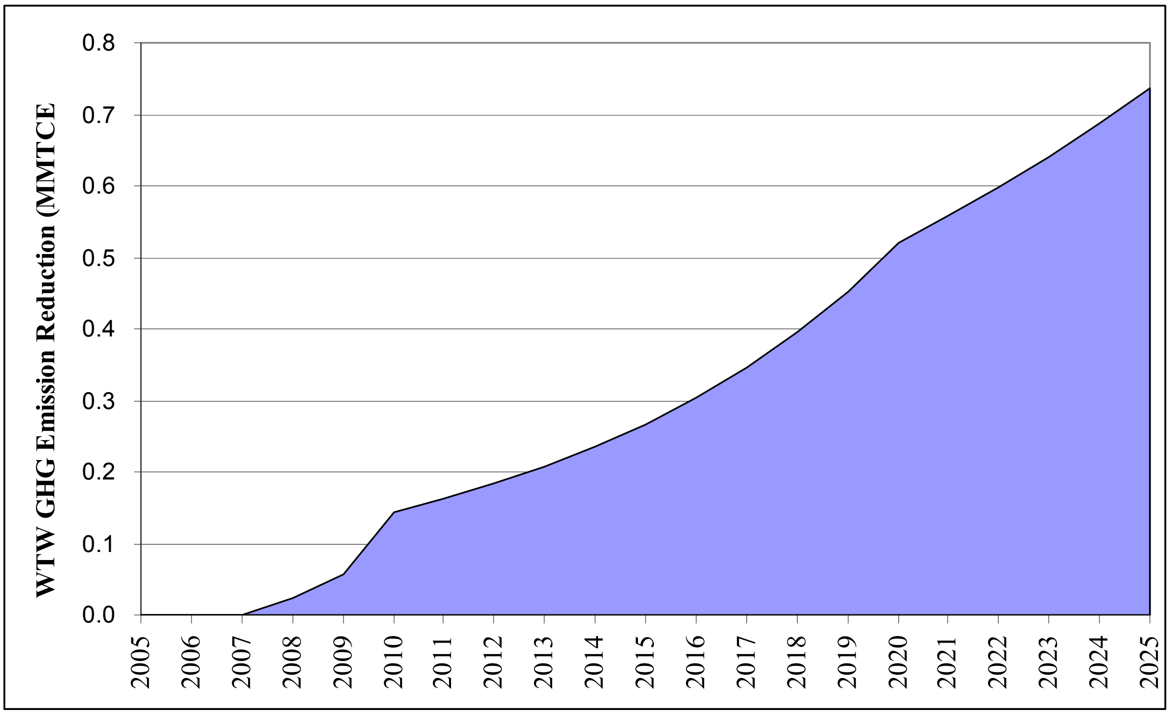

Figure 3.B-3. Corn Based Ethanol Supply RFS-WTW GHG Emission Reductions (2005-2025).

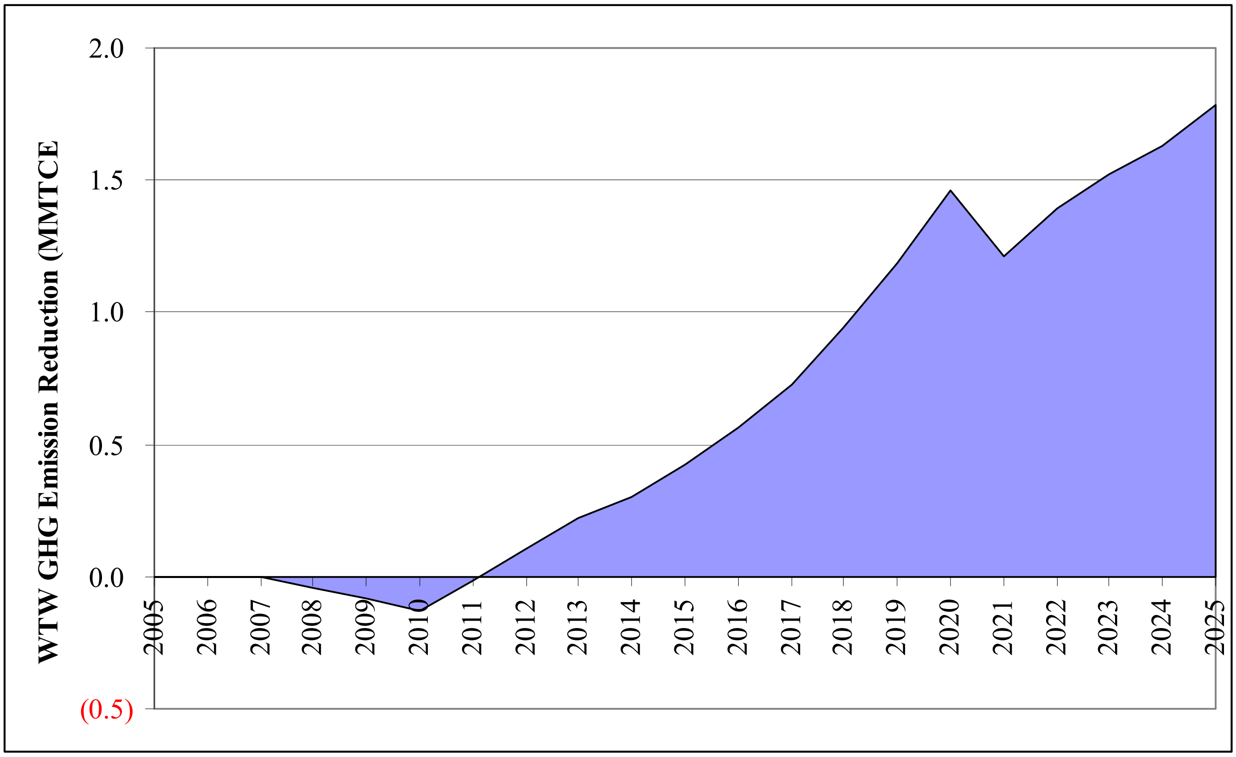

Figure 3.B-4. Cellulose Based Ethanol Supply RFS-WTW GHG Emission Reductions (2005-2025).

Assessing the GHG emissions benefits from an RFS, the MCCP team profiled Michigan's motor fuel usage. Figure 3.B-1 presents BAU activity for the types and quantities of motor fuel used in the state. Figure 3.B-5 presents how that fuel mix changes over the modeling period under the RFS. Figure 3.B-6 presents the cumulative reduction in petroleum based fuels (both conventional gasoline and petroleum diesel) throughout the modeling period. Figure 3.B-7 illustrates that, over the life of the RFS policy (2010-2025), over 9.1 billion gallons of petroleum were displaced from the Michigan transportation system, representing a significant step toward alleviating the state and country's dependence on foreign oil.

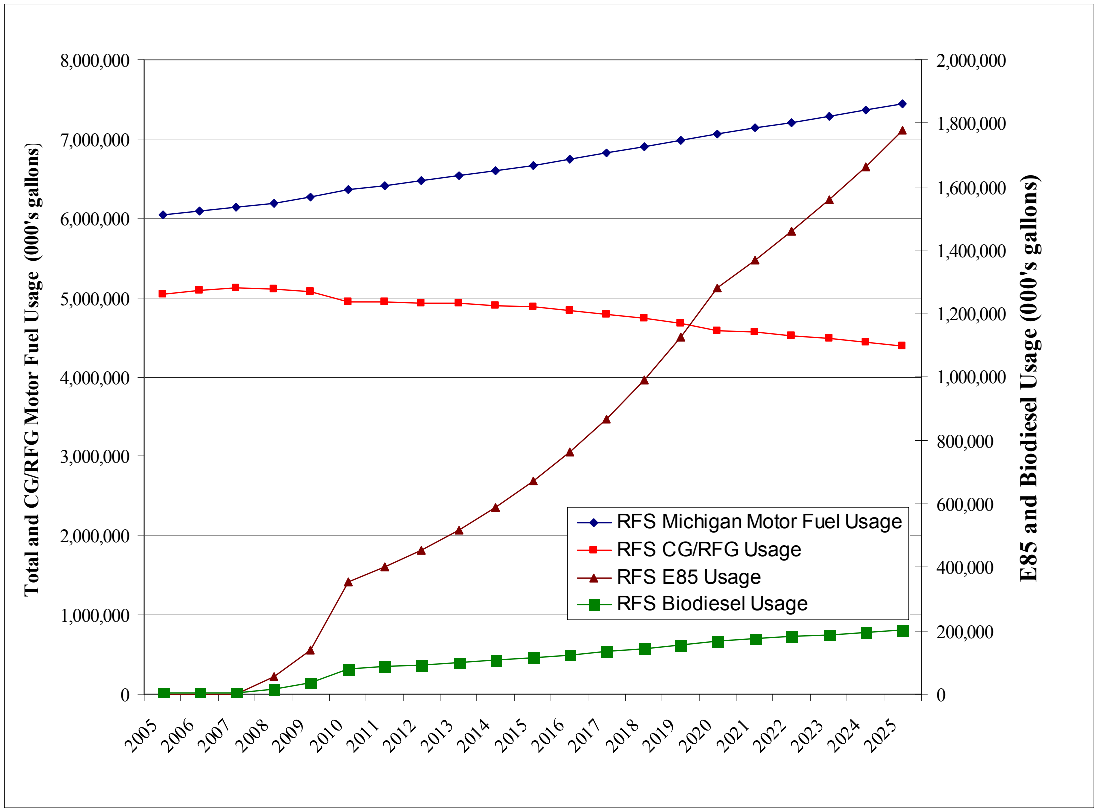

Figure 3.B-5. Michigan RFS Motor Fuel Usage (2005-2025).

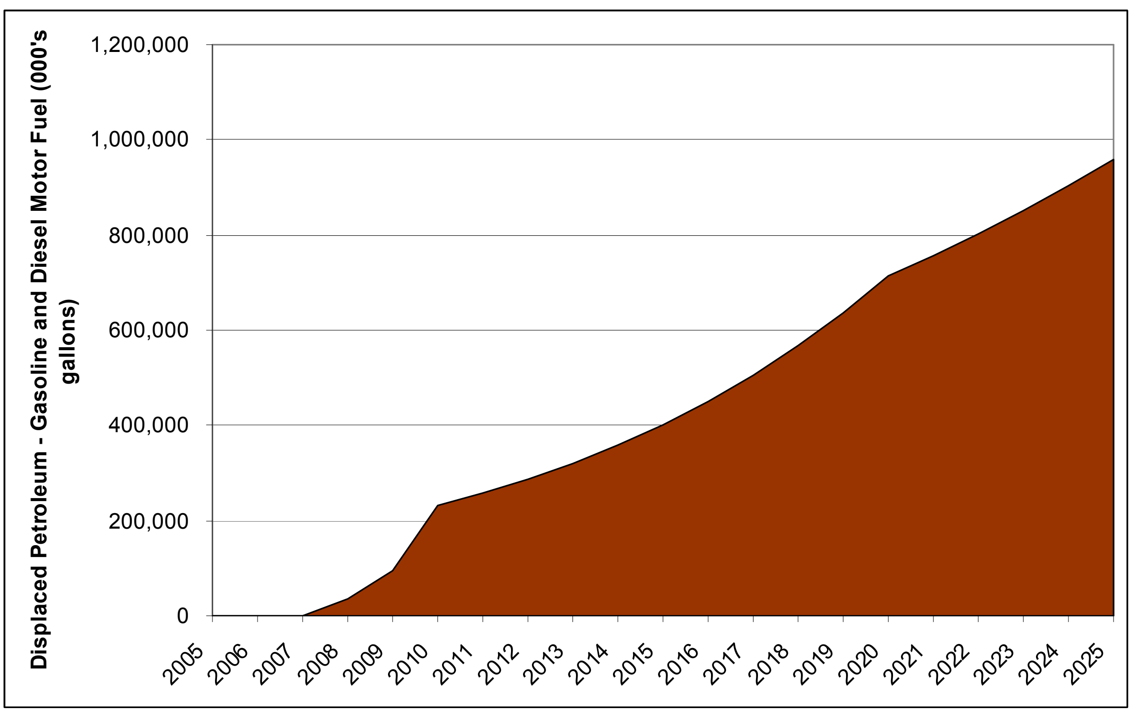

Figure 3.B-6. Cumulative Petroleum Fuel Displaced by the RFS (2005-2025).

Through the GHG modeling of the RFS, the MCCP team and the stakeholders recognized key concerns in the state's ability to maintain compliance with an RFS. The primary concern voiced by the stakeholders relates to the availability of ethanol to meet the RFS. As indicated in Figure 3.B-7, ethanol demand in the state grows from 160 million gallons in 2005, to nearly 1.7 billion gallons in 2025. As modeled in the Ethanol PTC policy, the in-state capacity of corn-based ethanol is approximately 525 million gallons of corn ethanol. If significant amounts of cellulosic ethanol are not produced in state, Michigan will be largely dependent on renewable fuel sources outside of the state. Current national ethanol capacity is approximately 5.6 billion gallons per year, with near term planned expansion to more than 11 billion.[63]

With national capacity of ethanol at this level, it might seem that Michigan would adequately meet the proposed RFS. However, there is a growing national trend for the oxygenate methyl-tert-butyl-ether (MTBE)[xl] to be replaced by ethanol in reformulated gasoline (RFG).[xli] This trend, along with the potential that (RFG) becomes the standard baseline motor fuel, will put unknown stress on the ethanol production system. In this context, obtaining enough ethanol to meet an RFS may become increasingly harder. It was outside of the scope of the MCCP to model the supply and demand scenarios for the corn ethanol sector, but the scenarios should be taken into consideration when evaluating a statewide RFS.

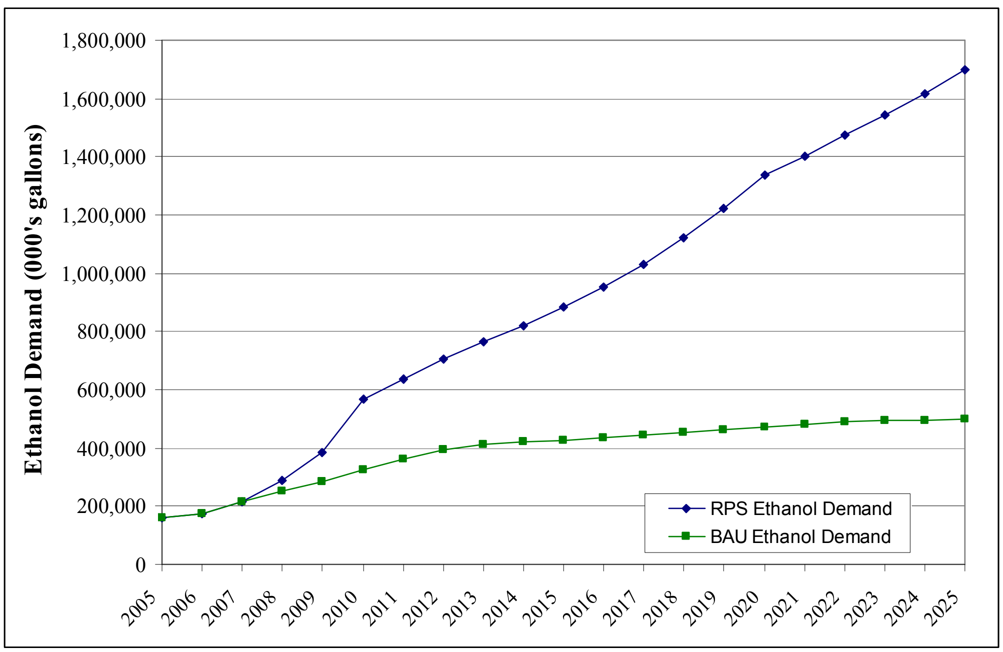

Figure 3.B-7. Ethanol Demand under BAU Conditions and the Proposed RFS (2005-2025).

[xl]Methyl-*tert*-butyl-ether (MTBE) is a chemical compound with molecular formula $C_5H_{12}O$. MTBE is a volatile, flammable, and colorless liquid relatively soluble in water. MTBE has an odor reminiscent of diethyl ether, leading to an unpleasant taste and odor in water. MTBE is almost exclusively used as a fuel component in motor gasoline, and is one of a group of chemicals commonly known as oxygenates because they raise the oxygen content of gasoline.

[xli]Reformulated gasoline is a motor-fuel product capable of being burned in almost all on-road internal combustion engines (non-diesel). It is typically a 90-93% gasoline:10%-7% oxygenate blend that improves fuel combustion in the engine.

A second key concern for implementing an RFS relates to the availability of alternative fuel vehicles capable of burning the necessary fuel to meet the standard. This issue arises only when looking at the amount of E85 needed to meet the standard. Both biodiesel and RFG are capable of being burned in existing vehicles. Figures 3.B-1 and 3.B-5 present the BAU adoption of E85 in the state and the RFS level of E85 adoption in the state. Figure 3.B-8 presents the projected annual VMT by E85 capable vehicles expected to be on the road under BAU conditions. Figure 3.B-8 also presents the VMT needed to consume all of the E85 included in the proposed RFS. The MCCP team modeled a vehicle shortage beginning in the year 2010. The MCCP modeling does not account for a change in the auto industry new vehicle mix in response to a state-supported fuel market, such as created by an RFS.

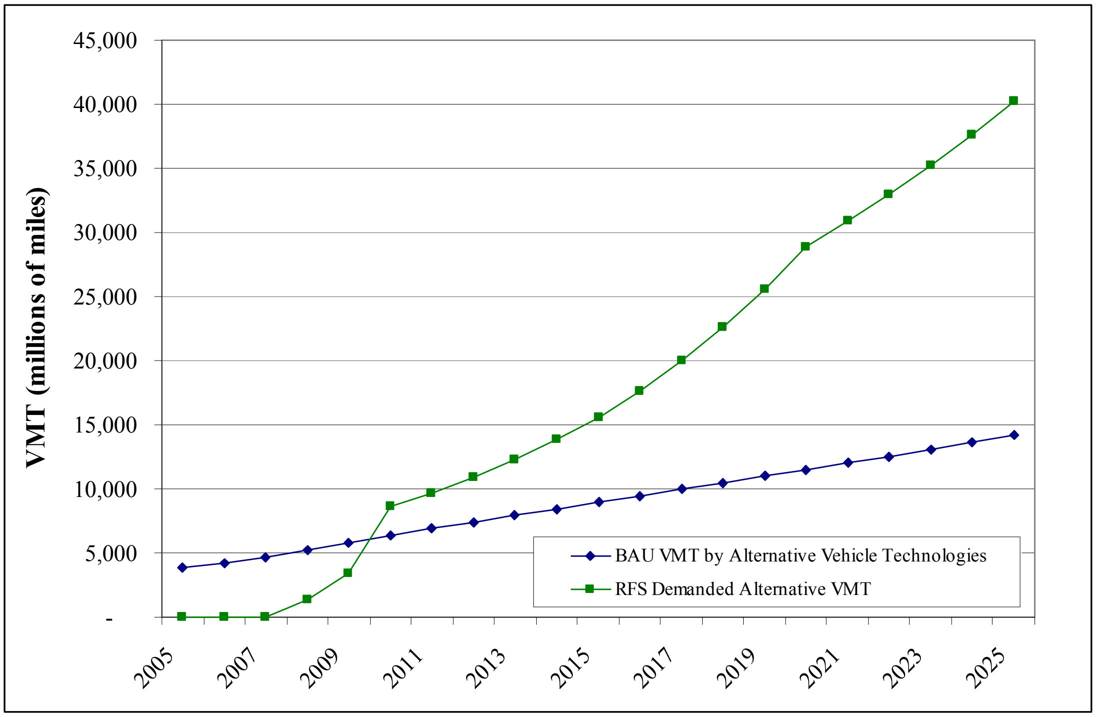

Figure 3.B-8. Michigan VMT of E85 Capable Vehicles under BAU Conditions and RFS Fuel Demand (2005-2025).

Two issues indicate that the proposed RFS may be too aggressive for the state to successfully implement. During Forum II, a stakeholder proposed that an RFS similar to the one recently adopted in the state of Washington could potentially result in a more successful implementation. Washington has created a flexible RFS linked to the in-state capabilities for renewable fuel production. In doing so, the state supports the local renewable fuel industry and creates an RFS that is self supplied.[64]

The MCCP team did not specifically model this scenario for the state of Michigan. However, insights can be gained between the results of the Ethanol PTC policy and the proposed RFS. The Ethanol PTC model indicates that there is a planned supply of ethanol in the amount of 500 million gallons per year. In comparison to the demand for ethanol presented in Figure 3-17, this level of capacity will adequately supply the BAU ethanol demand in the state and will support

Michigan's BAU renewable fuel level of 2.5% to 7.0% in 2025. However, the Ethanol PTC model suggested that 500 million gallons per year of corn ethanol was the state's capacity for producing corn ethanol. Therefore, any RFS that would promote additional renewable fuel usage would have to look either at new sources of in-state renewable energy or at an out-of-state supply.

3.B.3.2 RFS Economic Modeling Results

Figures 3.B-9 and 3.B-10 present the impacts to state GSP and annual job-years through the modeling period for both of the modeled RFS scenarios, as defined in section 3.B.2. The RFS proved to be very positive for the economy as demonstrated by the average annual increase to the state GSP of $320 million and the annual average increase in job-years of 1,500. This positive effect is largely explained by the cumulative changes in the demand for petroleum products and the increase in demand for chemical manufacturing processes and construction.

These two REMI variables most accurately account for the production and distribution of petroleum-based conventional gasoline and biofuels. The MCCP team selected these variables following conversations with both REMI modeling specialists and other institutions engaged in modeling the economic effects of renewable biofuel production using the REMI tool.[65] By using the Chemical Manufacturing REMI variable, the MCCP team is able to capture the switch from a product that is largely imported into the state (petroleum) to a product that has increased reliance on in-state resources. The switch accounts for shifting reliance on a product that keeps $0.18 for every dollar spent in state to a product that keeps $0.35 for every dollar spent in state.

This effect was also seen in the modeling of the Ethanol PTC. However, though the RFS affects a significantly larger fraction of motor fuel usage in the state, it also presents lower economic benefits when compared to the PTC. This can be explained by one primary difference in the models: a large portion of the renewable fuel used to achieve compliance with the RFS comes from out of state. Therefore, much of the economic benefit from the production of the renewable motor fuels for the RFS does not remain in state.

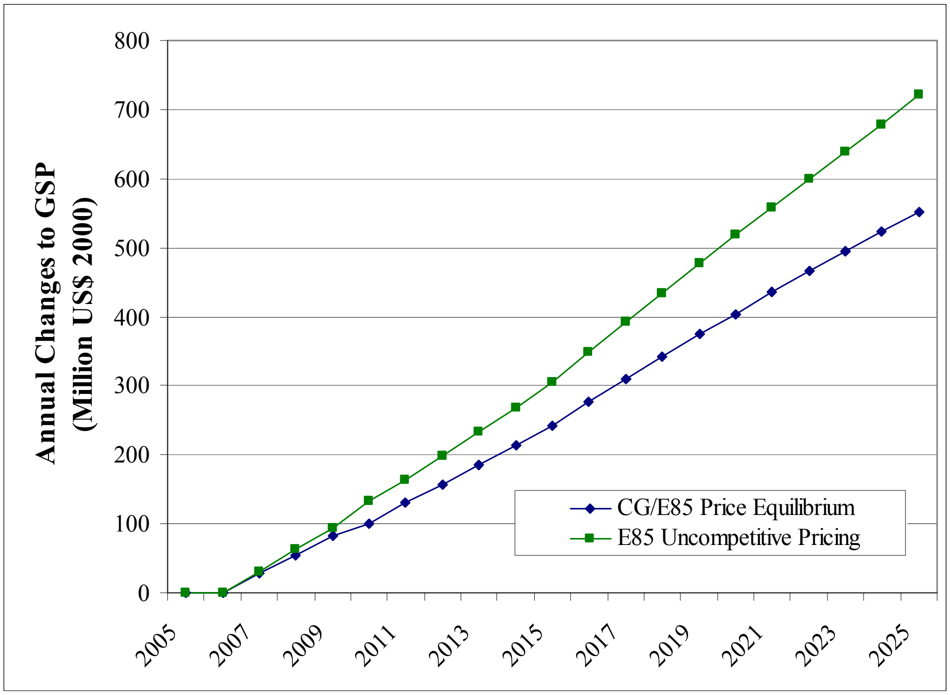

Figure 3.B-9. Changes to the Michigan GSP with 625 Million Gallons of Ethanol Production (2005-2025).

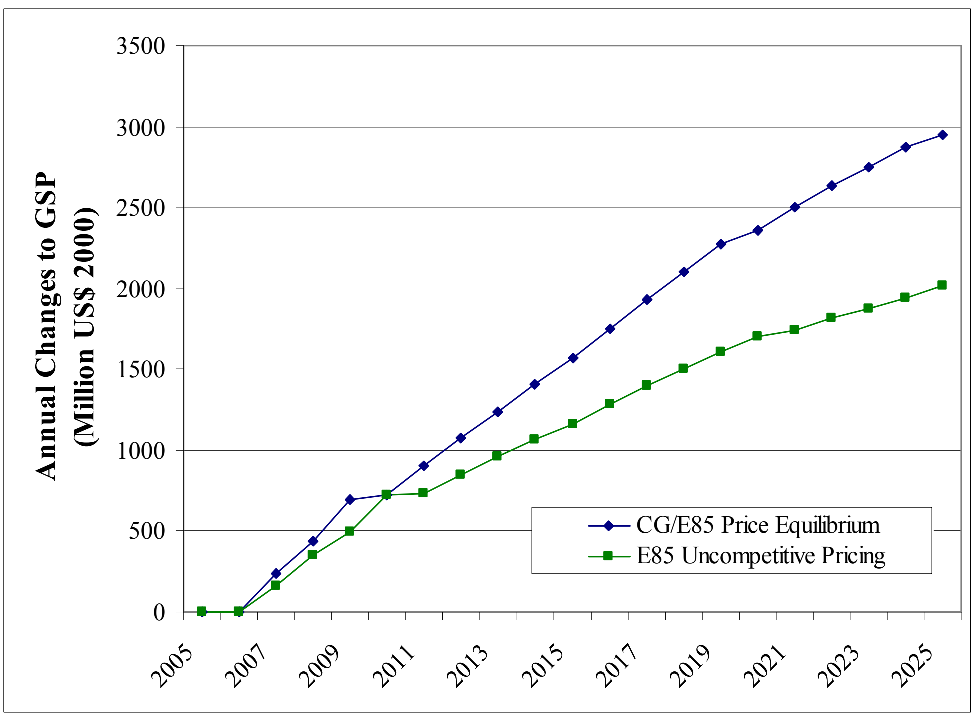

Figure 3.B-10. Changes in Michigan Employment (Job-Years) with 625 Million Gallons of Ethanol Production (2005-2025).

3.B.4 Conclusions

The modeling performed by the MCCP team presents key insights into the adoption of a statewide RFS. When looking at the focus of this project, GHG emission reduction potential and economic effects, the RFS performed very well. It was the fourth highest policy in terms of GHG emission reduction potential and, of the strategies targeted in this study, it has the second highest potential for increasing state GSP and employment. These positive results come largely from shifting the state's reliance on a heavily imported commodity (petroleum motor fuel) with a more regionally based supply of fuel. Beyond the base metrics for the MCCP, the modeling presented challenges that an RFS would face to be successfully implemented, primarily with renewable fuel availability and alternative vehicle availability.

Ultimately, the analysis of the proposed RFS, in addition to the results of the ethanol PTC, strongly suggests significant GHG emission and economic potential to developing, growing, and supporting the production and use of biofuels in the state of Michigan.

3.C. Alternative Vehicle Technology Incentive

The Alternative Vehicle Technology Incentive (AVTI) is intended to promote the availability and purchase of alternative-powered vehicle technologies. The AVTI policy can both reduce GHG emissions from the transportation sector and reduce the state's importation of foreign oil. The MCCP team designed and attempted to model the AVTI as a five-year program running from 2007 to 2011 and providing tax credits, ranging from $500 up to $10,000, to consumers for the purchase of alternative vehicle technologies (AVT). Table 3.C-1 presents the vehicle types and associated tax credits for each included AVT.[xlii]

Table 3.C-1. Summary of AVT Tax Credits.

AVT Type	AVT Description	Average Tax Credit per Vehicle ($)	Maximum Tax Credit per Vehicle ($)
LDC-D-HEV	Electric-Diesel Hybrid	1,580	3,400
LDC-E-FF	Ethanol-Flex Fuel ICE	496	5,000
LDC-EV	Electric Vehicle	4,000	4,000
LDC-G-HEV	Electric-Gasoline Hybrid	1,580	3,400
LDC-H-FC	Fuel Cell Hydrogen	10,500	12,000
LDT-D-HEV	Electric-Diesel Hybrid	1,456	3,400
LDT-E-FF	Ethanol-Flex Fuel ICE	1,493	5,000
LDT-EV	Electric Vehicle	4,000	4,000
LDT-G-HEV	Electric-Gasoline Hybrid	1,456	3,400
LDT-H-FC	Fuel Cell Hydrogen	9,500	12,000

Ultimately, the AVTI policy was not able to be fully modeled. By selecting the Energy 2020 and REMI models to perform the economic modeling for this project, the MCCP team was limited to the capabilities of these models. As such, the Energy 2020 and REMI models were unable to consistently capture the market pull effect of providing a tax credit to end consumers for alternative vehicle technology purchases. This chapter provides a brief description of the GHG model developed to track the increased adoption of AVT, with an estimate of increased adoption rate. Additionally, high-level economic data is presented with respect to the policy's likely cost of such a policy to the state.

3.C.1 AVTI GHG Model

3.C.1.1 Introduction

The AVTI GHG model evaluates the Well-to-Wheel (WTW) GHG emissions associated with displacing conventional motor vehicle VMTs by the VMTs of the additional AVTs spurred by the AVTI policy. "Well-to-Wheel" is a motor fuel lifecycle analysis term referring to the accounting of emissions from the point of origin of the fuel (well) through the operation of the vehicle on that fuel (Wheel). The AVTI GHG model accounts for the years 2005 through 2025. Figure 3.C-1 provides a simplified flow diagram of the AVTI GHG model.

[xlii]See Appendix H-7 for detailed calculations for estimating vehicle type tax credits.

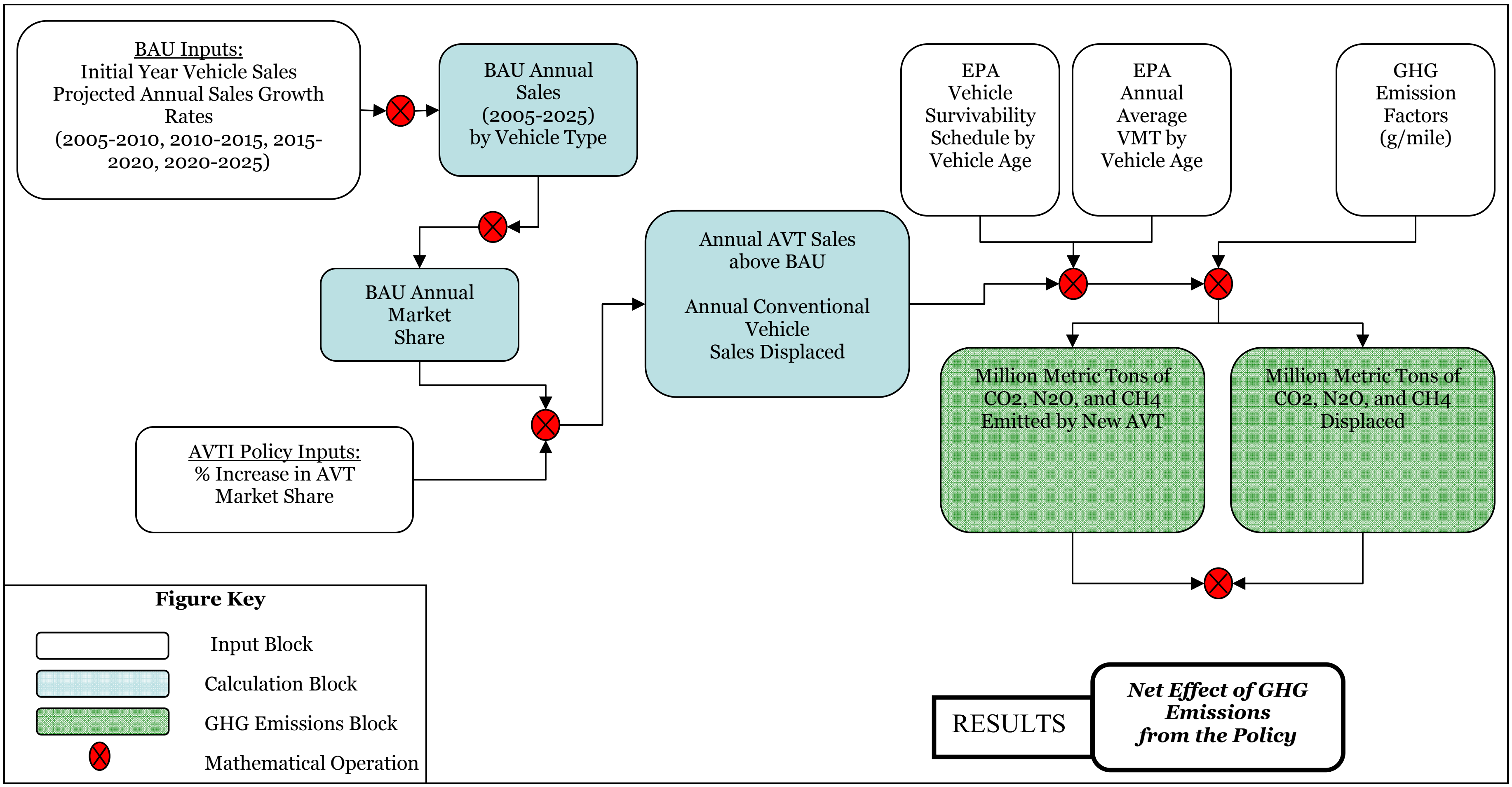

Figure 3.C-1. AVTI GHG Model Flow Diagram.

The AVTI GHG model compares statewide sales of conventional light-duty passenger vehicles and light-duty AVTs under a projected business-as-usual (BAU) scenario against statewide sales under the AVTI policy. There are two primary inputs necessary to establishing the BAU sales projections:

- First-year vehicle sales for each included light-duty vehicle (LDV) type. Table 3.C-2 presents the LDVs included in this model.
- Four sets of five-year LDV annual sales growth rates for each LDV type (i.e., for LDC-G-ICE annual sales growth of -0.53% in 2005-2010, -0.82% in 2010-2015, 0.02% in 2015-2020, and 0.51% in 2020-2025).

In creating this model, the MCCP team relied on data from the US Department of Energy and the US Federal Highway Association to establish Michigan-specific sales projections for the model period.[66] Appendix H.6 provides detailed tables of model inputs for the AVTI GHG model.

Table 3.C-2. LDV Types included in the AVTI GHG Model.

Vehicle Type	Light Duty Vehicle	Vehicle Type	Light Duty Vehicle
LDC-CNG-BF	Compressed Natural Gas Bi-fuel	LDT-CNG-BF	Compressed Natural Gas Bi-fuel
LDC-CNG-ICE	Compressed Natural Gas ICE	LDT-CNG-ICE	Compressed Natural Gas ICE
LDC-D-HEV	Electric-Diesel Hybrid	LDT-D-HEV	Electric-Diesel Hybrid
LDC-D-ICE	TDI Diesel ICE	LDT-D-ICE	TDI Diesel ICE
LDC-E-FF	Ethanol-Flex Fuel ICE	LDT-E-FF	Ethanol-Flex Fuel ICE
LDC-E-ICE	Ethanol ICE	LDT-E-ICE	Ethanol ICE
LDC-EV	Electric Vehicle	LDT-EV	Electric Vehicle
LDC-G-FC	Fuel Cell Gasoline	LDT-G-FC	Fuel Cell Gasoline
LDC-G-HEV	Electric-Gasoline Hybrid	LDT-G-HEV	Electric-Gasoline Hybrid
LDC-G-ICE	Gasoline ICE Vehicles	LDT-G-ICE	Gasoline ICE Vehicles
LDC-H-FC	Fuel Cell Hydrogen	LDT-H-FC	Fuel Cell Hydrogen
LDC-LPG-BF	Liquefied Petroleum Gas Bi-fuel	LDT-LPG-BF	Liquefied Petroleum Gas Bi-fuel
LDC-LPG-ICE	Liquefied Petroleum Gas ICE	LDT-LPG-ICE	Liquefied Petroleum Gas ICE
LDC-M-FC	Fuel Cell Methanol	LDT-M-FC	Fuel Cell Methanol
LDC-M-FF	Methanol-Flex Fuel ICE	LDT-M-FF	Methanol-Flex Fuel ICE
LDC-M-ICE	Methanol ICE	LDT-M-ICE	Methanol ICE

With the BAU input data established, the AVTI GHG model calculated an annual LDV sales profile for the 20 modeled years. Additionally, the model determined BAU market share for the included AVTs by dividing the sales of an individual LDV by the total LDV sales in that year. The BAU indicated that AVTs would account for 7.7% of vehicle sales in 2005, and just over 14% in 2025. The model then required an input for the years that the AVTI policy is in place and an indication of the additional market share AVTs will possess under the policy.

The MCCP team modeled the AVTI as a five-year program (2007-2011) and has estimated a market share increase of 5% in each of those years (i.e., 5% above the BAU market share). The 5% increase during policy years was selected by the MCCP team for demonstration purposes only and is not intended to indicate that a 5% increase in AVT sales would result from a policy as proposed.

The model then calculated the number of alternative vehicles sold above the baseline, as well as the number of conventional vehicles displaced. The MCCP team assumed that only a subset of all the available AVT types would be purchased . Table 3.C-3 provides the pared down list of these AVTs. This assumption allowed for simplification of the GHG emission calculation. Technologies not selected were those that had declining or zero sales under the BAU.

Table 3.C-3. Alternative LDV Types Selected under the AVTI Policy.

Vehicle Type	Light Duty Vehicle
LDC-D-HEV	Electric-Diesel Hybrid
LDC-E-FF	Ethanol-Flex Fuel ICE
LDC-EV	Electric Vehicle
LDC-G-HEV	Electric-Gasoline Hybrid
LDC-H-FC	Fuel Cell Hydrogen
LDT-D-HEV	Electric-Diesel Hybrid
LDT-E-FF	Ethanol-Flex Fuel ICE
LDT-EV	Electric Vehicle
LDT-G-HEV	Electric-Gasoline Hybrid
LDT-H-FC	Fuel Cell Hydrogen

The AVTI GHG model then determined annual VMT profiles for each modeled conventional vehicle and AVT. To generate these profiles, the MCCP team used average VMT and survivability by vehicle age data from the National Highway Traffic Safety Administration.[67] Appendix F provides a detailed explanation of this calculation. Finally, WTW GHG emission factors (grams pollutant/mile) were used to translate the VMT profiles into annual GHG emissions profiles. WTW GHG emission factors were generated using the Argonne National Lab's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model.[xliii]

3.C.1.2 AVT GHG Model Inputs and Assumptions

The following is a description of key inputs and assumptions made in designing the model.

BAU LDV Sales

As mentioned above, the MCCP team relied on two primary data sets to establish a BAU scenario for vehicle sales over the model period. The FHWA data was used to establish a relationship between the national market and Michigan's light-duty vehicle market. From the FHWA data set, the MCCP determined that Michigan accounts for 3.47% of the light-duty passenger cars (LDC) and 3.23% of the light-duty trucks (LDT) in the country. The EIA AEO 2006 report provided a forecast of national LDV sales by vehicle type, for all vehicles listed in Table 3.C-3. The MCCP team used the ratios for LDCs and LDTs from the FHWA to create a forecast (out to 2025) of LDV sales in Michigan.

[xliii]Modeled GHG pollutants include: Carbon Dioxide (CO2), Nitrous Oxide (N2O), and Methane (CH4).

The model takes as input first-year sales and then the four sets of annual growth rates. The MCCP team calculated annual growth rates for each vehicle type across the necessary five-year blocks from the LDV sales forecasts. Table F-1 in Appendix F presents the primary input block to the model. Table F-2 presents the Michigan LDV sales projections.

AVTI Policy

The model required a definition of the policy life and effect on the AVT market. The MCCP team expected to rely on the results of the economic model to dictate the level of adoption of AVT under the policy, given the per vehicle tax credit. However, as stated above, given the tax credits, the economic modeling was unable to simulate the increase of AVT sales above baseline. Therefore, MCCP elected to model a GHG AVTI scenario with a five-year policy (2007-2011), increasing AVT market share by 5% in each of those five years. The results of this scenario are provided below.

NHTSA Survivability and Mileage Data

The MCCP team used the NHTSA data presented in Table F-3 in Appendix F to model annual VMT profiles for each affected vehicle technology. Table F-4 presents an example profile for the gasoline hybrid electric AVT.

WTW GHG Emission Factors

The GREET model was used to estimate WTW vehicle type GHG emission factors for the modeled time period.[xliv] The MCCP team used GREET default parameters for fuel production, fuel distribution, and vehicle technology operation. Appendix F provides an input summary from the GREET model for both LDCs and LDTs and the resulting emission factors.

3.C.2 AVTI Economic Modeling

As previously stated, the economic modeling was not able to be completed for the AVTI policy. The MCCP team intended to use the tax credits presented in Table 3.C-1, along with corresponding estimates of vehicle sticker price (presented in Table G-1 in Appendix G), to determine the increased adoption of AVTs. These results could be translated to an increase in market share by various AVTs and could be modeled for their GHG benefits.

3.C.3 AVTI Results and Conclusions

In this section comments from stakeholders, obtained during Forum II breakout sessions, regarding the modeling results, are captured if relevant. Table 3.C-4 presents a summary of the cumulative GHG benefits through the years 2015 and 2025. Full economic modeling was not performed for this policy, therefore results are not included.

[xliv]GREET is limited to model year 2020. Therefore, the MCCP team utilized the GHG emission factors calculated for 2020 in each of the subsequent years (2021-2025).

Table 3.C-4. AVTI GHG Modeling Summary 2015 and 2025.

Scenario	MMTCE by 2015	MMTCE by 2025
AVT Tax Incentive	0.31	0.51

3.C.3.1 AVTI Modeling Results and Conclusions

The MCCP team modeled a 5% increase in AVT sales, above BAU, for the period 2007-2011, from the implementation of a state AVT tax credit. The tax credit schedule presented in Table 3.C-1 was used to estimate the cost of such a program to the state. Appendix H.5 presents a detailed description of the GHG modeling of this policy.

Using a 5% increase in market share for AVT as the reference case, the team notes two key findings. The first is the magnitude of the increase. As included in Table H.6-1 in Appendix H.6, a 5% increase represents approximately 30,000 new AVT per year. Though seemingly significant in quantity, these vehicles have only a fraction of improvement above BAU in terms of fuel efficiency (as measured by miles of gasoline equivalent). The ultimate benefit from these vehicles was relatively small, especially when considering the overall GHG emissions in the state and the effect of other policies modeled in this study.

The second key result is reflective of how this policy was defined. This policy makes no distinction between AVTs that would have been purchased regardless of the tax credit versus AVTs purchased because of the tax credit. This forces the state to provide a tax credit for every AVT sold in the state, not just for those consumers who need one to be convinced to buy an AVT. This has significant implications for the economic cost of such a program. Considering a BAU of approximately 50,000 AVT per year along with modeled 5% increase, the annual bill for this tax credit program amounts to $45,000,000.

Though demonstrating a potential reduction in GHG emissions, the AVTI has a much higher cost to the state relative to other transportation policies evaluated. Without full economic impact modeling it is difficult to determine how this policy would effect Michigan's economy. However, MCCP has shown in other policy analyses that significant up-front costs to state government typically reduce the overall benefit of a policy. MCCP would expect a AVTI to be a net negative for Michigan.

4. Carbon Sequestration

4A. Afforestation of Marginal Agricultural Land

4A.1 Introduction

The earth's vegetation and soil currently contain the equivalent of almost 7,500 gigatons of CO_2[68], more than is contained in all remaining oil stocks,[xlv, 69] and more than double the total amount of carbon currently accumulated in the atmosphere. The carbon presently sequestered in forest ecosystems is greater than the amount of carbon in the atmosphere.[xlvi, 70] The Center for Sustainable Systems' *Michigan Greenhouse Gas Inventory 1990 and 2002* (Inventory) reports that agriculture soils, in both years, were responsible for the majority of all agricultural GHG emissions. This was primarily due to the use of manure and other fertilizers in crop production.[71] In addition to greenhouse gas (GHG) emissions, the Inventory estimated the amount of carbon stored within biomass, the forest floor, and soil in the state to 1,643 million metric tons of carbon in 2002.

4A.2 Policy Background

Carbon sequestration is the uptake and storage of atmospheric carbon. At Forum I, the stakeholder group ranked carbon sequestration fourth out of all presented strategies, indicating interest in further study of this strategy. The MCCP team considered two types of carbon sequestration for further analysis: terrestrial and geologic (Chapter 4B). Terrestrial sequestration includes belowground storage of CO_2 in soil and aboveground storage in biomass. Terrestrial sequestration occurs when vegetation absorbs CO_2 during photosynthesis, releases the oxygen, and stores the carbon in its tissue (biomass) or transfers it to the soil. Geologic sequestration involves the capture of CO_2, from large industrial point sources such as cement plants or power plants and its storage in deep underground geologic formations.

The following is an explanation of how the MCCP team moved from a general carbon sequestration strategy to an afforestation[xlvii] of marginal agricultural lands (maglands) policy.

Determining the levels of carbon sequestered in forest ecosystems has become a concern of governments, businesses, and organizations.[72] However, due to uncertainties in forest statistics and carbon conversion factors, the question of how much carbon is sequestered by forest ecosystems cannot be answered accurately.[73] Although the most comprehensive and accurate regional estimates of carbon flux using inventory data are for above-ground biomass, sampling and measurements errors, as well as estimation errors in forest statistics, persist.[74]

Stakeholder feedback from Forum I indicated that the MCCP team should explore in more detail soil management as a carbon sequestration strategy. During background

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[xlv] UNDP estimates this at 2,400 gigatons (Gt) of CO_2, and includes both conventional and unconventional oil, known reserves, and as yet undiscovered sources.
[xlvi] Prentice at al (2001) estimates approximately 4,500 Gt in forest ecosystems, compared with approximately 3,000 $GtCO_2$, the level with atmospheric concentration levels of 380 ppm.
[xlvii] Afforestation is the direct human-induced conversion of land that has not been forested for a period of at least 50 years, to forested land through planting, seeding, and/or the human-induced promotion of natural seed sources.

research, the MCCP team realized that the aforementioned uncertainties related to soil carbon estimates would have required the team to make broad assumptions, making modeling efforts difficult. Lack of information about soil carbon flux over the modeling timeframe (2007-2025) and Michigan-specific saturation levels contributed too much uncertainty for the MCCP team to model a soil management policy. As a result, the MCCP team explored other carbon sequestration strategies better suited for the GHG and economic modeling scope of this report. The following section includes examples of national and state carbon sequestration initiatives. These examples served as a basis to develop a specific policy to model.

4A.2.1 Related Programs and Initiatives

In an effort to identify specific policy measures that the state could pursue, the MCCP team researched related legislation and initiatives from across the county. The following is a summary of this research.

Conservation Reserve Program (CRP)

CRP is a voluntary, federal assistance program within the US Department of Agriculture (USDA) that provides technical and financial assistance to eligible farmers and ranchers to address soil, water, and related natural resources concerns on their lands in an environmentally beneficial and cost-effective manner. It encourages farmers to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover, such as native grasses, trees, and filterstrips. Landowners can receive annual rental payments and cost-share assistance to establish long-term, resource conserving covers on eligible farmlands. The Commodity Credit Corporation (CCC) makes annual rent payments based on the agriculture rental value of the land and provides cost-share assistance for up to 50 percent of the participant's costs in establishing approved conservation practices. Participants enroll in contracts for 10 to 15 years.[75]

The Conservation Fund Carbon Sequestration Program

This program works with companies and public agencies to acquire and reforest marginal agricultural lands across the Southeast, as a means to offset carbon emissions and restore wildlife habitat. Thus far, the Fund and its partners have purchased more than 26,000 acres and planted more than five million trees, which will capture 10 million metric tons of CO_2 ($MMTCO_2$) over the next 70 years.[76] The Conservation Fund also has collaborated with DTE Energy.

Midwest Regional Carbon Sequestration Partnership

Led by Battelle Memorial Institute, this partnership has been assembled to identify GHG sources within its region and determine the technical feasibility and cost of capturing and sequestering these emissions in geologic formations, agricultural forests, and degraded land systems. The partnership region includes Indiana, Kentucky, Ohio, Pennsylvania, Maryland, Michigan, and West Virginia. In addition, nine organizations have joined the partnership: Michigan State

University, the University of Maryland, Western Michigan University, the Maryland Geologic Survey, AES Warrior Run Power Plant, the Maryland Energy Administration, DTE Energy, Alliance Resources Partners, and Constellation Energy.

Oregon- Forest Resource Trust Program

This program helps landowners establish and maintain healthy forests on under-producing forestlands.[xlviii] This land may contain brushland, cropland, pasture, or poorly stocked forests. The state enters into individual agreements with private sectors landowners committed to establishing and managing healthy "free-to-grow" forestlands.[77] In exchange for the direct payment of stand establishment costs, participating landowners enter into contracts with the State Forestry in which they agree to share a fixed percentage of the net timber harvest revenues from forests created by the trust and to pass the rights back to the carbon dioxide emission reduction offsets to the Oregon Department of Forestry.

DTE Energy Programs

Since 1995, DTE Energy has planted 20 million trees in Michigan. DTE is a participating member of the UtiliTree Carbon Company, a consortium of 41 utilities organized by the Edison Electric Institute to invest in a portfolio of forestry projects that manage GHG emissions. A $3.2 million investment in eight domestic and two international projects will capture over 3 $MMTCO_2$ over the life of these projects. DTE is also a founding member of PowerTree Carbon Company, LLC, and a voluntary carbon sequestration initiative. PowerTree, which has 25 member companies, will invest $3.4 million for reforestation of over 3,800 acres of bottomland hardwood projects in Arkansas, Mississippi, and Louisiana. The project will sequester over 2 $MMTCO_2$ over the 100-year project term.[78]

Department of Natural Resources Forest Land Enhancement Program (FLEP)

FLEP is intended to promote sustainable forest management on non-industrial private forestlands by offering educational, technical, and financial assistance to private landowners. FLEP will reimburse up to 65% of the cost-designated management activities, within established limits.[79] Eight land practices ranging from afforestation to wildfire and catastrophic event rehabilitation are covered under the cost-share. Both the USDA Forest Service and State Foresters have leadership responsibilities.

4A.3 Going from Strategy to Policy

Based on the above national and state carbon sequestration initiatives, the MCCP identified aboveground carbon sequestration, through tree-plantings, as a GHG reduction policy option. After discussions with stakeholders and further background research, the MCCP team decided to focus on marginal agricultural lands as areas within

[xlviii]Under-producing lands are lands that once had forests or are capable of growing forests, but currently are not occupied by a manageable stand of tress or seedlings. These are areas that might have been converted to farm or pasture, burned over by forest fires, or been poorly managed prior to the pass of the Oregon Forest Practices Act.

the state that could be used to sequester carbon by means of afforestation projects. The final policy modeled by the MCCP team is as follows:

Afforestation of marginal agricultural land cost-share program

- The program was defined as a 40:60 cost-share agreement between the state government and non-industrial private magland owners[xlix]respectively, to afforest maglands.
- Magland owners enter into ten-year agreements with the state, and agree to maintain the planted trees during that period. During the ten years, the state government owns any carbon credits generated by the afforestation projects.

4A.4 Greenhouse Gas Modeling

4A.4.1 Modeling Methodology

The MCCP's GHG model was designed to estimate GHG emission reductions (or offsets) from new tree plantings on maglands. Some trees already may have been planted or naturally regenerated on the maglands under consideration in this policy, but the MCCP team was unable to determine the occurrence of existing trees. As a result, the GHG model only accounted for carbon sequestered by new trees and not existing ones. The business-as-usual (BAU) scenario used in the GHG reductions model assumes no changes in land use during the model timeframe of 2007 through 2025; changes in land use include afforestation and natural regeneration of trees on marginal agricultural land. As a result, the total area of magland remains constant throughout the model timeframe and the BAU scenario results in no gains or reductions of GHGs emissions.

4A.4.2 Modeling Inputs

The MCCP team modeled tree plantings based on two main inputs: acres of magland planted and species of tree planted. Two percentages of total magland (1% and 10%) were used to demonstrate the potential for carbon offsets in the state. Plantings were modeled for two types of conifers, red pine and white spruce, and plantings were divided evenly, over the ten years of the program (2007-2016). The resulting percentages of maglands and species of tree configurations are in Table 4A-1.

Table 4A-1. Carbon Sequestration Model Configurations.

1% Magland Red Pines (*Pinus resinosa*)	10% Magland Red Pines(*Pinus resinosa*)
1% Magland White Spruce (*Picea glauca*)	10% Magland White Spruce (*Picea glauca*)

Marginal agricultural land was based on data used by the Midwest Regional Carbon Sequestration Partnership that estimates 3,039,330 acres in the state.[l, 80]

[xlix]A non-industrial private landowner is defined as any private individual, group, association, corporation, Indian tribe, or other private legal entity excluding corporations whose stocks are publicly traded or legal entity principally engaged in the production of wood products.

Annual sequestration rates for forest projects[li] from the Chicago Climate Exchange (CCX) were used to calculate GHG emission reductions (Table 4A-2). These rates were used because they already are used in an operating carbon exchange. Landowners use these sequestration rates to calculate the forest carbon offsets generated by their land. Only two species of trees were modeled, as they were the only trees listed for the Great Lakes Region by the CCX.[lii] Additionally the annual carbon accumulation rates used for CCX are in terms of 250 trees per acre, and the MCCP modeled the planting of 700 trees/acre and minimum survival rate of 500 trees/acre. Annual accumulation rates provided by the CCX assume that trees are more sparsely planted.[81] Furthermore, recommendations for planting white spruce suggest 600-800 trees per acre. The most common recommendations used for planting red pines are about 700-900 seedlings per acre. However, research has shown that maximum cubit-foot volume growth of red pine is attained with a stand averaging 800-1,000 established trees per acre.[82] Based on the range of plantings per acre for the two tree species, the MCCP modeled the planting of 700 trees. To account for this difference, the CCX carbon accumulation rates were multiplied by a factor of 2.

Table 4A-2. CCX Annual Accumulation Rates (>250 stems per acre) Forestation Project Carbon Accumulation Table (metric tons of CO_2 per acre per year).

Tree Type	Years Since Planting			
	0-5	5-10	10-15	15-20
White Spruce	3.61	4.78	4.66	5.01
Red Pine	2.10	2.45	2.56	4.31

Accumulated carbon includes the live biomass of the tree. Soil, leaf litter, and understory vegetation are not included.

Additional assumptions included in modeling were that no harvest or thinning of trees occurred during the model timeframe. Potential emissions resulting from afforestation practices were also not included in the model. The output of the carbon sequestration GHG model was in metric tons of CO_2. This was converted into million metric tons of carbon equivalent (MMTCE), as this unit is used in the rest of the report.[liii]

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[l]Marginal agricultural land was defined by MRCSP as severely-eroded prime cropland, non-eroded marginal cropland, severely-eroded marginal cropland, severely-eroded pastureland, non-eroded marginal pastureland, severely-eroded marginal pastureland, and barren land. The US Geological Survey (USGS) 1992 National Land Cover Dataset (NLDC) was used to identify land use in the MRCSP region and the US Department of Agriculture-Natural Resources Conservation Service State Soil Geographic database was the source for determination of land quality (i.e. prime or marginal farmland). The combination of the two datasets was used to reclassify the land use with different land qualities.

[li]The annual carbon sequestration rates provided from the CCX are 70% of the annualized accumulation quantities for carbon in live vegetation that are reported in "Regional Estimates of Timber Volume and Forest Carbon for Managed Timberlands," by Richard Birdsey in *Forests and Global Change*, Volume 2: Forest Management Opportunities for Mitigating Carbon Emissions, Sampson, R.N., and Hair, D., eds. The MCCP team did not recalculate the carbon accumulation rates to the 100% level of annualized carbon accumulation quantities.

[lii]The Chicago Climate Exchange lists annual CO_2 rates for many trees in urban settings. Unfortunately, for the purposes of this report, only two types of tree data were available through the CCX for rural tree plantings.

[liii]Carbon sequestration in trees is usually reported in $MTCO_2$ or $MMTCO_2$.

The flow diagram in Figure 4A-1 presents the GHG model used to calculate the carbon sequestered annually by tree-planting projects. Appendix I.1 provides a summary of the carbon sequestration GHG model inputs.

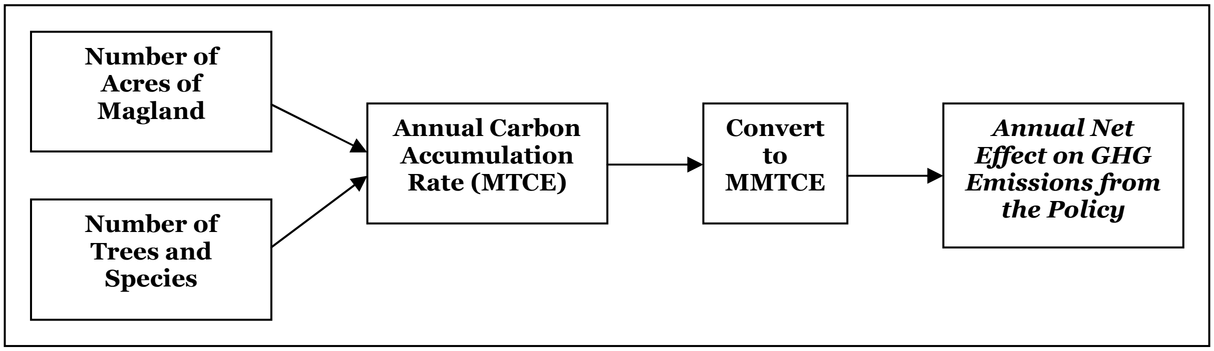


Figure 4A-1. Carbon Sequestration GHG Model Flow Diagram.

4A.5 Economic Modeling

4A.5.1 Modeling Methodology

The economic modeling of a magland afforestation cost-share program was intended to illustrate the economic effects associated with increased spending on tree plantings. The MCCP team utilized the REMI model to capture the costs and benefits of a ten-year, cost-share agreement between the state government (40% cost-share) and participating landowners (60% cost-share). The tree-planting program was modeled to begin in 2007 and run through 2016. After 2016, no additional economic activity was input to the model.

The additional parameters and assumptions the MCCP team used in the economic modeling are as follows:

- The harvest and sale of merchantable timber produced by the program was not included in the model.
- Economic benefits generated by the tree plantings in the form of carbon offset credits or future timber production was not included in the model. The MCCP team was unable to project a future price of carbon due to the uncertainty of future carbon legislation. However, the Chicago Climate Exchange has been operating a carbon-trading market since 2003, in which carbon has been modestly priced from $1-$5/metric tons of CO_2 ($MTCO_2$).
- Total cost of the program was based on cost-share guidelines for forest projects currently used in the State Forest Land Enhancement Program. (Appendix I.2 provides a break down of the total program costs.)

Stakeholder feedback from Forum II indicated that the federal government also should be modeled as a source of funding, using funds from the Conservation Reserve Program (CRP). Under this scenario, the state government would not be responsible for any of the costs associated with the tree-planting program. Therefore, the MCCP team included a model-run in which federal funds covered the 40% government-share of the program. Other policies in this report do not include federal funding sources in their scenarios, as state-level policies served as the scope of this report. Table 4A-3 represents the economic modeling scenarios.

Table 4A-3. Carbon Sequestration Economic Modeling Scenarios.

Scenario	Funding for 40% Cost-Share
Afforestation of 1% Magland	State
Afforestation of 10% Magland	State
Afforestation of 1% Magland	Federal CRP
Afforestation of 10% Magland	Federal CRP

4A.5.2 Modeling Inputs

The following is a discussion of the modeled variables and their impacts on the economic modeling. Names of the model variables are italicized. Appendix I.3 provides detailed input data for each of the presented variables, data tables, and figures illustrating the behavior of the modeled variables for this policy.

Input Variables and Rationale

- As described in the policy, the cost of the program was split between non-industrial private magland owners (farmers) and the state government. The cost was split such that non-industrial private magland owners paid 60% and the state government paid 40%.
- For non-industrial private magland owners, the team used the variable for *Farm Compensation* and reduced this variable by 60% of the total program costs.
- For state spending, the team reduced the amount of *Government Spending* for the state level by 40% of the program costs. The team reduced government spending to show that the state would have to cut spending for other programs to pay for this new program.
- The team did a second set of runs, assuming that non-industrial private magland owners spent the same amount, the state spent nothing, and the extra program costs came from the *Federal Government* (CRP). Since these funds are from outside of the state, the team did not model their portion of the cost of the program.
- The team increased the amount of *Firm Sales for Forestry et al* by the total cost of the program. The team used Firm Sales because this new demand would come in the form of cannibalistic demand and would compete with other pre-existing demand.

Variable Impact

- As expected, the increased *Firm Sales for Forestry et al* resulted in an overall increase in employment and state product across the state.

- The reduction in *Government Spending* and the reduction in *Farm Compensation* both had negative impacts on state employment and gross state product (GSP).

Economic Sectors Impacted

- The Forestry Sector was positively impacted by the policy.
- The primary negative impacts were for the Agriculture Sector, Construction, Wholesale and Retail Trade, Real Estate, Services Sector, and State Government.

4A.6 Results and Discussion

The following section presents the modeling results from afforestation of magland at the 1% and 10% levels, along with a discussion of the implications of pursuing such a policy.

4A.6.1 Greenhouse Gas Modeling Results

Table 4A-4 presents the cumulative GHG reductions by 2015 and 2025 from 10% of maglands planted with either red pine or white spruce. The results are 5.78 MMTCE and 10.3 MMTCE, respectively. As mentioned, the GHG model did not take current land use into consideration. The BAU scenario used for modeling was zero change in the carbon sequestered by the magland. The MCCP team could not determine a baseline scenario of current GHG emissions and reductions from different land use practices on magland acres.

The GHG reduction potential of the 10% Maglands with white spruce scenario, places third among the additional policies modeled in this report. Overall, all scenarios were effective at reducing GHG emissions by some degree. The GHG emission reductions are not affected by the funding source for the program.

Table 4A-4. Carbon Sequestration GHG Modeling Summary, 2015 and 2025.

Scenario	MMTCE by 2015	MMTCE by 2025
1% Maglands w/ Red Pines	0.16	0.58
10% Magland w/ Red Pines	1.60	5.78
1% Maglands w/ White Spruce	0.28	1.03
10% Maglands w/ White Spruce	2.81	10.3

Figures 4A-3 and 4A-3 present the yearly GHG reductions, at the 10% afforestation level for both species of trees. Overall, the higher sequestration rates of the white spruce result in higher GHG reductions, as compared to the GHG reductions from planting red pines.

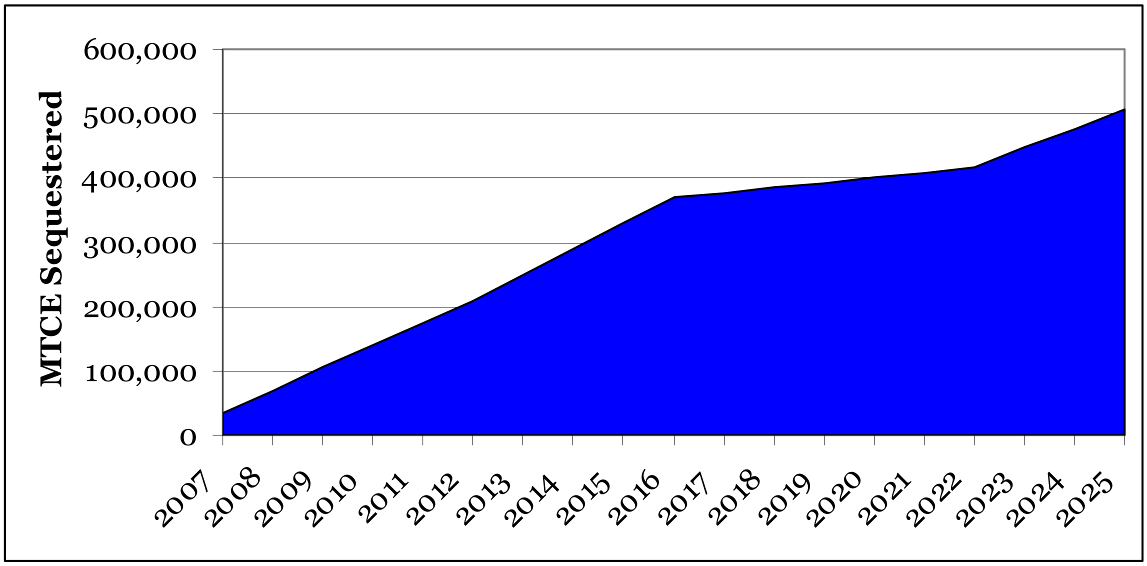


Figure 4A-2. 10% Red Pine GHG Reductions (2007-2025).

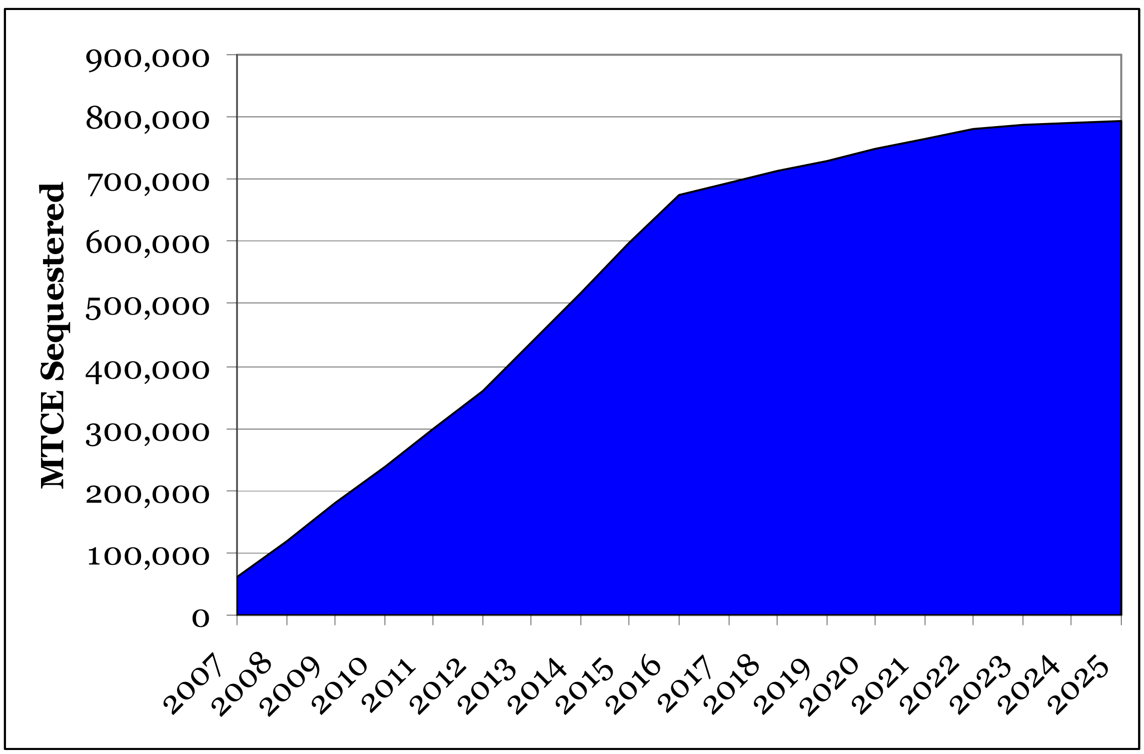


Figure 4A-3. 10% White Spruce GHG Reductions (2007-2025).

One factor not captured in the scope of the GHG model is that trees planted on maglands will continue to sequester carbon, outside of the model timeframe, at an increasing rate. Most carbon sequestration models for afforestation or reforestation use longer timeframes (50-100 years) to capture the full potential of trees for carbon storage. The following sources of further carbon sequestration potential were not included in the GHG model as the MCCP team was unable to determine the reasonable flux of carbon in these areas: forest floor, understory, and soil carbon. For these sources to be modeled, baseline carbon levels would have been required, and these levels were not available from the literature. Another way to incorporate these sources would be through direct field measurements, but such measurements were outside the scope of the MCCP. As discussed in the Policy Background section, uncertainty exists regarding the amount of carbon stored and the degree to which carbon remains sequestered in the soil over time. As field-measuring and monitoring techniques improve, annual sequestration rates of soils will become more standard.

4A.6.2 Economic Modeling Results

Tables 4A-5 and 4A-6 present the REMI modeling results in terms of average annual and cumulative economic effects during the modeling timeframe. Further breakdown of the economic modeling results can be found in Appendix I.3. A carbon sequestration program as outlined by this policy resulted in negative changes to the GSP and Employment (job-years). The decrease in GSP and Employment is attributed to the cost of the program and the reallocation of government spending to support the tree-planting program. Some jobs-years are added in the forestry sector. However, more job-years are lost than are added by this sector for all the modeled scenarios. Additional factors are the potential for trees to generate forest revenue in the form of carbon offsets and the possibility that after 2025, jobs could be created from the harvest of mature trees for timber. The Conservation Reserve Program could be another source of potential funding. Considering the 10.3 MMTCE sequestered by planting 10% of marginal agricultural land with conifers and the CCX's current range of carbon prices ($3.67-$18.33/MTCE), this policy could generate $37.8 million to $189 million through the trading of carbon forestry offsets. This revenue could defer the total cost of the planting trees ($204 million) and decrease the magnitude of the negative economic modeling results.

Table 4A-5. Carbon Sequestration Average Annual Economic Effects, 2015 and 2025.

Scenario	Change in GSP (millions 2000 fixed $) by 2015	Change in GSP (millions 2000 fixed $) by 2025	Change in Job-Years by 2015	Change in Job-Years by 2025
1% Magland, State Cost-Share	-9.80	-5.18	-60	-32
1% Magland, Federal Cost- Share	-8.76	-4.67	-39	-21
10% Magland, State Cost-Share	-98.1	-52.4	-602	-323
10% Magland, Federal Cost-Share	-87.6	-46.7	-397	-212

Table 4A-6. Carbon Sequestration Cumulative Economic Effects, 2015 and 2025.

Scenario	Change in GSP (millions 2000 fixed $) by 2015	Change in GSP (millions 2000 fixed $) by 2025	Change in Job-Years by 2015	Change in Job-Years by 2025
1% State 40% of Cost-Share	-88.2	-98.4	-543	-605
1% Federal 40% of Cost- Share	-78.8	-88.7	-355	-400
10% State 40% of Cost-Share	-882	-995	-5,422	-6,135
10% Federal 40% of Cost-Share	-788	-886	-3,576	-4,027

Note: 2016 was the last year of the program and no additional economic activity was modeled after that year, accounting for the small changes between 2015 and 2025 results.

Figures 4A-4 and 4A-5 present the annual changes in GSP and Employment when state and funds are included in the cost-share.

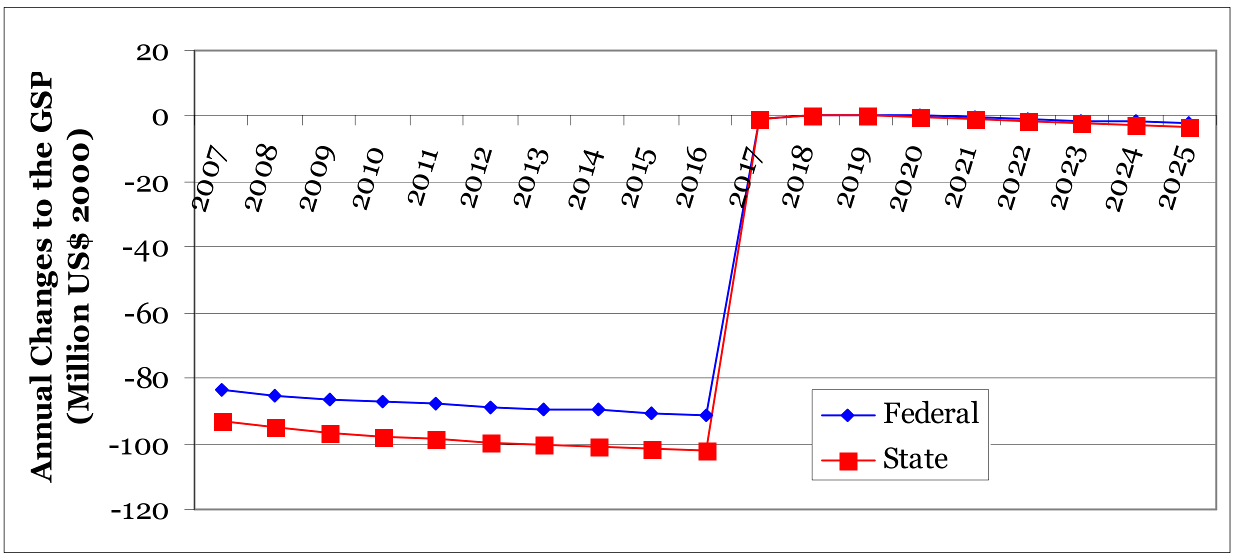


Figure 4A-4. 10% Magland-Changes to the Michigan GSP by Funding Source (2007-2025).

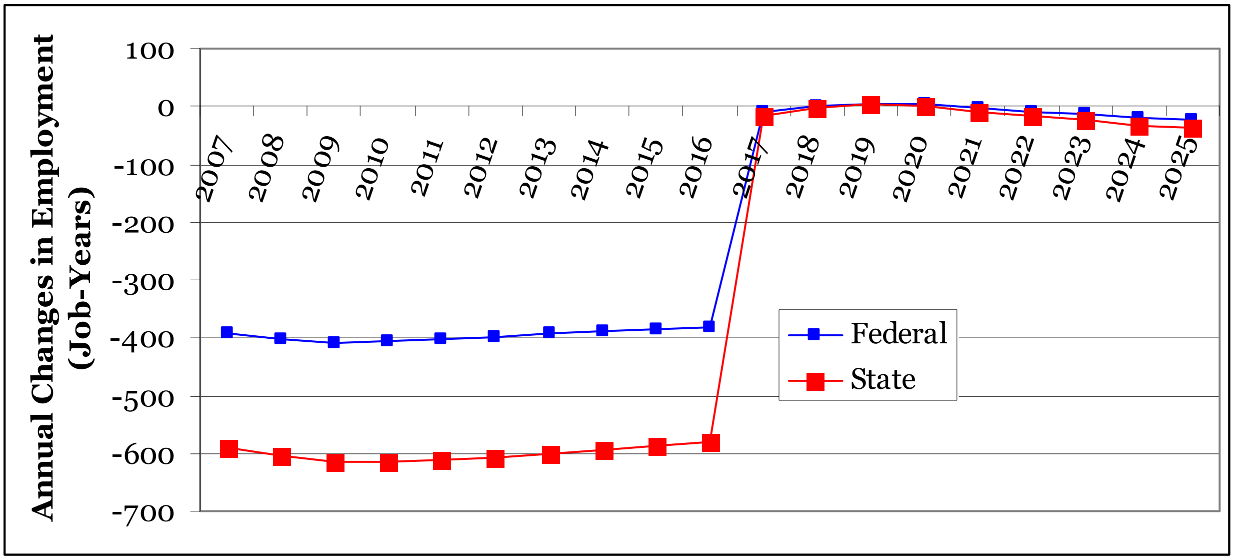


Figure 4A-5. 10% Magland-Changes in Michigan Employment by Funding Source (2007-2025).

The scenarios funded by the CRP continue to present negative economic effects in both GSP and Employment; as expected, these figures were not as negative as the state-funded scenarios. However, the economic effects are close to neutral once tree-planting stops because the ten-year span of the program has passed. At this point, no additional costs are included in the model. Compared to the other policies modeled in this report, this policy has the most negative economic effects. This policy would be more viable under a carbon-constrained world scenario, in which a price of carbon could be included as an economic input. For example, under a cap-and-trade scenario, it might be cheaper for a company to meet their emission levels by purchasing offsets from programs like this, instead of paying to modify their operations. This could result in a higher price and demand for carbon offsets, therefore potentially making this policy more economical.

In addition to the GHG reduction potential and economic effects of this policy, other factors are not captured in the models that should be evaluated. REMI was not able to capture all of the costs and benefits of an afforestation program. Benefits to wildlife, tourism, recreation, and biodiversity were not measured. An adaptation of this policy could use soil type, region of the state, and/or sequestration rate to determine what trees are planted. Additionally, planting mixes of trees would increase the biodiversity of the afforestation projects and move away from monoculture plantations.

Forests and tree planting programs have substantial opportunities for storing carbon in biomass and soils to help curb the threat from climate change. Trees are also subject to climate change. Global climate change will affect tree species, geographic range, and health and productivity of forests.[83] According to the Union of Concerned Scientists, warmer temperatures will likely cause boreal forests to shrink and other forest species to move northward.[84] This should be factored in when considering terrestrial carbon sequestration projects.

4A.7 Conclusion and Discussion

The modeling performed by the MCCP team indicates that carbon sequestration through tree plantings on marginal agricultural land would create significant GHG emission reductions. The economic effects of this policy, as modeled, are negative because of the costs to participating landowners and government to plant the trees. These costs would be significantly reduced if a price of carbon were factored into the economic model. The 10% Maglands with White Spruce scenario ranks third among the other policies in this report and stakeholders indicated strong interest in a policy of this nature, even when the economic effects were considered. This policy would be better suited within a carbon-trading market like the CCX or under a carbon-constrained world scenario, in which a price of carbon could create the need for mechanisms, like carbon sequestration projects, to offset GHG emissions.

4B. Geologic Sequestration: Capture, Compression, Transportation, and Storage Capabilities in Michigan

4B.1 Introduction

At Forum I, the stakeholders ranked carbon sequestration fourth out of all strategies, indicating their interest in further analysis of this strategy. Geologic sequestration was not specifically discussed, but during background research, the MCCP team learned that Michigan has a potentially suitable location for the geologic sequestration of carbon. Many variables will determine whether Michigan's geologic features are suitable for geologic sequestration and more in depth research is in the planning stages. Without knowing if Michigan's geologic formations can sequester carbon on a commercial-scale, the MCCP team decided that a specific geologic sequestration policy was not appropriate at this time. Several years are needed to research the area thoroughly and even more time is needed to monitor the site to determine if it is capable of long-term storage. Additional years would then be required to obtain the necessary permits and construct a commercial-scale project. Therefore, based on the uncertainty in the geology, timing issues, and stakeholder feedback, the MCCP team concluded that an individual policy for geologic sequestration was probably premature for the MCCP modeling timeframe (2007-2025).[85] Instead, the MCCP team chose to include the following informational section as geologic sequestration could play an important role in Michigan under a future carbon-constrained world scenario.

4B.2 Policy Background

Carbon sequestration is the uptake and storage of carbon dioxide (CO_2). Carbon dioxide can be stored naturally, for example in biomass or soil, or it can be captured, injected, and sequestered in deep geologic formations. Underground formations such as depleted oil and gas fields, unmineable coal seams, or saline aquifers can serve as storage locations. Geologic sequestration is a strategy that can mitigate climate change by capturing CO_2 from large point sources (like electrical power plants and natural gas processing plants) and subsequently storing it instead of allowing it to be released into the atmosphere.

To be geologically sequestered, carbon first needs to be captured. Carbon dioxide capture technologies are currently in use and undergoing further development. Natural gas processing plants often have to remove CO_2, to prevent dry ice from clogging gas tankers or to prevent CO_2 concentrations from exceeding the 2.5% maximum permitted on the natural gas distribution grid.[86] The US Department of Energy, academia, and industry are researching methods of capturing CO_2 directly from flue gases produced by the combustion of oil, natural gas, and other fossil fuels (US Department of Energy, Office of Fossil Energy).[liv, 87] Once CO_2 is captured, the gas is compressed into a near-liquid phase and is ready for transport.

Transportation options include pipeline or tanker. If the geologic storage site is less than 1,000 km from the point of capture, pipelines tend to be the preferred method of transport. The transport of CO_2 via pipeline is considered a mature technology and, in the United States, over 2,500 km of pipelines transport more than 40 million metric tons of CO_2/yr from natural and anthropogenic sources.[88] Most of these pipelines are located in the Southwest where enhanced oil recovery (EOR) operations use CO_2 to increase oil

[liv] The US Department of Energy's Office of Fossil Energy maintains the Fossil Research Database (FRED). This database provides standardized fact sheets and project status for more than 147 carbon sequestration research and development projects. Several of the projects are focused on the CO_2 removal from flue gases.

production from fields in the Permian Basin. Northern Michigan has tens of miles of CO_2 pipelines used to move CO_2 to depleted oil fields undergoing EOR.[89] Tankers are used when a geologic storage site is too distant for pipeline transport. Tankers can be moved via truck, rail, or ship, but pipelines are often more economically feasible and safer.

Storage of CO_2 involves injecting it into a depleting oil or gas well, unmineable coal seam, saline or shale formation, or other suitable geologic structure. EOR operations have been injecting CO_2 for more than 30 years. The injected CO_2 decreases the viscosity of the oil, enabling more of it to be recovered.[90] A portion of the CO_2 remains underground, although current industry practices are geared strongly towards minimizing the amount of CO_2 left underground and little or no attention is paid to the CO_2 that is not recovered.[91] EOR is not strategically being used for sequestration, but rather as a mechanism to increase the yield of a given oil field. One benefit of EOR is that the cost of geologic sequestration can be offset by the sale of the oil recovered; the geographic distribution and limited storage capacity of such structures are the primary disadvantages.

Saline aquifers are of particular interest in Michigan. Northern areas of the Lower Peninsula contain large saline aquifer formations, with estimated storage potential of 45,890 $MMTCO_2$ (as of April 2005).[92] Table 4B-1 provides geologic storage capacity estimates for the Midwest Region, as approximated by the Midwest Regional Carbon Sequestration Partnership (MRCSP), a public/private consortium of leading universities, state geological surveys, nongovernmental organizations, and private companies. According to these figures, Michigan has greatest total capacity in the region, with a potential 435 years of CO_2 storage. Additionally, several natural gas processing plants (large point sources of CO_2) are within the same area as the saline aquifer formation (Appendix I.5). The combination of a potentially suitable saline aquifer for geologic sequestration and a local CO_2 point source improves the opportunity for an injection site in that area.

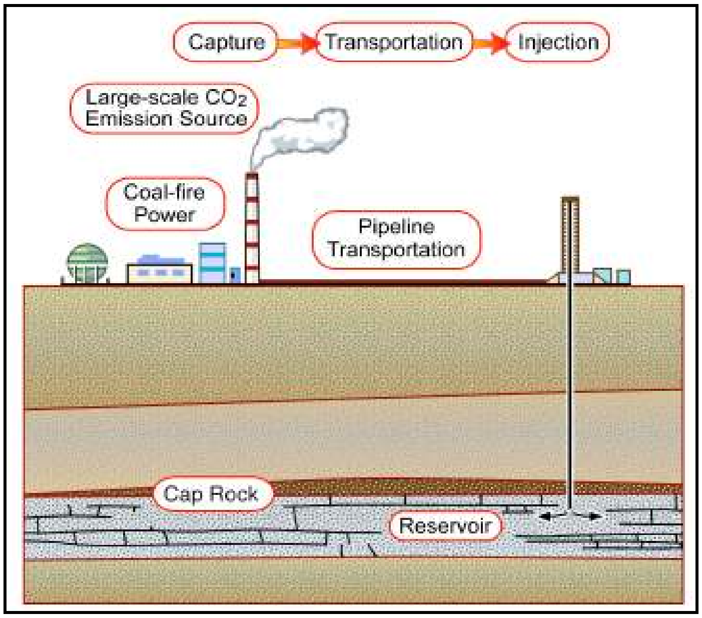
Table 4B-1. Preliminary Estimates of Geologic Storage Capacity for the MRCSP Region.

State	Estimated Geologic Storage Capacity ($MMTCO_2$)					# of Large CO_2 Sources	Annual Emissions from Large Point Sources ($ktCO_2$)	Years of Storage Capacity
	Deep Saline Formations	Coal Basins	Depleted Gas Basins	Depleted Oil Plays	Total			
IN	30,640	200	50	30	30,920	46	162,208	191
KY	17,340	142	110	30	17,622	30	101,711	173
MD	4,920	40	10	20	4,990	17	37,637	133
MI	45,890	20	290	100	46,300	44	93,542	495
OH	34,810	437	260	150	35,657	44	148,405	240
PA	14,420	922	380	80	15,802	66	126,779	125
WV	13,580	1,246	220	60	15,106	27	96,340	157
Total	~162,000	~3,000	~1,300	~470	~167,000	~274	~766,000	>200

Source: MRCSP Third Semi-Annual Progress Report. [93]

Saline aquifers are saltwater formations, located thousands of feet below the earth's surface. They are comprised of porous rock units overlain by one or more impermeable rock formations. For these reasons, saline aquifers have the potential to trap injected

CO_2. Researchers believe that over many years the stored CO_2 will dissolve into the brine and spread throughout surrounding sandstone formations. The CO_2 may also react with other minerals in the rock to form new minerals. Dense rock above the injection zone act as a seal for the stored CO_2, preventing its movement through the layers of rock above the reservoirs and up to the surface. This seal or rock layer is also known as the cap rock. (See Figure 4B-1.)



Source: Xu, Tianfu. CO_2 Geological Sequestration. Lawrence Berkley National Laboratory.[94]

Figure 4B-1. Geologic Sequestration.

Estimates are used because a standardized or accurate method of calculating aquifer capacity does not exist. Capacity is generally estimated through the preparation of regional maps of different geologic formations for their thickness and depth. Porosity data are mapped if they are available, but otherwise a generic porosity number may be used for the entire formation. The maps and porosity data are used to calculate total pore volume in a formation. However, because the pore spaces contain brine, only a fraction of the total pore space volume can be used for sequestration. This number varies based on preference and assumptions in the study.[95]

The following is an example equation for calculating CO_2 sequestration volumes for saline aquifers:

$$\mathbf{Q} = ((7758 * (\Phi * a * h)) * CO_2s)/ (1000 * 18.75)$$

Where:

Q = sequestration volume (metric tons)

Φ = porosity (percent) [96][lv]

a = area (acres)

h = net thickness (ft)

CO_2s = CO_2 solubility (scf/bbl water)

Assumptions:

Temperature (deg F) = 61 + 0.007 * depth (ft)

Pressure (psia) = 0.433 (psi) * depth (ft) [97]

A commercial-scale example using saline formations for geologic sequestration is located in the North Sea off the coast of Norway. Since 1997, Statoil, an integrated oil and gas company, has been capturing roughly 1 $MMTCO_2$/year from a natural gas processing platform and subsequently injecting it into the Sleipner Vest gas field, a saline formation 1,000 m below the ocean floor.[98] Planned storage for this site is 20 $MMTCO_2$.[99] Examples of US geologic sequestration field demonstration projects can be found in Appendix I.6.

4B.3 Costs of Carbon Capture and Storage

Multiple factors determine the total cost of capture, compression, transportation, and storage of CO_2. Costs vary according to emission source, point of capture, distance from point source, and type of storage and can be put in terms of $/metric ton of carbon (tC) stored or $/kWh. Recent estimates put current carbon capture and storage costs at about $229/tC for new Pulverized-Coal (PC) plants, $224/tC for new Natural Gas Combined-Cycle (NGCC) plants, and $138/tC for new Integrated Gasification Combined-Cycle (IGCC) coal plants, relative to those technologies without carbon capture and storage.[lvi][100] Table 4B-2 presents these costs according to the type of plant.

[lv]Mt. Simon Sandstone, Sylvania Sandstone, and Bois Blanc Dolomite sedimentary formations are under evaluation for storage in Michigan. Mt. Simon Sandstone is a promising host reservoir for CO_2 storage due to its favorable depth, thickness, permeability, and presence of cap rocks that have low permeability. Mt. Simon Sandstone formation porosity varies significantly in lateral and vertical directions, but is generally in the range of 8-13%.

[lvi]These costs assume a natural gas price of $3/Mbtu and transport and storage costs of $37/tC stored.

Table 4B-2. Costs of Carbon Capture and Storage ($/tC avoided).

New Power Plant System		
NGCC	**PC**	**IGCC**
224	229	138

Note: Average capture costs in $/tC avoided are given by ($c_{cap} - c_{nocap}$)/ ($e_{nocap} - e_{cap}$), where c is the cost in kWh, e is the rate of carbon emissions (tC/kWh), and the subscripts denote these variables with and without capture. Costs are relative to the specified technologies without carbon capture and storage. These costs assume a natural gas price of $3/MBtu and transport and storage costs of $37/tC stored.

Source: Soren Anderson and Richard Newell. June 2004.

Additionally, many factors determine the cost of a full carbon capture and storage system for electricity generation from a newly built, large-scale, fossil fuel-based power plant. Table 4B-3 compares the cost of carbon capture and geologic sequestration for PC, NGCC, and IGCC power plants in terms of $/kWh. IGCC with capture and geologic sequestration is estimated to cost less than PC with capture and geologic sequestration, but more than NGCC with capture and geologic sequestration. The numbers below assume experience with a large-scale plant. Gas prices are assumed to be 2.8-4.4 US$ per gigajoule (GJ), and coal prices 1-1.5 US$ GJ.

Table 4B-3. Costs of Carbon Capture and Storage (US$/kWh).

Power Plant System	NGCC	PC	IGCC
Without capture (reference plant)	0.03 – 0.05	0.04 – 0.05	0.04 – 0.06
With capture and geologic sequestration	0.04 – 0.08	0.06 – 0.10	0.05 – 0.09
With capture and EOR	0.04 – 0.07	0.05 – 0.08	0.04 – 0.07

Source: IGCC Report. Carbon Dioxide Capture and Storage.[101]

The cost of capture (including compression) is about 75%, the largest component of overall cost. Several industrial processes, like natural gas processing and cement manufacturing, produce highly concentrated streams of CO_2 as a byproduct. These plants make good capture targets because the captured CO_2 is integral to the total production process, resulting in relatively low incremental capture costs.[lvii] For example, natural gas ensuing from wells contains up to 20% CO_2 by volume and most of it must be removed to produce pipeline-quality gas.[102] Some of this removed CO_2 is used for industrial applications, like EOR operations (20% of the CO_2 used in EOR operations comes from the purification of natural gas), but most of it is released into the atmosphere.[103] However, this CO_2 could be captured, compressed, and stored.

[lvii] MEA solvents were developed 60 years ago specifically for this purpose.

Regardless of whether pipeline or tankers are used for transportation, the cost depends on the distance and the quantity transported. Costs for transportation via pipeline vary greatly because the cost depends on many factors such as terrain, pipe diameter, flow of CO_2, and population density. For pipelines in Michigan, costs increase if the pipeline travels through heavily congested areas and if the ground is frozen. Transportation costs are dominated by the investment in pipeline infrastructure, whereas operation and maintenance costs are small by comparison.[104] Economies of scale are realized when transporting over 10 $MMTCO_2$/yr via pipeline, and this cost is about $0.50/metric tons CO_2/100 km. This compares to truck transport at about $6/metric ton CO_2/100 km.[105]

The Midwest Regional Carbon Sequestration Partnership (MRCSP) recently completed a study examining the potential for geologic storage in the Midwest, including estimates of the costs for the different components of geologic sequestration. The study estimated capture and compression costs from $20 and $50/ tCO_2 for most types of large point sources in the MRCSP region. However, capture from natural gas processing plants presents the lowest estimated cost of $9-10/ tCO_2.[106]

The MRCSP study also investigated transportation costs and determined that transportation cost is mainly driven by the mass flow rate of CO_2 to be transported. The distance between the source and storage site are also factors. The study looked at different transportation scenarios and its estimates range from $0.20/$tCO_2$ for a very large coal-fired power plant requiring minimal pipeline length, to nearly $15/$tCO_2$ for a very small gas-fired power plant approximately 100 miles from the storage site.

Finally, the MRCSP study estimated the cost of injecting CO_2 into a geologic formation to range from $7- 12/$tCO_2$ based largely on the characteristics of the reservoir (depth, oil/gas recovery potential).[107] This included all necessary capital and operating costs for wells and distribution pipelines, as well as monitoring equipment and procedures.[108] The estimated total cost of capture, compression, transport, and injection ranges from $0 (due to revenues from EOR) to $100/$tCO_2$ stored.[109]

4B.4 Life Cycle Energy Requirements

Some estimates of the life-cycle energy requirements for various types of geologic sequestration are available. A basic life-cycle analysis of geologic sequestration includes the capture, compression, transportation, injection, and storage energy to sequester CO_2. Similar to the aforementioned cost estimates, these figures provide reference points. Much of the information about geologic sequestration life-cycle energy requirements is not publicly available. For example, primary data for the post-combustion technologies (e.g., used in coal-fired power plants) are unavailable.[110] The following energy and recovery estimations are from the limited data that was available.

Geologic sequestration research at the Sleipner Vest oil fields estimates an energy demand of 240 kWh/ton CO_2 for the extraction of CO_2 by amine scrubbing; energy required just for the injection of CO_2 into the saline aquifer is about 18 kWh/ton CO_2.[111] Research estimates for geologic sequestration with EOR indicate that the energy demand is 138 kWh/ton CO_2 for long distance pipeline transportation. Injection of CO_2 into underground media and oil recovery requires an additional 94 kWh/ton CO_2.[112]

4B.5 Risks and Uncertainty

A degree of uncertainty exists regarding the environmental effects of CO_2 storage in aquifers. Most studies suggest that adverse effects can be mitigated by choosing suitable locations for CO_2 storage.[113] Depending on the storage reservoir and the composition of the waste gas stream (pure CO_2 vs. mixtures of CO_2 with other gases), injection of CO_2 in geologic formations may cause physical and chemical phenomena. Examples include, but may not be limited to, miscible or immiscible displacement of native fluids; dissolution of injected fluid into reservoir fluid; changes in effective stress with associated porosity and permeability changes; and the possibility of inducing seismic activity or chemical interactions between fluid and solids.[114]

The local risks associated with CO_2 pipeline transport could be similar to or lower than those posed by hydrocarbon pipelines already in operation.[lviii] A sudden and large release of CO_2 would pose immediate dangers to human life and health if there were exposure to concentrations of CO_2 greater than 7-10% by volume air.[115] For existing CO_2 pipelines, mostly in areas of low population density, accident numbers reported per mile pipeline are very low and are comparable to those for hydrocarbon pipelines.

Another risk is the possibility of leakage through undetected faults and factures in which the release of CO_2 is more gradual and diffuse. In this case, hazards would primarily affect drinking water aquifers and ecosystems, where CO_2 accumulated in the zone between the surface and the top of the water table. Groundwater can be affected both by CO_2 leaking directly into the aquifer and brines that enter the aquifer because of displacement by CO_2 during the injection process. Acidification of soils and displacement of oxygen in soils is another possibility in this scenario. If leakage occurs in low-lying areas with little wind or in sumps and basements overlying these leaks, humans and animals would be harmed if the leak were undetected. Overall, any type of leakage of CO_2 defeats the purpose of sequestration.

4B.6 Role of the Electricity Sector in Geologic Sequestration

Recent estimates suggest that the application of carbon capture and storage in the electric power and industrial sectors could significantly reduce total US emissions. Estimates suggest that the incremental cost of applying carbon capture and storage to new conventional coal or natural gas plants would be about \$200/tC to \$250/tC.[116] For flue gas streams with low to moderate concentrations of CO_2, typically found in coal-fired and new natural gas power plants, the best existing capture method is absorption using a chemical solvent, such as monoethanol amine (MEA). With present technologies, the incremental cost of applying carbon capture and storage by means of chemical absorption to new conventional coal and gas plants is about \$225/tC to \$230/tC, but near-term technical improvements could reduce these costs to about \$160/tC to \$190/tC.[117]

Retrofitting existing coal plants with chemical capture currently costs about \$190/tC, including an assumed transportation and storage cost of \$37/tC stored.[118] Retrofitting existing power plants with CO_2 capture is expected to lead to higher costs and significantly reduced overall efficiencies, compared to newly built power plants with capture already incorporated in the design. The costs to retrofit vary, but industrial sources (like cement plants, natural gas processing plants) can more easily be retrofitted

[lviii] In this estimation of risks, it was assumed that the risk is the product of the probability that an event will occur and the consequences of the event if it does occur.

with CO_2 separation, while integrated power plant systems would need more profound adjustments. To reduce future retrofit costs, new plant designs could take future carbon capture and storage applications into account.[119]

4B.7 Integrated Gasification Combined Cycle Power Plants

In an EPA 2006 report, integrated gasification combined cycle (IGCC) was defined as follows: [120]

> [A] power generation process that uses a gasifier to transform coal (and other fuels) to a synthetic gas (syngas), consisting mainly of carbon monoxide and hydrogen. The high temperature and pressure process within an IGCC creates a controlled chemical reaction to produce the syngas, which is used to fuel a combined cycle power block to generate electricity. Combined-cycle power applications are one of the most efficient means of generating electricity because the exhaust gases from the syngas-fired turbine are used to create steam, using a heat recovery steam generator, which is then used by a steam turbine to produce additional electricity.[121]

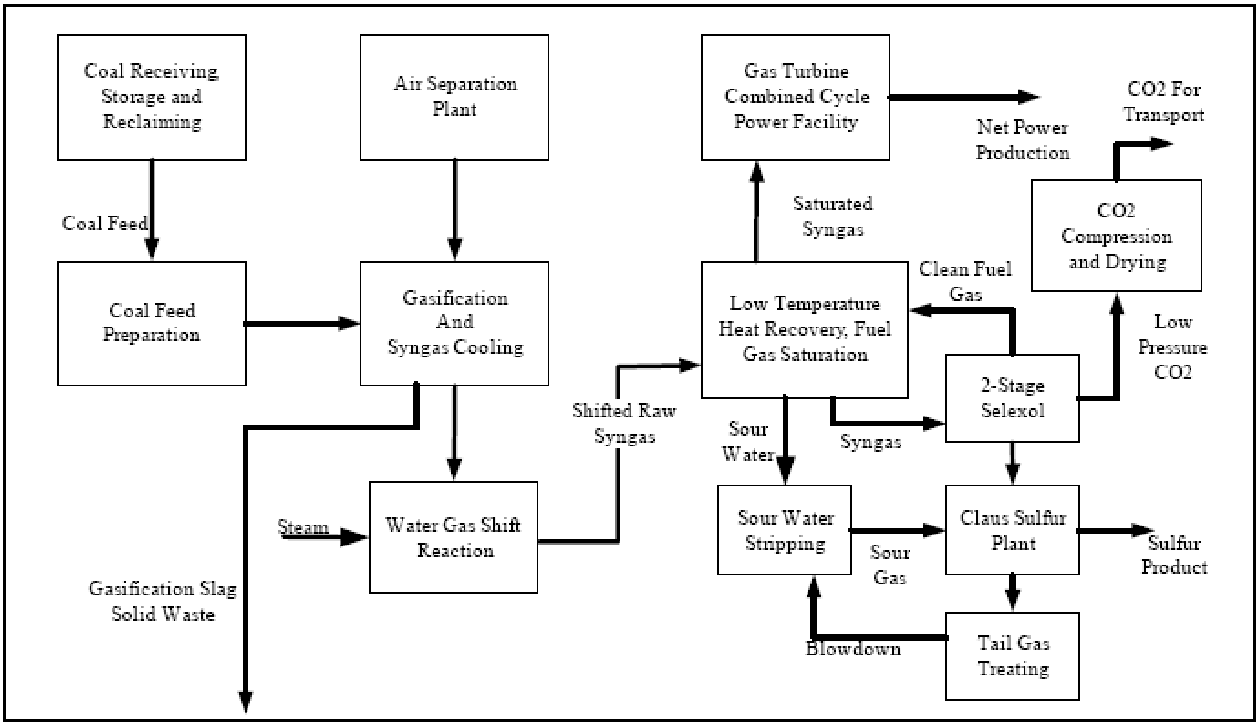
Only two coal-fired power plants in the country currently use IGCC technology (without capture and storage). However, several companies have announced plans to build and operate additional IGCC facilities.[122] Neither IGCC nor pulverized coal (PC) power plants inherently capture CO_2; it takes additional energy and cost to capture and store CO_2. Currently IGCC power plants without capture are 10-15% more expensive than PC power plants without capture and storage. The Electric Power Research Institute (EPRI) believes that western coals, utilized in IGCC and PC power plants with CO_2 capture, may be in competition regarding cost and emissions in 2015-2020. Currently PC with MEA capture is more expensive than IGCC with capture; the CO_2 capture accounts for the cost gap.[123] The incremental cost of applying capture is lower for IGCC plants (currently about $140/tC and with near-term technical improvements about $100/t C) than for conventional natural gas and coal plants.[124]

The DOE has approved the construction of what will be the world's first carbon capture and storage power plant. This initiative, known as FutureGen, will design, construct, and operate a 275-megawatt prototype plant that produces both electricity and hydrogen. States bid to host the demonstration project, and the four finalists (as of December 2006) are: Mattoon, IL; Tuscola, IL; Odessa, TX; and Jewett, TX.[125] These candidate sites will move forward to the next step of the selection process, which includes a comprehensive National Environmental Policy Act evaluation by DOE and more detailed site characterization. The project aims for completion by 2012.

Currently, there are no formal plans to build an IGCC power plant with/or without carbon capture and storage in Michigan, even though the state may have suitable geologic formations for the storage of CO_2.[126] Michigan's 21st Century Energy Plan (CEP) addresses future energy production and indicates that Michigan will continue to rely on coal and that nuclear power may not be available until the second half of the report's planning period, after 2015. While coal will continue to be used, the report also acknowledges the potential use of IGCC technologies. IGCC is presented in the report as follows:

> Utilities around the country are looking at integrated gasification combined cycle technology, because of its potential for capture of carbon

dioxide emissions. It is also possible that conventional plants cane be retrofitted to achieve carbon capture. If IGCC proves to be superior to other coal-based technologies, then air permitting agencies, including the Department of Environmental Quality and the EPA, as well as the Commission, may eventually require consideration of IGCC as an alternative to conventional coal-fired power plants before issuing any new permit or authority. In the meantime, the best protection against the risks associated with new coal-based generation is greater reliance on energy efficiency and renewable resources measures.[127]



Source: EPA 2006 IGCC Report.

Figure 4B-2. IGCC with CO_2 Separation and Capture Flow Diagram.

4B.8 Midwest Regional Carbon Sequestration Partnership

The MRCSP is a public/private consortium of leading universities, state geological surveys, nongovernmental organizations, and private companies. The group, led by Battelle, a non-profit research institute, has been assembled to assess the technical potential, economic viability, and public acceptability of carbon sequestration. The partnership's goal is to lower the cost of CO_2 storage and capture and to ensure permanent and safe storage. The MRCSP region consists of seven contiguous states: Indiana, Kentucky, Maryland, Michigan, Ohio, Pennsylvania, and West Virginia.[128] All participants contribute technical knowledge, expertise, and cost sharing in various amounts. The DOE through NETL is the single largest sponsor of the MRCSP research. The Ohio Coal Development Office is the second largest funding organization, followed by a number of the region's largest energy companies and other participating organizations.

In October 2003, the MRCSP initiated a two-year Phase I project, that was later completed in 2005. The objective of Phase I was to develop a coherent picture of CO_2 sources and sequestration opportunities in the MRCSP region. It created a carbon sequestration atlas for the region including large point sources and priority opportunities for sequestration field tests.

MRCSP is proceeding with a four-year Phase II project, scheduled for completion in 2009. The primary objective of Phase II is to move ahead with the priority sequestration demonstration projects identified in Phase I. During this phase, MRCSP will recommend technologies for several small-scale injection field tests at specific locations in the region. Michigan has a site in the Otsego County (Appendix I.7) undergoing well-drilling tests. Researchers are testing core samples for their porosity and the injectivity of different layers as well as the suitability of other layers as cap rock.[129] These tests will help map and define the sequestration potential of the region. Test sites were primarily selected according to their proximity to large point sources and the adjacent geologic formations thought to be suitable for sequestration. Over a period of several months, 3,000 to 10,000 tCO_2 is likely to be collected and injected into wells. This is a very small amount compared to the amount of CO_2 typically produced by a power plant.

4B.9 Conclusion and Discussion

The MCCP team determined that a specific geologic sequestration policy was probably premature for its modeling timeframe (2007-2025) considering the uncertainty of the state's storage capabilities, and the time required to permit and construct a commercial-scale geologic project. Nevertheless, geologic sequestration is relative to Michigan. Preliminary estimates by MRCSP suggest that Michigan may have 45,890 $MMTCO_2$ total geologic capacities in saline aquifers. Deep saline formations in Sylvania Sandstone or in other geologic layers in Northern Michigan could serve as possible injection sites.[130] A demonstration project would help identify: (1) the storage capabilities, (2) chemical reactions that occur in the sandstone, (3) underlying layers, and (4) if the cap rock is impermeable and prevents leaking. Geologic sequestration is promising in Michigan because of the availability of CO_2 from several large point sources, in the form of natural gas processing plants, well within transportation-range of potential injection sites (Appendix I.5). The natural gas being extracted is high in CO_2 and is currently vented into the atmosphere after it is processed.[131] Additionally, Michigan has experience with CO_2 injection for enhanced oil and gas recovery.

According to Dr. David Barnes, Western Michigan University associate professor of geosciences, "The state of Michigan possesses a substantial volume of underground void space. This huge volume of sub-surface space provides a potential repository for waste materials. This is a real economic opportunity for the state of Michigan."[132] With huge saline aquifer reserves, the state could eventually become the site for large, modern power plants, in which CO_2 is captured, liquefied, and pumped underground.[133] However, as previously mentioned, no formal plans presently exist for a new power plant with capture technologies.

The National Energy Technology Laboratory (NETL), in the DOE's Office of Fossil Energy and Battelle, is planning to initiate several short-term geologic sequestration demonstration projects.[134] The location of these future demonstration field projects will be determined in early 2007; it is likely that one of these projects will be sited in Gaylord (Otsego County), MI.[135] The project would take three to four years to complete, partially because it is important to monitor that the gas stays pressurized. The scope of the project is to capture, pressurize, and inject CO_2 underground into nearby saline aquifer formations.[136] A natural gas processing plant operated by DTE Energy would potentially serve as the source of CO_2. Simple drying/compression is used for this process.[137] The MRCSP also intends to work with Core Energy, a local gas and oil producer that operates a CO_2-compression facility and eight miles of existing pipeline that transports CO_2 into active EOR operations. The US Environmental Protection Agency (EPA) Region 5 Office has regulatory oversight of injection wells, and the MRCSP has already initiated discussions with the EPA regarding the aspirations for the Michigan field test. At this time, there are no formal plans for a large-scale test or commercial-scale geologic sequestration project.[138]

In the event that the MRCSP geologic-sequestration field demonstration moves forward, it will be several years before storage capabilities are better known. Even if the saline aquifers in Michigan are found suitable for geologic sequestration, a commercial-scale carbon capture and storage project is a long way off; plans at this scale are premature without more information about the saline aquifer's storage capabilities. Furthermore, DOE's FutureGen initiative does not include Michigan in its list of candidate sites best suited to host the FutureGen facility (DOE Dec. 2006).[lix,139] No projects of this scale are currently in the planning process and FutureGen will be the world's first zero-emissions power plant producing electricity and hydrogen from coal while capturing and storing CO_2.

Overall, geologic sequestration could become a more viable option for CO_2 mitigation as its price decreases. Additionally, a federal regulation on CO_2 emissions could spur the use of this technology. If the price of storage ($/ton stored), as a federal regulation, is lower than other offset options (e.g. purchasing credits from soil, forest, or other sequestration strategies) then geologic sequestration may become more common. However, without the context of a carbon-constrained world, there is no set price for carbon, no cap and trade, and no impending pressure to compress CO_2 and store it underground in Michigan.

[lix] As of December 2006, candidate sites include: Mattoon, IL; Tuscola, IL; Heart of Brazos near Jewett, TX; and Odessa, TX.

5. Residential Building Efficiency

5.1 Introduction

According to the US Energy Information Administration (EIA), in 2001, the Michigan residential sector used 789.5 trillion British thermal units (Btu) of energy. The commercial sector used 598.2 trillion Btu of energy in 2001.[140] Combined they are responsible for 9.7 million metric tons of carbon equivalent (MMTCE).[141] As reported in the Center for Sustainable Systems' (CSS) *Michigan Greenhouse Gas Inventory 1990 and 2002*, Michigan buildings were responsible for 44% of greenhouse gas (GHG) emissions from fossil fuel combustion and electricity use in 2002.[142] As one of the buildings are a primary driver of energy consumption, and therefore GHG emissions, taking actions to decrease building energy usage will help reduce future atmospheric GHG concentrations and the consequential effects of global climate change.

Initial research into the Building Energy Efficiency Strategy examined the potential for reducing GHG emissions associated with energy used to light, heat, and cool new and old buildings in the residential and commercial sectors. According to discussions at the MCCP Forum I, stakeholders were interest in revising state building codes with a focus on increasing energy efficiency through mandatory codes rather than through voluntary programs, such as Leadership in Energy and Environmental Design (LEED) or Energy Star. As with all of the selected policies, the MCCP team analyzed methods to reduce energy use and determine the associated GHG-emission reductions and economic effects of implementing the strategy.

5.1.1 Strategy Context and Background

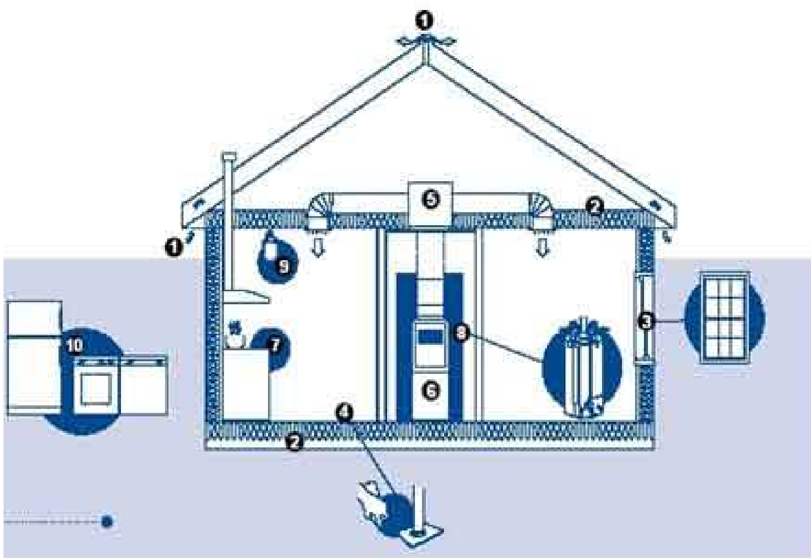
The following is an explanation of how the MCCP team moved from the building energy efficiency strategy and concluded with two mandatory residential energy code policies. The MCCP team could have analyzed many potential policies. To narrow the possible policy options, the MCCP team focused on three areas:

1. Increase Energy Code Stringency
    a. *Mandatory Residential Codes*
    b. *Mandatory Commercial Codes*
    c. *Promoting LEED and Energy Star Standards*
2. Improve Code Compliance
    a. *Training of Architects, Engineers, Contractors, and Inspectors*
    b. *Tighter Enforcement of Codes*
        i. Review plans
        ii. Review products, material, and equipment specifications
        iii. Review of tests, certification reports, and product listings
        iv. Review of supporting calculations
        v. Inspection of buildings and building systems during construction
        vi. Evaluation of material substituted in the field
        vii. Inspection immediately prior to occupancy[143]

3. Provide Financial Incentives for Energy Efficiency
    a. *Provide Energy Audits*
    b. *Provide Energy Efficient Mortgages and Energy Improvement Projects*
    c. *Support Utility Demand Side Management Programs*
    d. *Low-Income Assistance Programs-Weatherization*[lx]
    e. *State Government Building Requirements*

The MCCP team wanted to focus on a building policy that could be modeled in terms of its GHG-emission reduction potential and economic effects, and was reasonable considering what other states had implemented. After researching the three listed areas and with the support of MCCP stakeholders, the MCCP team determined that a new mandatory residential code met the policy-modeling criteria. For more information on commercial codes, energy code compliance, and incentive programs, see Appendix J-1.

The aspects of residential buildings considered for further analysis included: the building envelope, heating and cooling appliances, energy code compliance, inspector training programs, and funding for low-income residents to conduct upgrades. Figure 5.1 shows the areas and elements of a house in which opportunities exist to increase energy efficiency. Residential codes only affect the building envelope, which numbers 1-5 in Figure 5.1 show.



1. roof
2. ceiling
3. walls
4. floor
5. basement
6. furnace
7. appliances
8. water heater
9. lighting

Figure 5.1. House Energy-Efficiency Potential[144]

5.1.2 Residential Building Codes

Before describing the specific MCCP policies, it is important to understand Michigan's residential energy codes in the context of the building sector and international and federal code models. According to US Census Bureau 2000 data, Michigan's population was 9,938,444 people, with 4,331,986 housing units.

[lx]Weatherization can include weather stripping and caulking around doors and windows; cleaning, testing, repairs, or replacement of heating systems; replacement or repair of storm windows; replacement or repair of broken windows and/or outside doors; and the addition of insulation to walls or ceilings.

Since 2000, there has been an increase of 5.6% in new residential structures (one-unit homes to large apartment buildings), or approximately 250,000 new units. The mean value of owner-occupied units in 2000 was $115,600. For perspective, permits were authorized for 46,989 such units in 2005. As of 2002, construction work contributed $36 billion to Michigan's economy: $22.5 billion for new construction; $8 billion for additions, alterations, and/or reconstruction; and $5 million for maintenance and repairs. The construction sector employs 220,000 people with earnings of $8 billion, of which 160,000 sector employees are construction workers, earning $5.6 billion.[145] These statistics are affected by building codes and, in turn, affect the construction sector and new home starts.

In 2001, the US Department of Energy (DOE) required states to certify that they had considered updating their residential building codes to International Energy Conservation Code (IECC) 2000 standards. In addition, no new single-family or multi-family low-rise residential buildings were to be built to standards less stringent than the DOE-developed Model Energy Codes (MEC) 1993. Currently Michigan is out of compliance, as it has not certified that it considered 2000 IECC and has not met the equivalent of MEC 1993.[146] Enforcement actions have not been taken to address Michigan's non-compliance, but the state could lose DOE support for energy-efficiency programs in the future. Most states have considered updating their codes, even if they have not implemented IECC 2000. By 2005, 12 states had updated all or portions of their energy codes to IECC 2004 standards[147] and 19 states had adopted the IECC 2003 standards. Of the 46 states with residential energy building codes, Michigan is on par with six other states, all of which have the weakest standards in the country. The code status for all 50 states is depicted in Figure 5.2.[lxi]

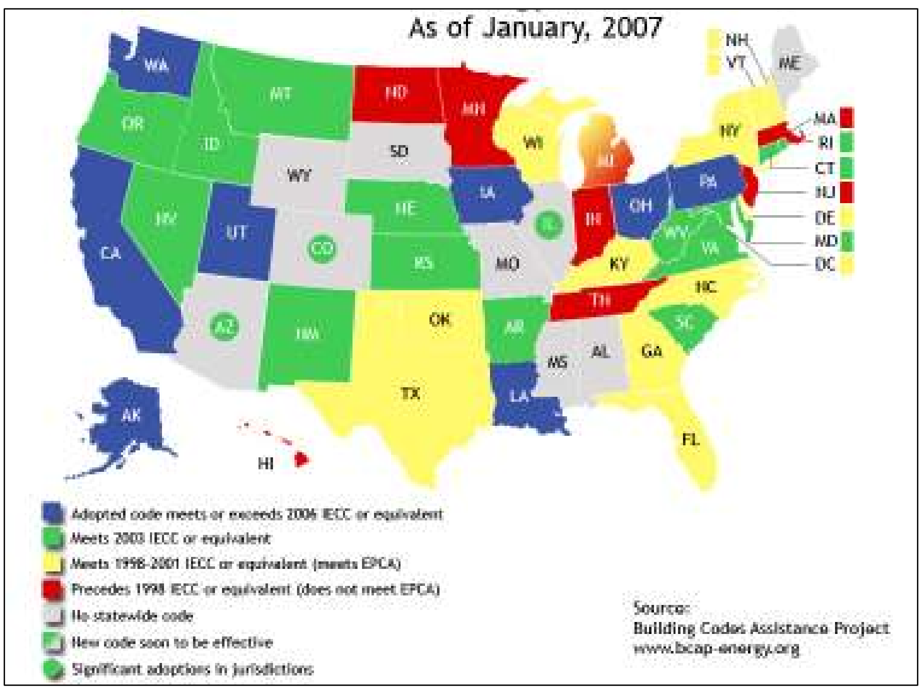


Figure 5.2 Residential State Energy Code Status [148]

[lxi] Michigan's color is mixed red and yellow because a proposed code is currently held up in court. The old code is weaker than IECC 1998, but the new code would fulfill the criteria to be equivalent to 1998-2001 IECC.

5.1.3 Current Michigan Code

In Michigan, two state agencies have jurisdiction over building energy issues. Energy standards are determined by the Michigan Uniform Energy Code (MUEC), which falls under the purview of the Michigan Bureau of Construction Codes and Fire Safety (BCC). Energy savings and efficiency programs are run by the Energy Office, a division of the Department of Labor and Economic Growth. As previously stated, the current MUEC 1999 is less stringent than the MEC 1993. According to the legislation enacting the MUEC, the building codes are supposed to be reviewed every three years.[149] They were most recently reviewed in 2004, but have not been updated. The state BCC proposed updating the code to the International Residential Code (IRC) 2004, similar to the IECC 2000 code for residential buildings. However, the Michigan Homebuilders Association filed a lawsuit challenging the administrative implementation of the new code in the absence of explicit legislative authorization. The case has not yet been resolved.

In 2004, the Michigan Energy Office produced a report explaining to the public the effects of the proposed IRC 2004, which average a net present value savings of $1,000 per homeowner. The report modeled required higher R-values[lxii] for wall assemblies, windows and openings, roof/ceiling assemblies, floors over unconditioned spaces, slab on grade construction, crawl spaces, walls, and insulation, and took into account climate differences across the state. It also provided information on how the state could have greater energy efficiency through compliance with other standards, such as IECC 2000, Energy Star, or the federal Home Energy Rating Service (HERS) program.[150] (See Appendix J-1 for program descriptions.)

According to energy efficiency advocates, Michigan has missed opportunities to realize energy savings through energy efficient buildings because the codes are out of date. For example, as a result of the current codes and continued building in this sector, from 1990 to 2002, Michigan electricity sales to the residential sector (in megawatt hours) increased by 36%.[151] Despite economic hardship and a slowing housing market, without implementing significant policy measures, it is expected that residential building energy consumption will continue to increase.

5.1.4 Modeled Policies

After discussions with stakeholders and further background research, the MCCP team decided to focus on residential building codes. The final modeled policy and scenarios are as follows:

Mandate an increase in R-values as required and specified by the Residential Michigan Uniform Energy Code, for all new single-family residences.

- IRC 2004: Equivalent to the International Residential Code 2004.
- MCCP 2006: Based on a combination of IECC 2006 and the DOE Insulation Recommendations according to climate zones.[152]

[lxii] A unit of thermal resistance used for comparing insulating values of different materials. The higher the R-Value of a material, the greater its insulating properties and the slower the heat flows through it.

Due to modeling complexity, this study addressed only a prescriptive approach for implementation and did not include performance-based standards. In addition, estimates were limited to new single-family houses, though other residential structures would be affected by the residential energy code.[lxiii] The current Michigan Uniform Energy Code (MUEC) 1999 was used to define the business-as-usual (BAU) case.

5.2 Greenhouse Gas Model

5.2.1 GHG Emission Reduction Potential

In assessing GHG emissions from the state's energy system, the MCCP analysis utilizes US Department of Energy's Energy Information Administration data, state utility electricity production data, and the same EPA emission factors and global warming potentials as the Michigan GHG Inventory.[153]

The model for the building code policy is designed to estimate GHG emission reductions from various housing configurations based on two primary parameters: regional climate and house square footage for each of the three building energy code policy scenarios. The MCCP team modeled 27 different house configurations based on these parameters. Counties were used as the borders for the climate regions, which were roughly equivalent to IECC 2006 regions 5, 6, and 7 (see Appendix J-2 for each county's assigned climate region).[lxiv, 154] The three house sizes were selected based on the census data of the average small, medium, and large homes built in the state over the past five years (see Appendix J-3 for the percentages of average sq. ft. size). House sizes of 1,200, 2,200, and 3,500 sq. ft. were determined to be the most representative for new house sizes built in Michigan.[155]

These house configurations and climates where then used with each of the three different building codes policies. The MCCP team compared three different codes: the current residential building code, MUEC 1999; the proposed code currently under litigation, similar to the IRC 2004; and a more stringent code, MCCP Prescriptive 2006 (see Table 4.1 for corresponding R-values).[156] The MCCP team used the Home Energy Saver (HES) model developed by Lawrence Berkley National Labs to determine each house's heating and cooling energy use estimates. Appendix J-4 provides a detailed breakdown of the primary inputs into the HES model, including specifications for house location, house size, insulation R-values, weather stripping, and duct sealing.

[lxiii]Building Code Revisions apply to some reconstructed or remodeled homes depending on the percentage of the house affected.

[lxiv]Generally, Region 5 is the lower half of mainland Michigan, Region 6 is the upper half, and Region 7 is the Upper Peninsula.

Table 5.1. R-Values for Michigan Residential Energy Code.

	Current MUEC 1999	Proposed IRC 2004	Proposed MCCP 2006
Walls			
Climate Zone 1	R-13	R-21	R-21
Climate Zone 2	R-15	R-21	R-26
Climate Zone 3	R-19	R-21	R-26
Windows (U values)			
Climate Zone 1	U 0.4-0.5	U 0.35	U 0.35
Climate Zone 2	U 0.4-0.5	U 0.35	U 0.35
Climate Zone 3	U 0.4-0.5	U 0.35	U 0.35
Roof/Ceiling			
Climate Zone 1	R-30	R-49	R-49
Climate Zone 2	R-38	R-49	R-49
Climate Zone 3	R-38	R-49	R-49
Floors			
Climate Zone 1	R-21	R-21	R-30
Climate Zone 2	R-30	R-21	R-30
Climate Zone 3	R-30	R-21	R-30
Basement Walls			
Climate Zone 1	R-5	R-11	R-11
Climate Zone 2	R-5	R-11	R-11
Climate Zone 3	R-5	R-19	R-19

To determine the full GHG reductions from this policy, the MCCP team needed to determine the number of new homes that would be affected by the policy each year. The total number of new home builds each year, 41,212, was determined based on Michigan new single family home permit data for each county from 2001-2005 and averaged over the five years as shown in Appendix J-2. Total new home builds for each configuration type were calculated using a weighted average distribution of the number of new home builds in the state in each climate region for a particular sized house (Table 5.2).

Table 5.2. Number of Homes per Configuration.

Climate Region	Sq. Feet	approx % homes	# of homes
Climate 5	1200	4.1	1,726
Climate 5	2200	61.3	25,890
Climate 5	3500	16.4	6,904
Climate 6	1200	0.8	318
Climate 6	2200	11.3	4,768
Climate 6	3500	0.6	268
Climate 7	1200	0.2	67
Climate 7	2200	2.4	1,004
Climate 7	3500	0.6	268
Total			41,212

The output of the HSE model was electricity usage for cooling and heating measured in kilowatts-hours (kWh) and natural gas for heating measured in therms. The HSE model broke down the kWh and therms used for heating and cooling the home in comparison to lighting and appliances, and the MCCP team was able to determine the amount of energy affected by the building codes. The kWh and therms used by each house configuration was multiplied by the corresponding number of homes (from Table 5.2). The MCCP team then took the net kWh and therms of IRC 2004 and the MUEC 1999 codes and the MCCP 2006 and the MUEC 1999 codes (See Appendix J-5 for these calculations). Transmission and distribution losses and conversion efficiencies of the various fuels were calculated to determine the total amount of kWh and therms generated.

1. Transmission and distribution losses of 9%.[157]
2. Conversion efficiencies of electricity generation from various fuels from EPA data (coal = 0.379, natural gas = 0.379, and oil= 0.362; home furnaces included in residential natural gas emission factors).[158]

The net energy reduction from the proposed codes and the existing code represent a reduction of new BAU fossil fuel energy supply in the state, and is assumed in the modeling of the renewable portfolio standard and appliance policies.[lxv] In determining where the reductions came from, the MCCP modeled assumed that rather than taking current generation off the grid, the policy would displace new energy development in a ratio of 88% coal and 12% natural gas for electricity generation and 100% natural gas for heating.[159] The next step was to use the state fuel data to determine how much of each fuel type contributed to the kWh. For residential heating, the fuel mix included primarily natural gas (78%) and also wood, electricity, propane, coal, and solar, but primarily consisted of natural gas (see Appendix J-6 for exact breakdown).

[lxv] It was assumed that new generation would be either coal or natural gas and according to recently added generation in MI and other states. Note that since the emissions calculations were done strictly at the point of generation (rather than the full life cycle), it assumed zero GHG emissions for all renewable energy sources, including biomass and wood.

For each fuel, the energy savings were converted from kWh and Therms into British Thermal Units (BTUs). The model then calculated GHG emissions by multiplying the net energy savings in BTUs by GHG emission factors (see Table 5.3 and 5.4). Then, the Global Warming Potential of each of the GHG emissions was factored in: CO2: 1, N_2O: 310, and CH_4: 21. The final step was to convert pounds (lbs) of GHG to million metric tons of carbon equivalent (MMTCE).

Table 5.3. Emission Factors for Electricity at Point of Generation.[160]

Fuel Type	CO_2	CH_4	N_2O
Coal	57.29 lbsC/MBtu	.001 MtonCH_4/BBtu	.001 MtonN_2O/BBtu
Natural Gas	31.91 lbsC/Mbtu	.001 MtonCH_4/BBtu	9x10^5 MtonN_2O /BBtu

Table 5.4. Emission Factors for Natural Gas Home Heating.

Fuel Type	CO_2	CH_4	N_2O
Natural Gas	31.91 lbsC/Mbtu	.0047 MtonCH_4/BBtu	.0037 MtonN_2O/BBtu

5.3 Economic Effects Model

The economic effects of the residential building code policy were determined using a combination of the Energy 2020 model and REMI Inc.'s Policy Insight model. The electricity use measured in kWh and natural gas for home heating unit Therms were converted into Btus as the input for the Energy 2020 model. Then the Energy 2020 outputs in economic units were entered into the REMI model. The process was iterative to ensure that the results of both models matched in terms of results of the impacts on the different sectors (household, utility, etc), the Gross State Product, and jobs in Michigan. (See Appendix J-7 for economic impacts by sector. Figure 5.3 represents these impacts graphically.[lxvi])

[lxvi]The Production Costs for utilities were affected by the general increase in demand across the state requiring a new coal plant to be added, thus increasing costs for the utility in 2021.

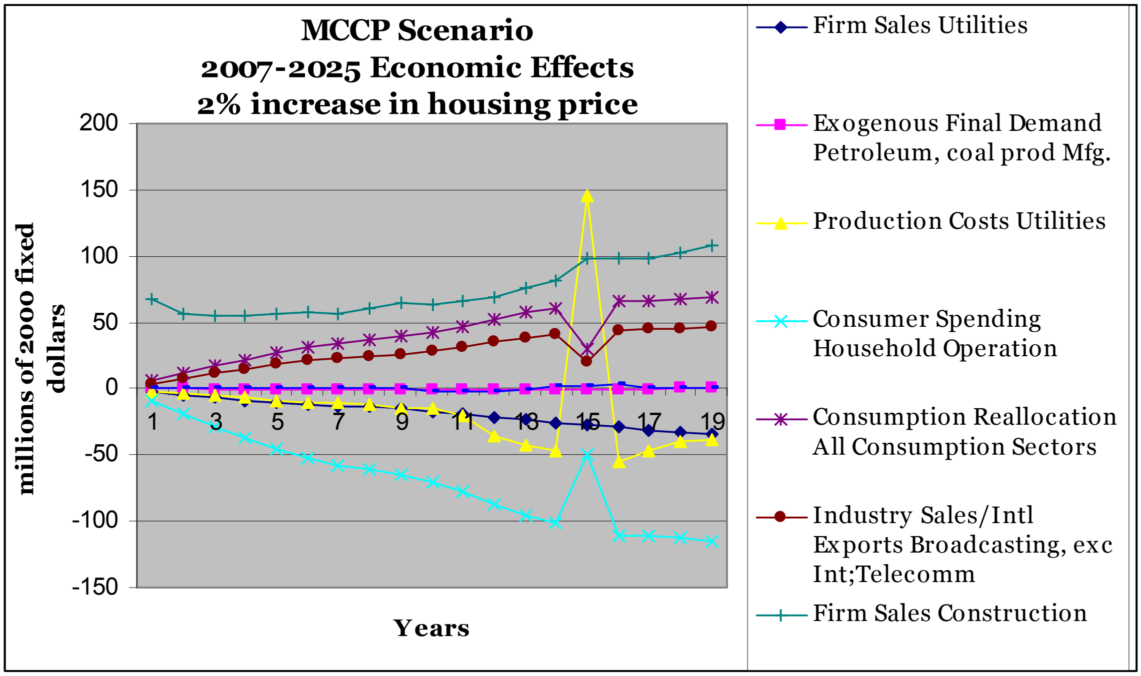


Figure 5.3. MCCP 2006 Code Economic Sector Effects.

5.3.1 Key Inputs and Rationale

Construction Sector

The total cost estimated in the Home Energy Saver model only accounted for the extra materials cost and the energy savings, not the full costs and savings to the construction sector due to the higher codes. Therefore, the team used a proxy to determine the impact. As home owners can apply for better mortgage rates or purchase a 2% more costly home through Energy efficient mortgages, the analysis incorporated an estimated increase of 2% in housing price due to higher costs for compliance with the IRC 2004 and MCCP 2006 codes.[lxvii] The MCCP team also assumed 100% of that cost would be passed onto the customer. In this case, the REMI model input increased the share of the Consumer Price for Housing, causing an increase in the amount of Firm Sales for Construction reflecting the higher home prices.

Households

The reduction in electricity and heating bills was included and the savings were moved to other parts of consumer spending. Energy 2020 determined that Consumer Spending for Household Operation was decreased as spending for electricity was lower because of more efficient homes. REMI then reallocated 60% of the savings from Consumer Spending for Household Operations to all

[lxvii]Energy Star allows for 2% stretch for debt-to-equity for energy-star qualified homes, allowing a person to buy a more expensive greener home more easily. Also, the Michigan study on the cost of energy efficiency upgrades was approximately 1% (~$1,000 on a $100,000 home). On the other hand, the HBA estimated a 6% increase in home price due to the upgrades.

other Consumption sectors (consumer spending categories). REMI reallocated the other 40% of the consumer savings to the Industry Sales/International Exports for Broadcasting because spending on Broadcasting is a major portion of this Consumer Spending category and is not affected by the policy.

<u>Utility Sector</u>

Energy 2020 inputs into REMI caused a decrease in the amount of Firm Sales for Utilities because of the decreased demand for electricity due to more efficient homes. This also led to a decreased amount of Exogenous Final Demand for Petroleum, Coal Product Manufacturing--a decrease in coal purchases by utilities due to decreased electricity demand. The Utility Sector also had a decrease in the amount of Production Costs to show the decreased amount of capital expansion needed due to decreased electricity demand. REMI used production costs instead of capital costs, as the model assumes that a change in capital costs is due to a change in the price of capital, and then readjusts the production function to account for this change. The production cost variable does not have this issue. Energy 2020 decreased the amount of Firm Sales for Construction to the Electricity sector to account for the reduced capital expansion due to decreased electricity demands. It also reduced the amount of Exogenous Final Demand for Electrical Equipment Manufacturing to show the decrease in Machinery purchased by the utility sector.

5.3.2 Variable Impacts

- The increased amount of Firm Sales for Construction has a positive impact on employment and gross state product.
- The shift in consumer spending has positive impact on employment and gross state product.
- The increase in home prices has a negative impact on employment and gross state product.
- The reduction in Exogenous Final Demand for Petroleum, Coal Product Manufacturing has negative impacts on employment and gross state product.
- The decreased amount of Firm Sales for the Utility Sector negatively impacts employment and gross state product.
- The decrease in Production Costs for the Utility Sector positively impacts employment and gross state product.
- The decrease in Exogenous Final Demand for Electrical Equipment Manufacturing has negative impact on employment and gross state product.

<u>Economic Sectors Impacted</u>

The sectors that are positively impacted by this policy include the Construction sector (which is broader than just the home builders); Retail Trade; Information and Finance; services such as Health Care, Accommodations and Food Services; and Educational Services (due to increased consumer spending in these areas).

The Utility sector is the primary sector that is negatively impacted by the policy.

5.4 Results and Discussion

The following section presents the results of the mandatory residential building code policy along with considerations and implications of pursing such a policy. In the MCCP 2006 scenario (based on IECC 2006 and Energy Department Insulation recommendations), by 2025 the policy would result in 5.51 MMTCE reductions in GHG with and an increase of $352 million in the Michigan economy. See Table 5.5 for the full set of results.

Table 5.5. Cumulative GHG and Economic Model Results.

Policy	*2015*	*2025*
MMTCE Reductions		
International Residential Code (2004)	1.01	4.18
Michigan at a Climate Crossroads Proposal	1.35	5.51
Change in Gross State Product (millions of 2000 dollars)		
International Residential Code (2004)	155	244
Michigan at a Climate Crossroads Proposal	327	539
Change in Employment		
International Residential Code (2004)	2460	3460
Michigan at a Climate Crossroads Proposal	4370	6440

Presented results reflect net changes from a business-as-usual case starting January 1, 2007, through 2025.

5.4.1 GHG Modeling Results

Strictly enforced building codes as per the IRC policy result in savings of 5,100,000 kWh and 10,700,000 therms, and reductions up to 3.85 MMTCE by 2025. The MCCP Policy reduced energy use by 6,700,000 kWh and 13,500,000 therms resulting in 5.51 MMTCE of savings. Both of the building code energy efficiency scenarios reduced GHG emissions in the state. By using less electricity and natural gas for heating and cooling, new generating facilities were displaced and, thus, fewer GHG emissions were released.

5.4.2 Economic Modeling Results

Some stakeholders (see Appendix J-8 for a list of MCCP stakeholders' organizations involved in the development of the Building Codes policies) were surprised to find that the net economic effects of both of these policies created positive economic returns of both jobs and Gross State Product. Some industries gained from the policy (primarily the construction sector) while others did not fair as well (primarily, the utility sector). See Figures 5.4 and 5.5 for the Average Annual Impact on GSP and Job-Years.

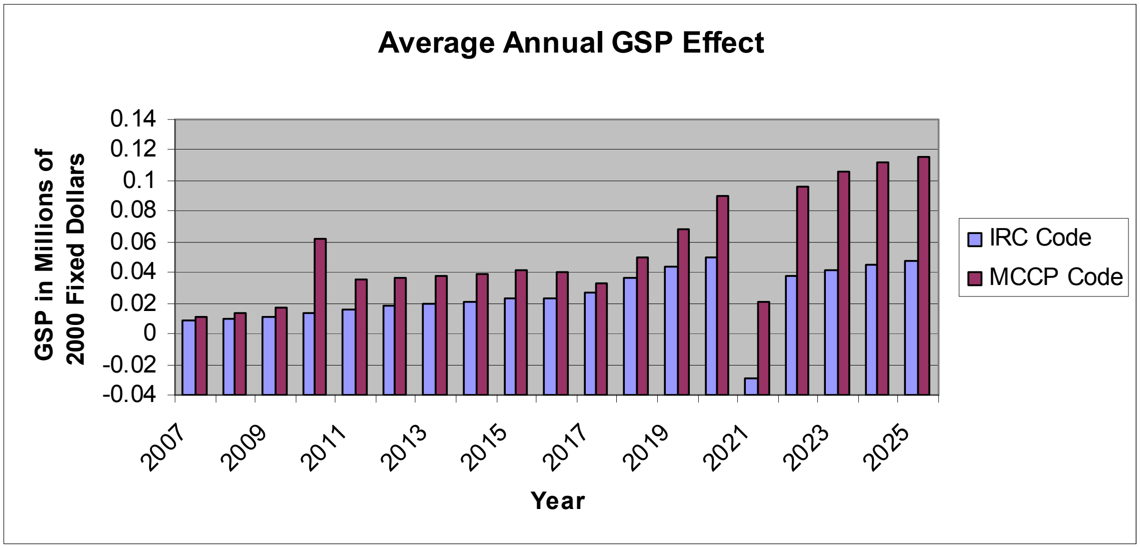


Figure 5.4. Average Annual Effect of IRC 2004and MCCP 2006 Codes on GSP.

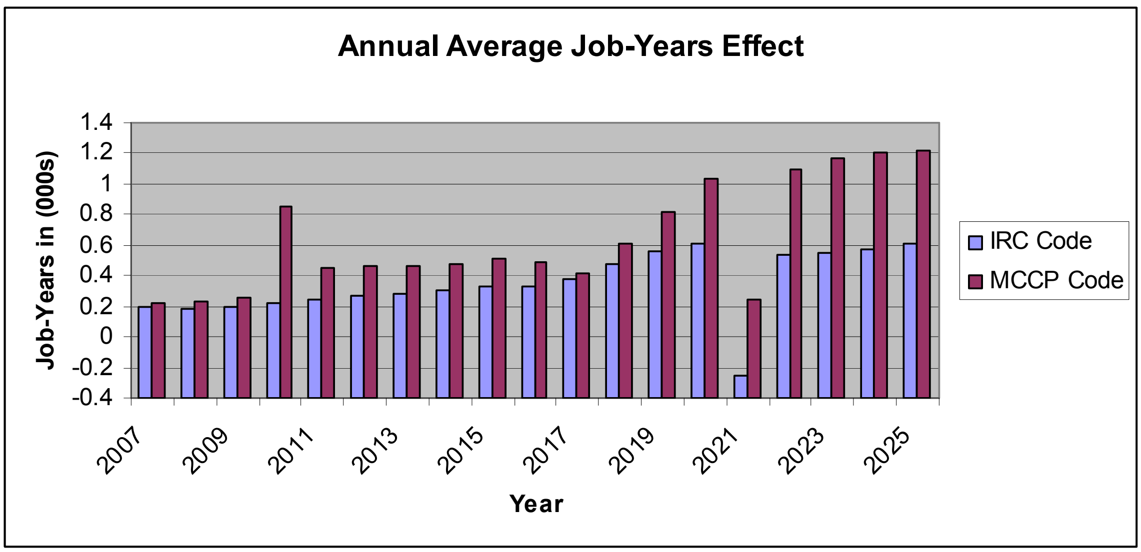


Figure 5.5. Average Annual Effect of IRC 2004 and MCCP 2006 Codes on Job-Years.

5.4.3 Summary of Findings and Considerations

As with any modeling, the results provide only a partial picture of the complex impacts of increasing R-value for residential buildings. A couple of issues must be considered to understand the full potential effects of implementation. Some issues increase the positive impact, while others lessen it.

The positive economic effects could be reduced under different scenarios. For example, the MCCP Team assumed that the 2% increase in home price would not affect home buyers' ability to purchase because of their ability to utilize lower home mortgage rates through energy efficiency lenders. Also, the Energy 2020 model assumes that codes will be implemented perfectly and actual construction will follow the plans. An additional reduction of the policy's initial efficacy is a learning curve that affects the industry when new materials or methods are used. It may take time for the construction sector to have easy access to energy efficiency materials and knowledgeable contractors in order to keep cost of compliance with the new codes low. However, based on other states, such as Iowa, after a year or two, the changes become commonplace.

On the other hand, positive emission and economic results may occur beyond those shown in the model. One of the primary omissions is that the time scale used during the modeling does not fully cover the lifespan of a house. As all model timeframes in the MCCP report concluded in 2025 and new homes last longer than 17 years, more savings as a result of the home energy efficiency improvement will accrue. Also, these models were only able to account for new house construction in the state. Renovations, which would be subject to codes, were not taken into account, indicating potential benefits are not fully captured in this study. Another benefit might occur if technology improves and insulation was less costly and/or more efficient, or if a smaller furnace could be used.

Other issues are not covered in this model, but they do need to be considered before implementing any new building code policy. As beneficial as implementing new energy codes may be, they do not address the energy efficiency of the current housing stock. The majority of homes and buildings and are generally even less efficient than the current code prescribes. In addition, the HES model could only build homes based on a prescriptive code, and there is a debate in the field as to whether performance based codes would provide even more results. However, with the lack of flexible housing models available, the MCCP team was unable to model homes built to performance code standards.

In conclusion, Michigan Building Codes will affect an average of 40,000 new houses' building envelopes and their required R-values built each year. In addition, the policy will create savings for those remodeling projects that fall under the code. The model results are intuitive for the GHG emission reductions, as with lower energy demands, less energy will be produced and fewer GHGs emitted. The modeling also demonstrates the positive effect of the codes on GSP and jobs. The economic results will benefit the consumers through lower utility bills due to lower usage, but the homes will have higher upfront costs. Overall this policy falls in the middle of the MCCP policy in both GHG and economic criteria. The MCCP Team concluded that this policy may not provide the most impact, but definitely provides a positive one.

6. Mass Transit Enhancement and Development

6A. Fuel-Switching

6A.1 Introduction

According to the *Michigan Greenhouse Gas Inventory 1990 and 2002*, the electricity generation sector accounted for 33% of total emissions in 1990 and 2002, making it the largest contributor to total greenhouse gas (GHG) emissions. The second largest contributor for both years was the transportation sector. Transportation emissions accounted for 24 percent of total GHG emissions in 1990, and 26 percent of total GHG emissions in 2002.[lxviii] Additionally, mobile combustion of fossil fuels made up the largest absolute gain in emissions over this period. The growing prevalence of less fuel-efficient vehicles, such as sport-utility vehicles and light-duty trucks, along with an increase in vehicle miles traveled (VMT) per capita, likely explains much of the rise in emissions from mobile combustion.[161] Included in this rise of mobile GHG emissions is the combustion of fossil fuels from mass transit buses. For comparison, the US Department of Energy (DOE) estimates that personal trucks use 4,057 Btu per passenger-mile, while transit buses use 4,127 Btu per passenger-mile. Increasing the load factor for transit buses could lower this number significantly.[162]

6A.2 Policy Background

National Transportation Inventory

According to the US Environmental Protection Agency (EPA) *GHG Emissions from the Transportation Sector 1990- 2003* report, buses (all types) produced approximately 0.5 percent of total national transportation GHG emissions and 0.6 percent of on-road emissions in 2003. GHG emissions for all types of buses increased about 15 percent from 1990. Best estimates suggest that intra-city transit buses produced about 46 percent of total bus GHGs in 2003, followed by school buses at 38 percent, and intercity buses at 16 percent. At the national level, transit bus[lxix] VMT increased 45 percent between 1990 and 2002, growing from 1.67 billion to 2.43 billion vehicle miles. The number of school buses in service was estimated to have risen by 21 percent over the same timeframe, increasing from approximately 508,000 to 617,067. Intercity bus passenger-miles and energy use also increased over this period.[163] Most of the buses identified in the report utilized diesel fuel while a small number utilized gasoline and alternative fuels. During the period of this report, alternative fuels (biodiesel, ethanol, methanol, compressed natural gas, and liquefied natural gas) began to play an increased role in bus travel. For example, between 1990 and 2003, VMT for all types of buses running on alternative fuels increased by 273 percent.[164]

Michigan Inventory

As previously mentioned, the Michigan GHG Inventory reported that the transportation sector was the second largest contributor of GHG emissions in the state, for 1990 and 2002. Transportation emissions accounted for 24 percent of total GHG emissions in

[lxviii] Inventory emissions were calculated at the point of fuel combustion. Emissions related to the production of fuel were not included. i.e., a life cycle approach was not used.
[lxix] Includes trolley buses.

1990, and 26 percent of total GHG emissions in 2002.[lxx] The Michigan GHG Inventory breaks down emissions by fuel and vehicle type, but does not specifically report the fuel usage and corresponding emissions for mass transit buses. Heavy-duty diesel vehicle (HDDV) emissions were reported at 2,212 MTCE (4.7% share by vehicle type) in 1990, and 2,349 MTCE (6.6% share by vehicle type) in 2002, although a further breakdown of HDDVs according to vehicle type was not included. The Michigan GHG Inventory does not report emissions from alternative fuels usage.

Forum I

At Forum I, the Mass Transportation Enhancement and Development strategy was ranked number six. In the afternoon discussions, stakeholders voiced concerns about the need for significant improvements in Michigan's mass transportation system. The southeast region of the state is in need of extensive transit system improvements. The group mostly agreed that there was a problem with the current state of mass transit; however, the solution was not particularly obvious to the group. Some suggestions for further analysis included a new type of bus system such as bus rapid transit, use of Michigan-grown alternative fuels in transportation vehicles, and development of an ultra-light personal mass transit system.

6A.2.1 Related Legislation and Initiatives

To identify specific policy measures that the state could pursue, the MCCP team researched related legislation and initiatives from across the county. The following is a summary of this research.

The President's Executive Order (EO) 13149

Signed in April 2000, this EO requires federal fleets of 20 or more vehicles to consume at least 20% less petroleum by 2005. Fueling diesel vehicles with B20 would accomplish this goal without engine modifications.[165]

New York: Clean-Fueled Bus Program

The Clean-Fueled Bus Program is administered by the New York State Energy Research and Development Authority (NYSERDA). The program provides funding for the incremental cost of a clean-fueled bus (primarily CNG buses) over a diesel bus. Eligible participants include transit authorities, state agencies, state universities, municipalities, and school bus fleets. Applications are evaluated primarily on emission reductions per program dollar, whether the bus will operate in a "non-attainment" area (an area that has failed to attain one or more national ambient air-quality standards), and the volume of petroleum displaced.[166]

[lxx]Inventory emissions were calculated at the point of fuel combustion. Emissions related to the production of fuel were not included. i.e., a life cycle approach was not used.

Minnesota: B2 Mandate

In March 2002, Minnesota enacted the nation's first biodiesel mandate requiring nearly all diesel fuel sold in the state to contain at least 2 percent biodiesel by 2005. On at least one occasion, the state has temporarily suspended the B2 mandate due to quality issues with biodiesel.

Michigan: Fuel-Switching

Many school systems, companies, and agencies have switched from diesel fuel to various biodiesel blends. Examples include the Michigan Department of Management and Budget, University of Michigan Transportation Services, Ann Arbor Transit Authority, Pictured Rocks National Lake Shore, St. Johns Public Schools, Ithaca Public Schools, Zeeland Public Schools, and Consumer Energy.[167]

Michigan Biodiesel Processing Plants

Two biodiesel processing plants are currently in operation in Michigan. In August 2006, Ag Solutions Inc. opened a plant in Gladstone that has a capacity of at least 5 million gallon per year. Another plant in Bangor (with a capacity of 10 million gallons per year) opened in January 2007. Additional plants are under serious consideration for development including: Michigan Biofuels LLC in Belleville, Biodiesel Industries LLC in Detroit, and Milan Biodiesel Company in Milan Monroe Co. (all three plants would be in southeast Michigan).

6A.3 Moving from Strategy to Policy

The MCCP team considered the stakeholders' interest in a Mass Transportation Enhancement and Development policy and the background research findings, as summarized above, and identified the Southeast Michigan Council of Governments' (SEMCOG) Ann Arbor to Detroit Rapid Transit Study Project (RTSP) as a potential candidate for further analysis. After communications with SEMCOG Transportation Planners, the MCCP team planned to focus on modeling the GHG emissions because they were not included as part of the study. SEMCOG already had plans to use the REMI model for economic analysis.

However, due to delays in the SEMCOG study results, the MCCP team was unable to model a mass transit enhancement and development policy and a ground-up independent analysis of such a mass transit solution was not within the scope of the MCCP. The MCCP team decided to focus on mass transportation enhancement instead of modeling an entirely new transportation development. Phase I research results pointed toward an increase in the use of alternative fuels in mass transit systems. As a result, the MCCP team designated an alternative fuel strategy for mass transit systems as the new mass transit enhancement and development policy for GHG and economic analysis.

Ultimately, the MCCP team defined a mandatory fuel-switching policy aimed at all urban mass transit authorities. The policy does not include an incentive to spur the fuel-switch, but relies on the fact that urban transit authorities receive funding from the state, and that the state has the authority to require such a policy. The purpose of this policy was to demonstrate the GHG reduction potential and economic effects of a small scale fuel-switch. The policy was defined as follows:

A mandatory use of biodiesel (B20) in all diesel-powered urban mass transit buses.

- In 2007, all urban mass transportation authorities receiving state funding would be required to use Michigan-produced B20 in all diesel-powered public transit buses.
- Gasoline-powered buses, compressed natural gas-powered buses, and demand response vehicles are not included in the policy. [lxxi]

For the purpose of this report, the MCCP team defined diesel as on-highway, low-sulfur diesel made from crude oil.[lxxii] Biodiesel refers to any diesel fuel substitute derived from biomass, such as rapeseed or soybeans.[lxxiii,168] Blends of biodiesel and petroleum are designated with the letter "B" followed by the volumetric percentage of biodiesel in the blend. For example, B20 contains 20 percent biodiesel and 80 percent petroleum diesel; B100 is pure biodiesel.[169] In this report, biodiesel refers to B20. Pure biodiesel, or other volumetric percentages, are specified when necessary. A B20 blend was chosen for this policy because higher blends might not work well under winter conditions.

Further parameters of the policy include the construction of an additional 5 million gallon per year biodiesel refinery plant that uses Michigan-produced soybeans as feedstock to supply the biodiesel required to fulfill the policy. Other policies concerning alternative fuel sources could have been modeled. Policies covering engine warranty issues for buses or the transfer of pumps to biodiesel also could have been modeled. Biodiesel from soybeans is manufactured by a trans-esterification reaction between the oil and methanol in the presence of a catalyst such as potassium hydroxide or sodium methoxide.

The chemical reaction is as follows[170]:

Oil or Fat	+	Alcohol	=	Ester (Biodiesel)	+	Glycerin
100 pounds		*10 pounds*		*100 pounds*		*10 pounds*

The benefits of using biodiesel are substantial. Biodiesel can:

- reduce foreign petroleum consumption.
- be used in unmodified diesel engines, unlike other alternative fuels, (e.g. ethanol and compressed natural gas (CNG).

[lxxi]Demand response vehicles do not follow a fixed route and transport passengers according to their requests; often called "Dial-a-Ride."

[lxxii]Tougher restrictions for on-highway diesel fuel have been set by the EPA as part of its enforcement of the 1990 Clean Air Act Amendments. On-highway diesel must now meet lower sulfur content limits, an order of magnitude lower than previously allowed. However, low-sulfur diesel, instead of the ultra-low sulfur diesel, was used in this report because the DOE and US Department of Agriculture (USDA) well-to-wheel emission factors used for modeling were given for low-sulfur diesel.

[lxxiii]Biodiesel can be made by chemically combining any agricultural oil or fat with an alcohol such as methanol or ethanol. Soybean oil serves as the primary feedstock for biodiesel in the United States, as this country is the world's largest producer of soybean oil, whereas rapeseed oil is the preferred feedstock in Europe. Recycled cooking oil from restaurants, yellow grease, and animal fats can also be used to produce biodiesel (DOE/USDA 1998).

- benefit US domestic economy. Michigan produced 85,140 thousand bushels of soybeans in 2006[lxxiv] [171] (compared to 3,203,908 thousand bushels nationally, 2.657%).[172]
- biodegrade.
- be made from renewable resources.
- improve fuel lubricity.
- reduce greenhouse gas emissions.
- reduce particulate matter (PM), carbon monoxide (CO), hydrocarbons, SO_x and NO_x emissions.[173] [174]
- be safer to handle, as it has a higher flashpoint than diesel.
- be used without building new refueling infrastructure.
- perform similar to diesel fuel. The horsepower, torque, acceleration, and cruising speed of biodiesel are comparable to diesel fuel.[175]

Concurrently, there are disadvantages of using biodiesel. Biodiesel:

- increases nitrogen oxide emissions.[lxxv]
- can lower fuel economy. The energy content per gallon of biodiesel is approximately 11 percent lower than the energy content per gallon of petroleum.[176] Vehicles running on B20 are therefore expected to achieve 2.2 percent (20 percent * 11 percent) fewer miles per gallon of fuel.[lxxvi]
- on a large scale, would require considerable use of the United States' arable area.
- loosens deposits in vehicular systems formed by petroleum diesel that can migrate and clog fuel lines and filters. [177]
- may be incompatible with seals used in the fuel systems of older vehicles and machinery, requiring them to be replaced.
- has higher cloud and pour points than diesel.[lxxvii] Biodiesel from yellow grease is worse than soybeans in this case.
- may invalidate warranties for engines and car companies.[lxxviii]

[lxxiv] 85,140 thousand bushels of soybeans can produce 11,919,600 gallons of B100 or 595,980,000 gallons of B20.

[lxxv] The increase of nitrogen oxide emissions from biodiesel is of enough concern that the National Renewable Energy Laboratory (NREL) has sponsored research to find biodiesel formations that do not increase nitrogen oxide emissions.

[lxxvi] The MCCP team assumed the same miles per gallon (mpg) for biodiesel (B20) and petroleum diesel. Energy efficiency is the percentage of the fuel's thermal energy delivered as engine output, and biodiesel has shown no significant effect in the energy efficiency of any test engine. Volumetric efficiency, a measure more familiar to most vehicle users, usually is expressed as miles traveled per gallon of fuel (Anthony Radich, 2004).

[lxxvii] Cloud point is the temperature at which wax crystals start to form and the fuel begins to look cloudy. Pour point is the temperature below which the fuel will not flow.

[lxxviii] A recent Michigan Department of Agriculture (MDA) study reported that most OEMs indicate that their engine warranties remain viable while using biodiesel blends up to B5, some even higher (MDA, 2006).

6A.4 Greenhouse Gas Modeling

6A.4.1 Modeling Methodology

The MCCP's GHG model was designed to assess the GHG emission reduction potential of a fuel-switch in mass transit buses. The model evaluates the Well-to-Wheel (WTW) GHG emissions associated with increasing biodiesel use in mass transit buses, and the associated reduction in WTW GHG emissions from displaced conventional diesel. "Well-to-Wheel" is a motor fuel life cycle analysis term referring to the complete accounting of emissions from the point of origin of the fuel (Well) through the operation of a vehicle using the fuel (Wheel). The Mass Transit Fuel-Switch GHG model accounted for GHG emissions during the modeling years of 2007 through 2025; with the policy immediately coming into effect in 2007.

The Mass Transit Fuel-Switch model compared a projected diesel and biodiesel BAU scenario for the effected mass transit agencies against a scenario in which all mass transit agencies switch to biodiesel. In establishing the BAU scenario, the MCCP team used data from the Federal Transit Administration's (FTA) primary database for statistics on the transit industry, the National Transit Database (NTD). Figure 6A-1 presents the modeled BAU fuel usage scenario.

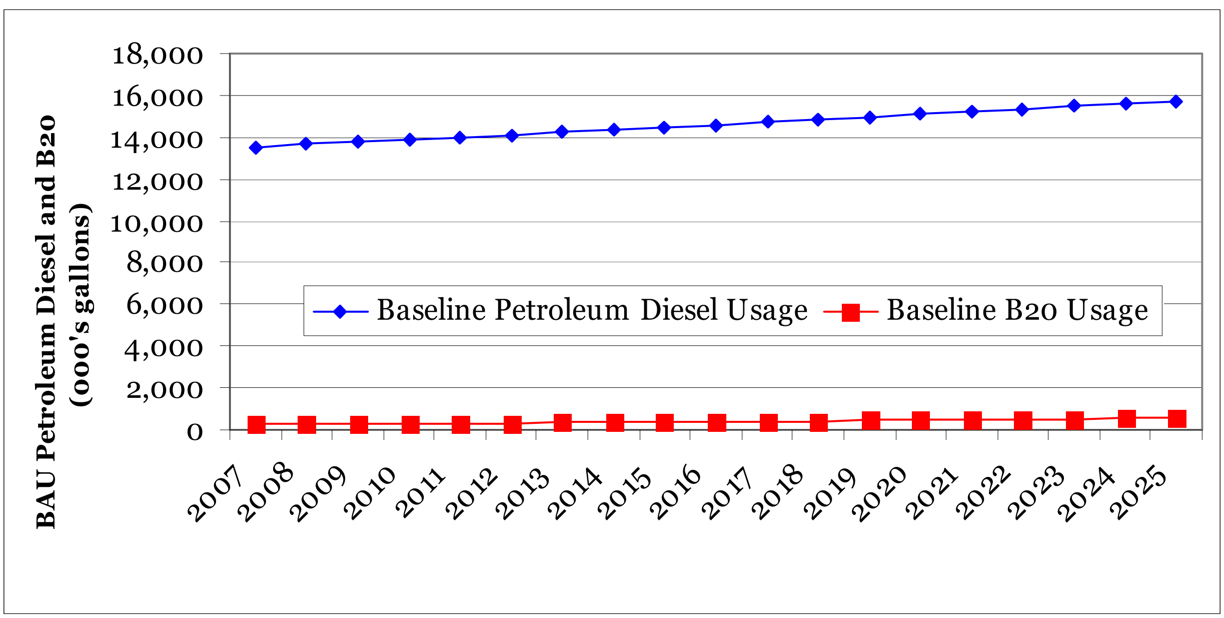


Figure 6A-1. BAU Michigan Mass Transit Bus Fuel Usage, 2007 – 2025.

Figure 6A-2 provides a simplified process flow of the Mass Transit Fuel-Switch GHG model.

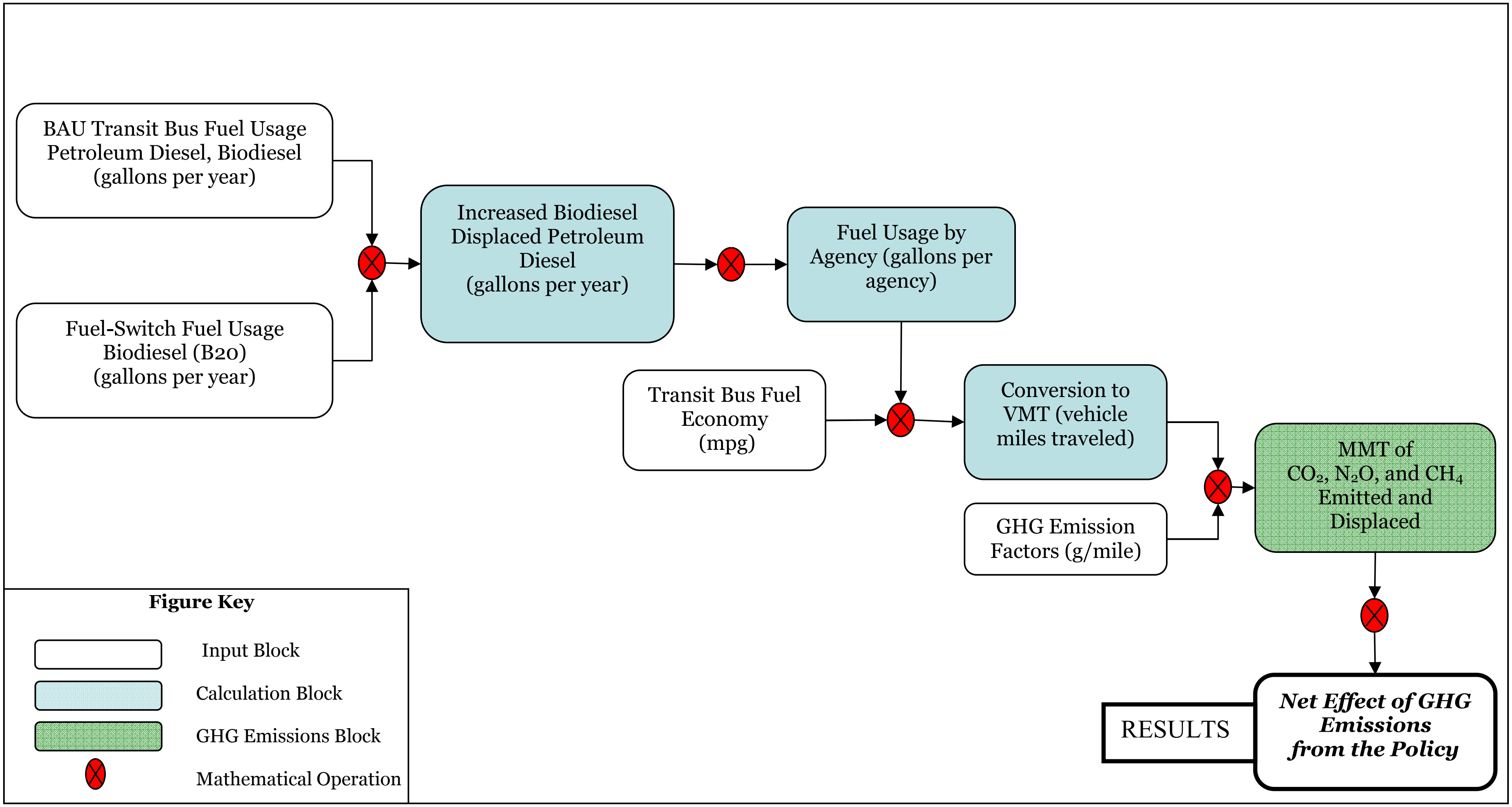


Figure 6A-2. Mass Transit Fuel-Switch GHG Model Flow Diagram.

6A.4.2 Modeling Inputs

For both the GHG and economic modeling, the MCCP team used historical fuel consumption (in gallons) data from the Federal Transit Administration's (FTA) primary database for statistics on the transit industry, the National Transit Database (NTD). Historical diesel and biodiesel fuel consumed by Michigan mass transit buses was extrapolated from the 1997-2004 annual reports (Table 6A-1 and Figure 6A-3).[lxxix] Using the 1997-2004 data, the MCCP team calculated the annual changes in fuel usage for diesel and biodiesel, and then calculated the average change in fuel usage for diesel and biodiesel. The average annual changes in diesel and biodiesel usage were then used to project fuel usage for the modeling period 2007-2025 (Figure 6A-4 and Appendix K.1). Mass transit authorities receiving FTA funding under the Urbanized Area Formula Program (§ 5307)[lxxx] or Non-Urbanized Area Funding Program (§ 5311)[lxxxi] are required by statute to submit annual reports to the NTD. Diesel and biodiesel were the only two fuels used in estimating the total fuel demand; gasoline, CNG and other fuels were not included in the policy parameters because vehicles powered by these other fuels cannot run on biodiesel.

Table 6A-1. Historical Fuel Usage in Michigan Mass Transit Buses (thousand gallons), 1997-2004.

	1997	1998	1999	2000	2001	2002	2003	2004
Petroleum Diesel	12,512	13,397	13,877	13,896	13,759	13,246	12,676	13,197
Biodiesel (B20)	0	0	0	0	0	220	225	239

Source: NTD 1997-2004.

[lxxix] NTD indicates that extensive efforts have been made to ensure the quality of information contained in the reports, but it is impossible to achieve complete accuracy and consistency. Reported data do not include all relevant information generally necessary to explain apparent differences in performance (e.g., climate, unusual events such as strikes, and topography). However, this was the best dataset available to the MCCP team.

[lxxx] Section 5307 : Formula grant program for urbanized areas (over 50,000 population) providing capital, operating (for agencies under 200,000 population), and planning assistance for mass transportation. Funds are apportioned to urbanized areas utilizing a formula based on population, population density, and other factors associated with transit service and ridership. It provides funding for capital and planning at 80 percent and for operation up to 50 percent.

[lxxxi] Section 5311: Provides funding for public transportation in non-urbanized areas. Funds are apportioned to the states according to a statutory formula based on each state's population in rural and small urban areas (under 50,000 population). Capital and administration expenses are funded at up to 80 percent of net costs, while operation expenses are funded at up to 50 percent of net project costs. Eligible recipients include public bodies and private nonprofit organizations. Each state must spend 15 percent of its appropriations for the support of intercity bus transportation, unless the governor certifies that the intercity bus transportation needs of the state are adequately met.

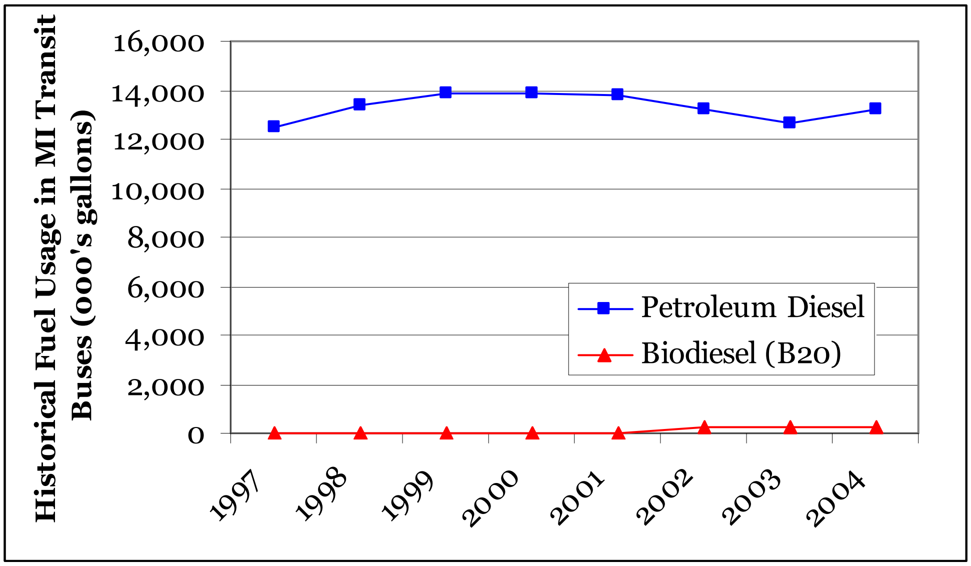


Figure 6A-3. Historical Fuel Usage in Michigan Mass Transit Buses, 1997- 2004.

Using the NTD data, the average annual change in Michigan diesel demand for the transit buses within the team's parameters was 0.840%. This percentage was used to establish the BAU diesel use for Michigan mass transit agencies, with the model timeframe 2007-2025 (Figure 6A-4). For comparison, data from the DOE and US Federal Highway Association estimates that diesel usage, for all Michigan diesel vehicles, will increase 1.25% during the same timeframe.[178] Additionally, the Energy Information Administration's (EIA) national estimate for all diesel vehicles is 1.27%. The MCCP team was unable to find a national or Michigan-specific projection for diesel fuel use, specifically for mass transit buses.

Using the NTD data, the average annual change in Michigan biodiesel demand for the transit buses within the team's parameters was 4.23%. This percent was used to establish the BAU biodiesel use for Michigan mass transit agencies, within the model timeframe 2007-2025 (Figure 6A-4). For comparison, data from the DOE and US Federal Highway Association estimates that biodiesel usage, for all Michigan diesel vehicles, will increase 5.28% during the same timeframe. The years 2002, 2003, and 2004 are the only years biodiesel use was documented and the University of Michigan Transportation Services was the only transit authority using biodiesel at that time. Since 2004, other mass transit authorities have started using biodiesel or are in the process of switching over to various biodiesel blends. A national or Michigan-specific projection for biodiesel fuel use, specifically for mass transit buses, was not available. However, evidence exists that alternative fuel use in mass transit buses is increasing. The NTD reports that alternative fuel use in the nation's bus fleet has increased from 1.2% in 1992, to 7.5% in 2000.[179]

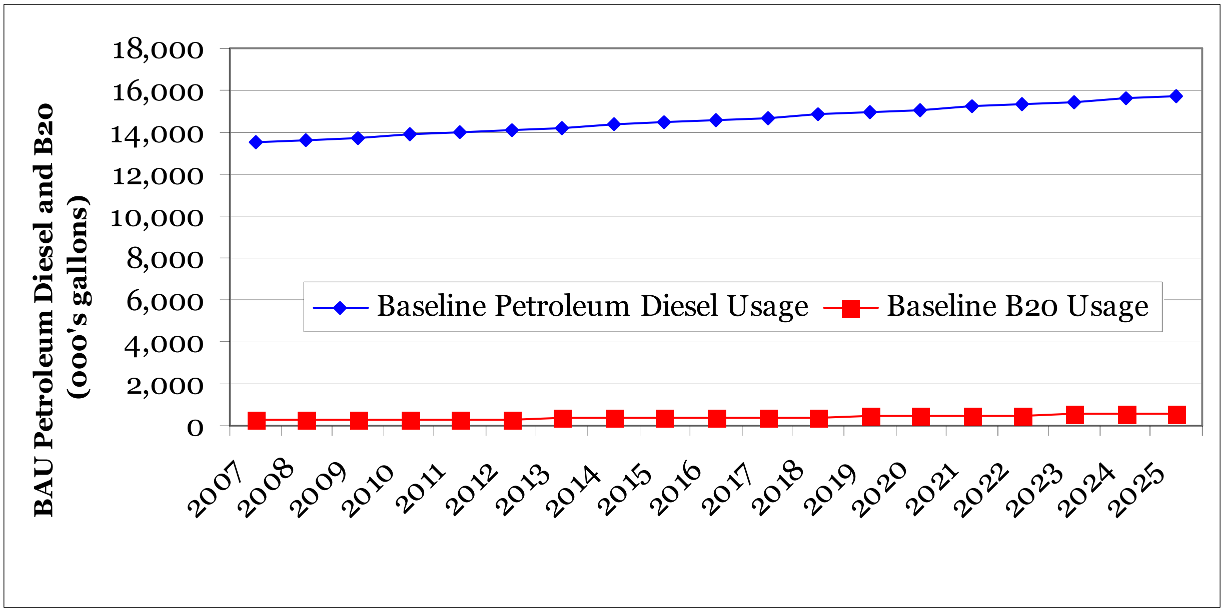


Figure 6A-4. BAU Fuel Usage for Michigan Mass Transit Buses, 2007-2025.

Parameters and Assumptions

The following is a list of urban mass transit agencies that the MCCP team identified through the Michigan Department of Transportation as being affected by the fuel-switching strategy. The agencies reporting information varied from year to year because some transit systems started up within the 1997-2004 timeframe.

- Ann Arbor Transit Authority (AATA)
- Battle Creek Transit
- Bay Metro Transit Authority-Bay County
- Benton Harbor
- Detroit Department of Transportation (DDOT)
- Suburban Mobility Authority for Regional Transportation (SMART)-Wayne, Oakland, Macomb, and Monroe Counties
- Flint Mass Transportation Authority (MTA)
- The Rapid-Grand Rapids
- Jackson Transit Authority
- Kalamazoo Metro Transit
- Capital Area Transit Authority (CATA)-Lansing
- Muskegon Area Transit System (MATS)
- Blue Water Area Transportation Commission-Port Huron

- Saginaw Transit Authority Regional Services (STARS)
- University of Michigan Transportation Services[180]

The following is a list of the major assumptions used to model the greenhouse gas emission reductions:

- Equal fuel economy of 3.65 miles per gallon of diesel or biodiesel.[lxxxii, 181]
- No changes in city growth, routes, or services that would alter the vehicle miles traveled by the agencies. [lxxxiii]
- BAU annual increase of 0.84% for diesel fuel use (see above for method of calculation).
- BAU annual increase of 4.23% B20 fuel use (see above for method of calculation).

The total volume of fuel required to fulfill the Mass Transit Fuel-Switch is the same for both the BAU and policy scenarios (with an assumed similar fuel economy), but the ratio of diesel to biodiesel fuel-demand differs between the two scenarios.

Emission Factors

The MCCP team calculated CO_2, CH_4, and N_2O emissions for mass transit buses from two primary inputs:

- Activity data (VMT), as calculated from projected fuel usage and bus vehicle fuel economy.
- Emission factors (g/mi). The US EPA 1998 Heavy-Duty Diesel Vehicle conversion factors (bhp-hr/mi) were used to convert US DOE/USDA bus life cycle emission factors (g/bhp-hr) into a (g/mi) emission factor.[lxxxiv]

Using these two inputs, the GHG emission factors were applied to the BAU and Fuel-Switch scenarios and converted to MMTCE. The difference between the BAU and Fuel-Switch scenarios is the GHG reduction potential of the policy. The

[lxxxii] Based on these data, neat biodiesel and biodiesel blends should exhibit a fuel economy proportional to the lower heating value of the blend. No improvement in energy efficiency is expected. Therefore, the fuel economy of the biodiesel bus is assumed to be the same as a conventional diesel fueled bus 7.5MJ/bhp-hr. (DOE/USDA NREL 2004)

[lxxxiii] Fuel-demand estimates for mass transit buses are sensitive to factors such as changes in routes, funding cuts, strikes, fuel prices, economic growth, and technology adoption. However, for modeling purposes these variables were not included in the modeling.

[lxxxiv] The team used a linear regression to obtain emission factors to 2025 and account for increases in bus engine performance. These emission factors are reported in brake-horsepower hour (bhp-hr). This common unit of work is the measure of an engine's horsepower without the loss in power caused by the gearbox, generator, differential, water pump, and other auxiliaries. The actual horsepower delivered to the driving wheels is less. An engine would have to be retested to obtain a rating in another system.

EPA (bhp-hr/mi), DOE/USDA (g/bhp-hr), and converted emission factors (g/mi) can be found in Appendix K.2.

Well-to-Wheel

The DOE/USDA transit bus lifecycle emission factors used to model GHG reductions represent the emissions from the full life cycles of both diesel and biodiesel. The emissions were calculated differently for the Michigan GHG Inventory because the Inventory reported transportation emissions from point of combustion/tailpipe (Pump-to-Wheel).

In general, life cycle assessment of emissions and energy use for these motor fuels begins with soybean cultivation and petroleum extraction, proceeds with all applicable processing and transportation, and ends with combustion in the (bus) engine. The growth of the soybean plant is assumed to absorb as much CO_2 as is emitted by decomposition of crop residue after the harvest and by combustion of biodiesel in the engine.[182] Petroleum-based chemicals and fuels are used to produce the soybeans, but the soybean oil biodiesel contains energy from other sources, like solar energy.

The DOE/USDA study includes a full account of the boundaries of the life cycle for diesel and biodiesel. The following is an abbreviated list of the activities within the boundaries of the study system: [183]

Petroleum diesel

- Extract crude oil from the ground.
- Transport crude oil to an oil refinery.
- Refine crude oil to diesel fuel.
- Transport diesel fuel to its point of use.
- Use fuel in a diesel bus engine.

Biodiesel (B100)

- Produce soybeans.
- Transport soybeans to a soy crushing facility.
- Recover soybean oil at the crusher.
- Transport soybean oil to a biodiesel manufacturing facility.
- Convert soybean oil to biodiesel.
- Transport biodiesel fuel to the point of use.
- Use fuel in a diesel bus engine.

Biodiesel and petroleum diesel production processes are almost equally efficient at converting raw energy resources (petroleum or soybean oil) into fuels. The difference in the two fuels is in the ability of biodiesel to utilize a renewable energy source. As a result, biodiesel requires less fossil energy (0.31 units) to make 1 unit of fuel. In other terms, biodiesel yields 3.2 units of fuel product energy for every unit of fossil energy consumed in its life cycle. The production of B20 yields 0.98 units of fuel product energy for every unit of fossil energy consumed.[184]

6A.5 Economic Modeling

This mandatory biodiesel fuel switch-policy assumes that Michigan-produced biodiesel is used to carry out the policy and that Michigan soybeans serve as the main feedstock. Currently only two major soybean crushing facilities are located in the state, and they concentrate on food-grade soybean oils. One facility is the Thumb Oilseed Producers in Ulby, and the other is Zeeland Farm Services in Zeeland. The Zeeland facility recently opened a $5 million soybean oil refinery that produces food-grade soybean oil and/or refined feedstock for a biodiesel production plant to make biodiesel.[185] It is uncertain if this plant could crush all the soybeans required for the new biodiesel refinery. Crushing facilities generate a lot of waste because 80% of the soybean is left after the crushing process. This left over soybean material can be used as animal feed. Even if Michigan were capable of crushing all of the biodiesel soybeans, there still would not be an in-state market for the leftover soybean because there are not enough livestock to consume it.[lxxxv]

Energy 2020 and the REMI model were both used to evaluate the effects of a fuel-switch for mass transit buses. The main information input to Energy 2020 was the same historical state fuel consumption data (1997-2004) used in the GHG model. The MCCP team assumed similar prices for biodiesel and diesel, one reason being that, during summer 2006, the price difference between diesel and biodiesel narrowed. Another reason was that it is impossible to project reasonable future fuel prices, as they are the product of many variables.

REMI

For the policy, the MCCP team modeled the construction of one 5 million gallon per year biodiesel production facility with acid esterification potential, to be completed in 2006 (not within the team's modeling timeframe). The REMI model required a different set of input variables. Actual input data can be found in Appendix K.3. The variables and impacts are as follows:

- The MCCP team decreased the overall statewide demand for petroleum (REMI Variable Name: *Exogenous Final Demand for Petroleum, Coal Product Manufacturing*), accounting for biodiesel displacing petroleum diesel as a motor fuel due to the policy. This negatively impacted employment and GSP.
- The MCCP team increased the amount of chemical processing in the state (REMI Variable Name: *Industry Sales/ International Exports for Chemical Manufacturing*) by the same amount that the team decreased the statewide demand for petroleum, to model the production and sale of biodiesel. The MCCP team assumed the reduced demand for petroleum would be distributed among both in-state and out-of-state supply. The team also assumed that all new

[lxxxv] Some stakeholders were concerned that if a new crusher were added, more confined animal feed operations would follow due to a closer food supplier.

biodiesel production would be within the state, [lxxxvi] positively impacting employment and GSP. These positive impacts are slightly greater than the negative impact from the decrease in Petroleum Demand.

- The MCCP team increased the amount of construction activity in the state (REMI Variable Names: *Firm Sales for Construction* and *Firm Sales for Electrical Equipment*) to model the capital costs, in labor and equipment, for the construction of a new biodiesel refinery.[lxxxvii] This construction was modeled to occur within 2006, prior to the mandatory fuel switching in 2007. This positively impacts employment and GSP.

The team did not model the sale of glycerin, a by-product of the biodiesel reaction. Glycerin is used in cosmetics and pharmaceuticals and is minimally treated to yield a crude grade of glycerin that can be sold for further refinement into high-quality refined glycerin.

Weaknesses in the Models

Neither of the models directly represents changes in the agricultural sector as a result of the policy. Energy2020 is an energy model that works best with the electricity sector. Using the REMI model, the team modified the intermediary inputs to the chemical sector to best represent the agricultural inputs to the biodiesel facility.

6A.6 Results and Discussion

The following section presents the GHG and economic modeling results for a mandatory fuel-switch in urban mass transit buses. Tables 6A-2 and 6A-3 present a summary of the modeling results for cumulative GHG reductions and economic effects through the years 2007-2025. Annual GHG reductions and economic results can be found in Appendix K.2 and K.3.

Table 6A-2. Mass Transit Bus Fuel-Switch GHG Modeling Summary Cumulative Reductions by 2015 and 2025.

Scenario	**MMTCE Reduced by 2015**	**MMTCE Reduced by 2025**
Mandatory B20 Use in Urban Mass Transit Buses	**0.06**	**0.13**

[lxxxvi]Soybeans were grown, refined to oil, and produced into biodiesel in Michigan. Most likely, Michigan would not be able to crush all of the soybeans required for the policy, but out–of-state crushing was not accounted for in the modeling.
[lxxxvii]Used the capital costs of $8.2 million for a 5 million gallon per year stand-alone biodiesel refinery with acid esterification process capabilities. Acid esterification provides the flexibility to take advantage of more difficult–to-process but lower-cost feedstock such as yellow grease or turkey fat that might be available. The cost estimates were based on late 2004-early 2005 construction commodity costs and may have fluctuated (MDA 2006).

Table 6A-3. Mass Transit Bus Fuel-Switch Average Annual Economic Effects, 2007-2025.

Scenario	Change in GSP (millions 2000 fixed $)	Change in Job-Years
Mandatory B20 Use in Urban Mass Transit Buses	**4.48**	**31.2**

6A.6.1 Greenhouse Gas Modeling Results

The GHG benefits of a B20 mandate for urban mass transit buses were modeled in the context of displacing BAU VMT by conventional diesel by VMT of vehicles powered by B20. Figure 6A-5 and 6A-6 present the annual and cumulative WTW GHG reductions from the mass transit bus fuel-switch. From a GHG emission reduction standpoint, increasing the use of B20 in transit buses results in noticeable reductions in BAU GHG emissions. However, these GHG emission reductions would be significantly larger if applied on a larger scale, such as in all diesel-powered vehicles. The GHG reduction potential from increased renewable fuel use is discussed in the Alternative Fuel Infrastructure, Flex and Bio Fuels section, in which a more aggressive use of renewable fuels is modeled in the form of a Renewable Fuel Standard.

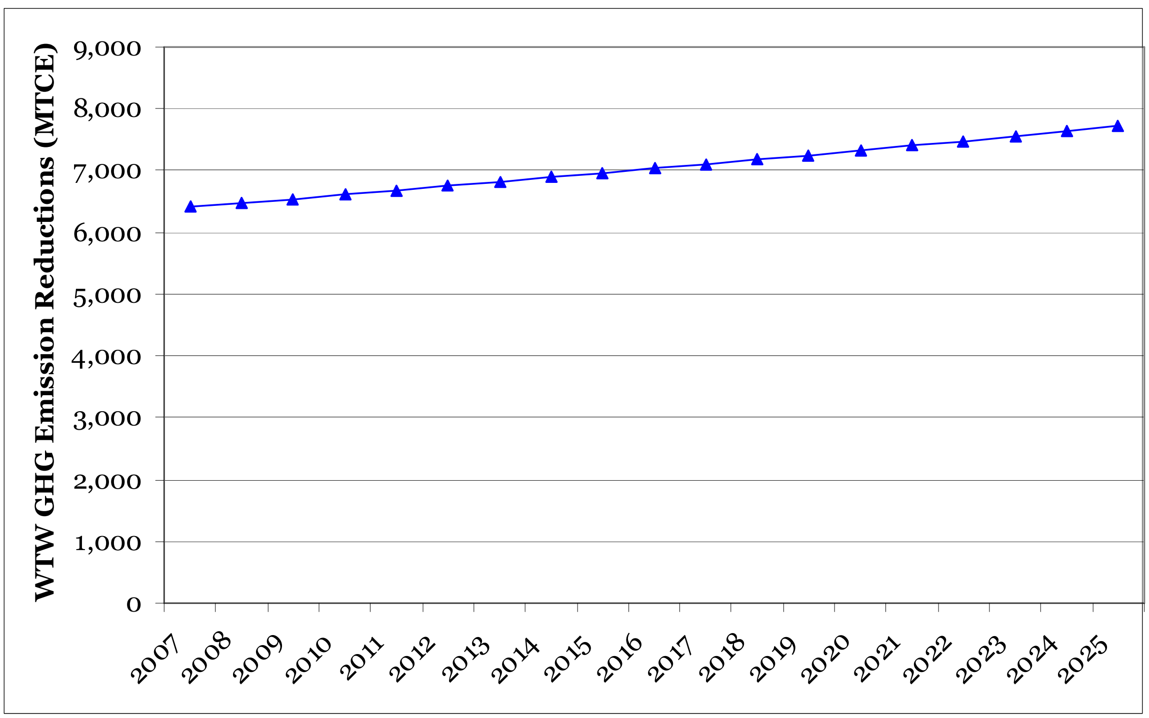


Figure 6A-5. Mass Transit Fuel-Switch-WTW Annual GHG Emission Reductions, 2007-2025.

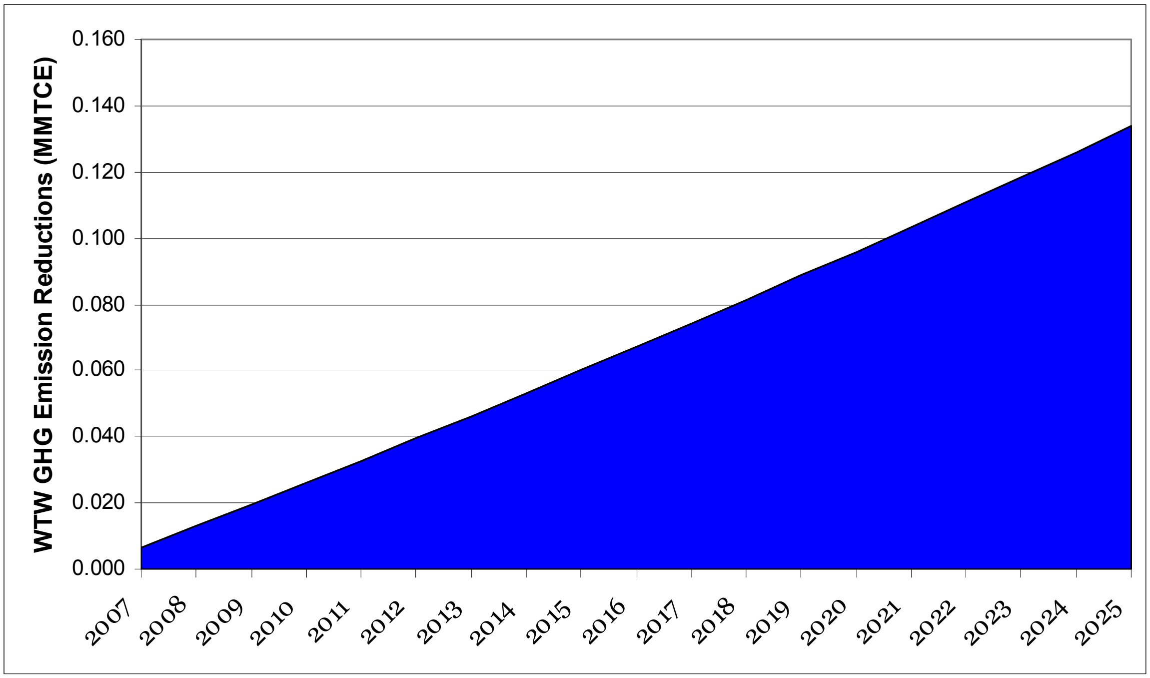


Figure 6A-6. Mass Transit Fuel-Switch-WTW Cumulative GHG Emission Reductions, 2007-2025.

Figure 6A-7 presents the diesel fuel displaced by the mandatory fuel-switch over the modeling period. Over 55.5 million gallons of petroleum diesel were displaced as a result of the policy. This represents a step towards reducing the consumption of foreign oil. As mentioned earlier, the volume of petroleum diesel could be displaced by applying this policy to more diesel vehicles and/or increasing the volumetric percentage of biodiesel used.

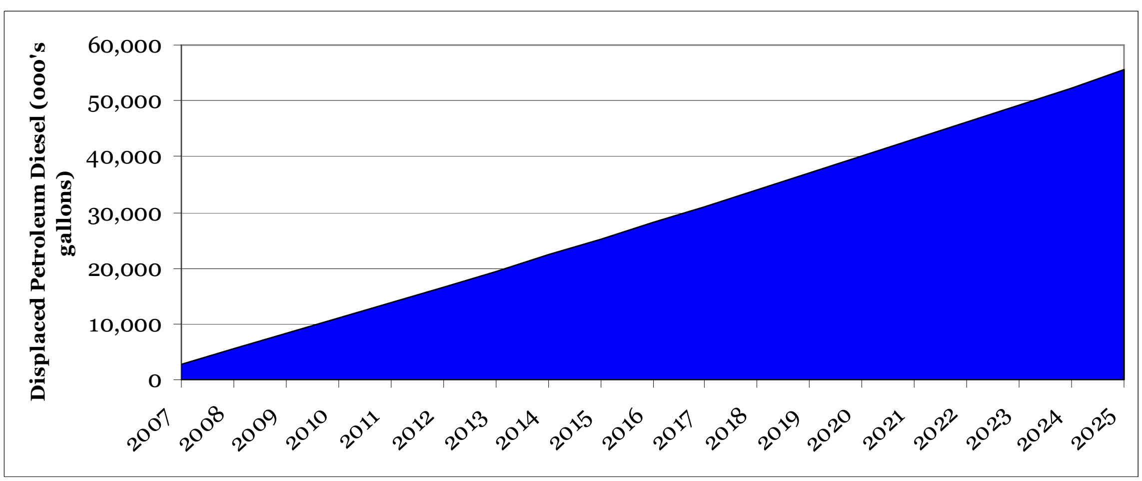


Figure 6A-7. Cumulative Petroleum Diesel Fuel Displaced by the Mass Transit Fuel-Switch, 2007-2025.

6A.6.2 Economic Modeling Results

Figure 6A-8 and 6A-9 show the economic impacts to Gross State Product (GSP) and annual job-years through the modeling period for the mandatory mass transit bus fuel-switch. This policy has positive effects on the economy, as the average annual increase to the GSP was $ 4.48 million and an annual average increase in job-years of 31. 2 was output by the model. The REMI economic sectors positively impacted by the policy were the Chemical Sector, due to the increased demand for biodiesel processing chemicals, the Construction and Electrical Equipment sectors (primarily in the construction year), and general services. The primary sector negatively impacted was the Petroleum and Coal Product Manufacturing sector. The negative impacts incurred by this sector are the result of petroleum diesel fuel being displaced by Michigan-produced biodiesel. Overall, this policy has positive economic effects on employment and a measurable reduction in GHG emissions, and can serve to reduce our dependence on foreign oil.

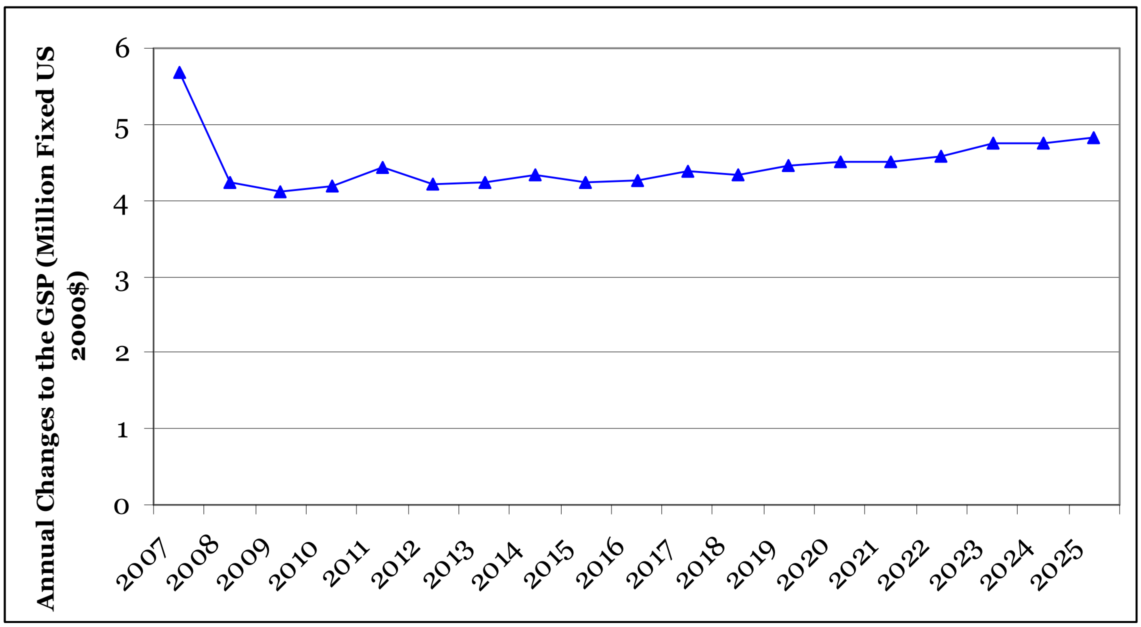


Figure 6A-8. Changes to the Michigan GSP with a Mandatory Fuel-Switch in Mass Transit Buses, 2007-2025.

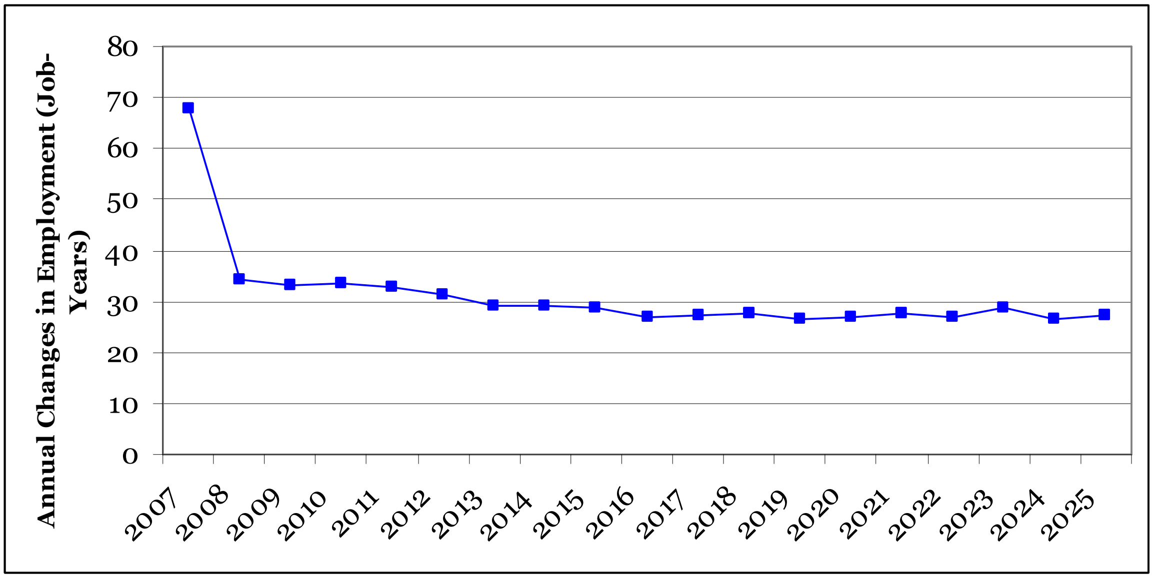


Figure 6A-9. Changes in Michigan Employment (Job-Years) with a Mandatory Fuel-Switch in Mass Transit Buses, 2007-2025.

6A.7 Conclusion and Discussion

Fuel-switching in urban mass transit buses demonstrates the potential to reduce GHG emissions, create positive economic effects, and reduce foreign oil consumption. This policy is small in scale (mass transit buses only) and produces the lowest cumulative GHG reductions (0.13 MMTCE) of all the analyzed policies. Nevertheless, even this small scale policy produces positive results in terms of GHG reductions and economic effects. A broader-scope policy, focused on a larger number of diesel vehicles, could further increase the GHG reduction potential and economic benefits of a fuel-switching policy. However, in a carbon-constrained world, any level of GHG emission reductions is a benefit and provides opportunities to reduce GHG levels. At Forum II, there was overall support of the policy. The aforementioned (6A.2 Policy Background) benefits of using biodiesel should also be considered when weighing this policy option. Finally, in Forum II, the majority of stakeholders' comments stressed the need for SEMCOG to release information in order that the proposed transportation alternatives could be modeled.

6B. Ann Arbor to Detroit Rapid Transit Study Project

6B.1 Introduction

The Mass Transportation Enhancement and Development strategy was ranked number 6 at Forum I. During the afternoon discussion sessions, stakeholders voiced concerns about the need for significant improvements in Michigan's mass transportation system. The southeast region of the state was identified as having a high degree of need for improvements. The group mostly agreed that there was a problem with the current state of mass transit; the solution was not particularly obvious to the group. Some suggestions for further analysis included a new type of bus system, such as bus rapid transit; use of Michigan-grown alternative fuels in transportation vehicles; and development of an ultra-light personal mass transit system. More specific policy solutions were not mentioned by the stakeholder group.

6B.2 Policy Background

The following section covers ongoing transportation initiatives in Michigan.

SEMCOG Study: Improving Transit in Southeast Michigan: A Framework for Action

This study found that an improved transit system would benefit the entire transportation system by providing a balance of viable options. A comprehensive transit system would enhance the region's economic competitiveness, address needs of the transit dependent, and provide an option for those who do not need to use transit. The study calls for a four-tiered transit system: a 12-corridor, rapid transit network; an enhanced fixed-route bus service; an improved and expanded community transit; and the establishment of regional transit links. [186]

Woodward Transit Alternative Study

This initiative was started in 1999 to develop a transit alternative along Woodward Avenue within the city of Detroit. Bus rapid transit (BRT) was one of the main options under consideration. The study identified BRT[lxxxviii] and light rail transit (LRT)[lxxxix] as the two appropriate transit options on Woodward Avenue. No funding has been allocated at this time for further study.[187]

Grand Valley Region Transit Enhancement

The plan, *Getting There Together: A Citizens' Agenda to Move Transit Forward in the Grand Valley Region*, outlined steps for ramping up regional bus service, updating planning and development standards to speed urban revitalization, and reforming

[lxxxviii] BRT is a rubber-tire form of rapid transit offering many of the same features as light rail, including the use of dedicated lanes, traffic signal prioritization, advance fare payment, quick passenger loading, and fast and frequent service. Source: SEMCOG Transportation Plan Glossary. http://www.semcog.org/TranPlan/Glossary.htm#AtoD.

[lxxxix] LRT uses lightweight passenger rail cars that operate on fixed rails, separate from auto traffic, but usually in the same right-of-way.

outdated public spending practices to provide more transportation choices for students, workers, senior citizens, and people with disabilities in Western Michigan.[188] Michigan H.B. 4993 would have allowed voters to authorize the local transportation authority to levy a tax on real property for public transportation purposes from the current limit of five years up to 25 years, thus benefiting this plan. An amendment to the bill limited the changes to apply only to counties with populations greater than 500,000 and less than 750,000. As a result, the amendment would have applied only to Kent County, the region included in the Grand Valley Regional Plan.[189] The amended population requirement, singling out one county in the state, eventually caused the bill to be vetoed by Governor Granholm.

Michigan Department of Transportation (MDOT)-New Services Program

New Services Program is funded out of the discretionary portion of the Public Transportation Development account. It provides capital and operating assistance for new services not currently provided. Capital will be funded at 100 percent. Operating will be funded at 90 percent of eligible cost for the first year, 80 percent for the second year, and 70 percent for the third year. No funds are currently available for this program.

6B.3 Going from Strategy to Policy

In the course of background research, the MCCP team identified the Southeast Michigan Council of Governments' (SEMCOG) Ann Arbor to Detroit Rapid Transit Study Project (RTSP) as a potential option for greenhouse gas (GHG) and economic analysis. This project was chosen because it was current, fit within our time frame (2007-2025), could be modeled in terms of both economic effects and GHG emissions reduction potential, and would have the potential to affect a large region of the state. SEMCOG is the regional planner in Southeast Michigan that supports local government planning in the areas of transportation, environment, community and economic development, and education. SEMCOG has cross-jurisdictional boundaries in the Southeast Michigan region that encompasses Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, and Wayne counties. After communications with SEMCOG Transportation Planners, the MCCP team planned to focus only on the GHG reduction potential of the study because it was not included in the study. Additionally, SEMCOG planned to use the REMI model for economic analysis and the team did not intend to conduct a separate economic analysis.

The RTSP is one of the key state-level transit planning efforts underway. It covers the rapid transit alternatives of BRT, LRT, and commuter rail transit (CRT)[xc] in the Southeast Michigan area along a 50-mile-long, five-to-ten mile-wide corridor extending from west of Ann Arbor to downtown Detroit, including the Metro Airport area. The alternatives analyzed in detail include a Transportation Systems Management (TSM) as the baseline and five build alternatives, each with different options (Appendix A):[xci,190]

[xc]CRT is generally defined as passenger train service that operates on existing freight railroad tracks. Many commuter train systems are integrated with other transit services, such as a bus system, to encourage transfers throughout the region.

[xci]TSM is a management system designed to better manage and operate the existing roadway system, e.g., through the use of Intelligent Transportation Systems technologies. It includes activities or strategies that improve the operational efficiency of transportation systems. SEMCOG Glossary www.semcog.org/TranPlan/Glossary.htm.

- BRT 5: Michigan Avenue.
- BRT 6: I-94/ Michigan Avenue.
- LRT 5: Michigan Avenue.
- CRT 1: Norfolk Southern Michigan Line.
- CRT 2: Norfolk Southern Detroit Division, BRT on I-94.

As previously mentioned, the MCCP team intended to focus on calculating the GHG reduction potential of one or all of the proposed alternatives in the study. Federal air pollution regulations require SEMCOG to demonstrate that transportation projects in its long-range Region Transportation Plan and Transportation Improvement Plan will not:

- cause or contribute to any new violation of any new standard in any area,
- increase the frequency or severity of any existing violation of any standard in any area, or
- delay timely attainment of any national ambient air quality standard (NAAQS) or any required interim reductions or other milestones in any area.[191]

The above requirements are required of all areas that have been, or are currently, in violation of the NAAQS for ozone, particulate matter, carbon monoxide, and nitrogen dioxide. CO_2 and other GHGs are not defined as criteria air pollutants, and, therefore, the SEMCOG Air Quality division was not required to calculate these emissions as part of the study.

The RTSP was originally scheduled to be completed in June 2006, but the date was pushed back. In August 2006, a SEMCOG memo indicated that there were difficulties with the travel demand forecast model.[xcii] More specific reasons for the delay were that:

- a new model was being used, and unexpected complications needed to be addressed and
- models are developed to simulate existing situations before they are used to project the future. Modeling efforts were difficult because there is currently no public transit of any kind between Ann Arbor and Detroit and there is very little transit in general in the corridor.[192]

The travel demand numbers needed to be as representative of the region as possible, because they would eventually serve as inputs to the Federal Transit Administration (FTA) model that would prioritize this project against other proposed transportation projects across the country. The FTA's New Starts Program provides major funding for local communities to design and construct rapid transit systems such as subways, trolley networks, and commuter rail service, but the program is very competitive. This project will have to compete with other projects from across the country that in some cases already have strong evidence to support their ridership estimates.

6B.4 Conclusion and Discussion

Throughout the course of the MCCP timeline, the MCCP team attempted to obtain the assumptions and parameters used in the RTSP, in order that ridership numbers for the TSM and five build alternatives could be derived to model the GHG emissions and GHG

[xcii]A model used to project current and future ridership estimates for each of the proposed alternatives.

emissions reductions associated with the proposal.[xciii] Unfortunately, because the study was still in progress, the information was not made available and without it the MCCP team was unable to model the RTSP. Furthermore, it would have been outside the MCCP timeframe (and abilities) to conduct an independent study and acquire the necessary information that had taken SEMCOG several years to generate.[xciv] As a result, the MCCP team decided to model a different Mass Transit Enhancement and Development policy. As a revised policy, the MCCP team decided to model a mass transit enhancement policy (fuel-switching in mass transit buses) instead of modeling an entirely new mass transportation development. The Fuel-Switching policy is described in detail in Chapter 6A.

In November 2006, SEMCOG released its analysis of the cost and ridership estimates for the five alternatives.[193] Assumptions and parameters used to forecast ridership were not included. A summary of its results for each or all of the 5 alternatives included: (1) daily ridership projections ranging from 600-6,000 people; (2) capital costs ranging from $600 million-$3 billion; and (3) annual operating costs ranging from $25 million-$110 million.[194] Additionally, it stated that none of the alternatives were likely to be competitive for federal New Starts funding, primarily due to the low ridership estimates.

Currently SEMCOG is in the process of refining some of the build alternatives and will publish more detailed information in early 2007. SEMCOG also is evaluating the potential for a temporary starter service, in the form of a locally funded, basic commuter rail service.[195] Once the alternatives are refined, SEMCOG policy bodies, along with input from the public, will make a decision on whether or not to recommend an alternative to advance to the next phase of design. If an alternative is recommended, it will be designated as the Locally Preferred Alternative. The effected entities in the region would then formally adopt the alternative as part of their long-range transportation plans and the project would proceed to the next phase of Preliminary Engineering and preparation of the Final Environmental Impact Assessment. When the key assumptions and parameters of the Locally Preferred Alternative become available, it will be possible to model this project in terms of its GHG emissions.

[xciii]Ridership numbers are important because they are used to calculate projected revenue and operating costs, though the MCCP team did not intend to model the economic impacts of the study, as the REMI model was going to be used during the project analysis.
[xciv]The study began in June 2004.

7. Renewable Electricity Production Tax Credit

7.1. Introduction

In the 1990 to 2002 interval, GHG emissions from electricity generation in the state of Michigan increased from 18.2 million metric tons of carbon equivalent (MMTCE) to 19.8 MMTCE, an increase of 9.2 percent.[196] Generating electricity is the largest source of CO_2 emissions in the state, and represents 38% of such emissions from fossil fuel combustion.[197] Any serious attempt to reduce GHG emissions must therefore address the electricity generation sector.

At Forum I, stakeholders expressed interest in the Renewable Electricity Production Tax Credit (REPTC) and Renewable Portfolio Standard (Chapter III-1) strategies. The purpose of the REPTC strategy was to reduce electricity-sector GHG emissions through a technology push by improving the cost effectiveness of renewable energy development and generation. The MCCP team modeled the REPTC as a five-year program starting in 2007, providing tax credits of $0.01/kWh, with a maximum of $4,000 per site for the production of renewable energy. This policy is in addition to the federal renewable energy production tax credit of $0.019/kWh and the same renewable sources qualify (wind, solar, geothermal, biomass, landfill gas, and hydro (no pump storage). Table 7-1 presents a summary of the REPTC policy.

Table 7-1 Summary of Renewable Energy Production Tax Credit.

PTC	Qualifying Source	Tax Credit ($/kWh)	Maximum Tax Credit ($/yr)
Renewable Energy	Wind, Solar, Biomass, Geothermal, Landfill Gas, and Hydro	$0.01	$4,000

7.2 GHG Model

For the REPTC, the MCCP team modeled two scenarios: a business as usual case with no Renewable Energy PTC (BAU), and a REPTC scenario where the team assumed that renewable energy generation increases annually by 0.5%. The REPTC GHG model accounted for GHG emissions during the modeling years of 2007 through 2025; with the policy only providing funding for the five years 2007-2011. More information on the state's electricity industry, fuel mix and potential benefits of renewable energy in general are in the RPS section of this report, Chapter III-1.

It was difficult for the MCCP team to model a REPTC, because it was supposed to be an iterative process with the economic results determining the pull of renewable energy development by the PTC and thus the impact of the PTC on GHG emissions reductions. Therefore, the PTC model should be viewed as a template, which could be used if the 0.5% assumptions are correct or could be altered to reflect the actual effect of a technology push.

7.2.1 GHG Model Inputs and Assumptions

The GHG model used the revised demand growth projections for overall annual electric demand (increasing by 1.1% per year) based on the updated Capacity Need Forum Projections from the 21st Century Energy Plan. For the BAU case, projections for annual sales by fuel were calculated using the following assumptions:

- Electricity produced from nuclear, oil, hydro, landfill gas, and wood remains constant during the modeling period (2007 – 2025).
- Electricity produced from wind, solar and biomass combined, increases annually by 0.5 %.
- Electricity produced from coal and natural gas increases annually by 0.6% (to meet the 1.1%/year growth). This non-renewable portion is apportioned among coal (88%), natural gas (12%). (These percentages reflect the relative contributions to load growth in 2004 among coal and natural gas, and assume that nuclear generation remains constant over time.) [198]

For the REPTC scenario, the following assumptions were made:

- Electricity produced from renewable energy sources increase annually by an additional 0.5% above the BAU case.
- New renewables were allocated among wind (87%), biomass (12%), and solar (1%).
- New renewables displaced coal and natural gas, according to the same proportions as noted above.

The MCCP team calculated GHG emissions by taking the annual differences between the BAU and PTC (Appendix L-1) scenarios electricity sales (in MWh) according to fuel type. This difference was then converted to million metric tons of carbon equivalent (MMTCE). Transmission and distribution losses of 9% and conversion efficiencies of electricity generation according to fuel type, using EPA data (coal = 0.379, natural gas = 0.379, oil= 0.362), were used to determine the total amount of kWh generated. [199], [200]

The net reduction in electricity consumption from the PTC was derived using the reduction in the amount of new fossil fuel electric generation in the state; this was also assumed in the RPS GHG model.[xcv] Next, state fuel data were used to determine how much of each fuel type contributed to the savings (in kWh). For each fuel, the energy savings were converted from kWh to British Thermal Units (BTUs). GHG emissions were then calculated by multiplying the net energy savings in BTUs by GHG emission factors (see Table 7.2). The team utilized Global Warming Potential of each of the GHGs: CO_2: 1, N_2O: 310, and CH_4: 21. Finally, GHG emissions were converted from pounds (lbs.) of carbon equivalent to MMTCE.

[xcv] It was assumed that new generation would be either coal or natural gas and according to recently added generation in Michigan and other states. Since the team's emissions calculations were done at the point of generation (except biomass, for which the full life cycle was used), the MCCP team assumed zero GHG emissions for all renewable energy sources, including biomass and wood.[xcv] Keoleian & Spitzley (2006)

Table 7-2. Emission Factors for Electricity at Point of Generation.[201]

Fuel Type	CO_2	CH_4	N_2O
	(lbsC/MBtu)	($MtonCH_4$/BBtu)	($MtonN_2O$/BBtu)
Coal	57.29	0.001	0.001
Natural Gas	31.91	0.001	9x10^5

One information point the team did not incorporate into the calculations was the effect of the PTC on electricity imports, as Michigan currently imports around 10% of its electricity. The MCCP was unable to find enough data to confidently estimate whether the PTC would increase or decrease imports and by how much.

7.3 Economic Modeling

As previously stated, the MCCP team was unable to model the economic effects of the REPTC policy. The MCCP team was constrained by the capabilities of the Energy 2020 and REMI models, and thus not able to model the REPTC policy. The models were unable to capture the market push effect of providing a tax credit to renewable energy developers. The team had intended to use the tax credit presented in Table 7-1, along with corresponding estimates of generation increases, to determine the increase in renewable electric generation due to the policy.

7.4 Results and Conclusions

Table 7-3 presents a summary of the cumulative GHG emission reductions through the years 2015 and 2025.

Table 7-3. REPTC GHG Modeling Summary 2015 and 2025.

Scenario	MMTCE by 2015	MMTCE by 2025
Renewable Energy PTC	0.46	1.11

This policy would displace electric generation from fossil fuel sources by 57.9 million MWh by 2025. Of that reduced electric demand, 49.8 million MWh is the share derived from coal, and 8.11 million MWh is the share derived from natural gas. However, as the duration of the program is only from 2007-2011, the total amount of qualifying MWh is 9.23 million. At $0.01/kWh, that results in a state subsidy of $93 million over the five-year period. Adding a 0.5% increase in renewable energy to the state electricity fuel mix annually results in two key findings. The first is the magnitude of the increase. Compared to the impact of adding new renewable energy to the full mix through the RPS, the Production Tax Credit provides far fewer emissions reductions and a much greater economic cost to the state. Secondly, this policy makes no distinction between those renewable energy projects that were developed because of the tax credit, and those that would have been developed in the absence of the REPTC. By virtue of this policy's design, this causes the state to provide a tax credit to all qualified renewable energy generators in the state, and not just to those that would need it in order to develop.

8. Tax Incentives: Combined Heat and Power

This section describes the MCCP study of incentives to induce the adoption and operation of Combined Heat and Power (CHP) as a source of both steam and electricity in the state of Michigan. For more information on Tax Incentives, see Appendix M.15.

8.1 Background

At Forum I in January 2006, stakeholders of the MCCP project listed Tax Incentive Strategies as one of their top priorities for the MCCP study. In addition to developing new and innovative greenhouse gas (GHG) emissions reduction strategies, the MCCP team sought to build upon existing efforts taking place in Michigan. In April 2006, Michigan Governor Jennifer Granholm issued executive directive 2006-2, calling for a comprehensive energy plan to meet the state's electric power needs. Better known as the 21st Century Energy Plan (21CEP), the directive was coordinated by the Michigan Public Service Commission and executed by a series of working groups dedicated to the various topics[xcvi] covered by the plan. Through the research efforts of the Alternative Technology: Combined Heat and Power Working Group[202] (of which the MCCP team was a member), CHP shows promise as an in-state source of power.

CHP is a term used to identify various technologies that can either produce both heat and electricity, or produce electricity from a heat or steam source. CHP systems include prime mover, heat recovery, and thermally activated technologies, and can run on a variety of fuels including steam, coal, and natural gas.[203] Examples of qualifying CHP systems include backpressure steam turbines, gas turbines, and reciprocating internal combustion engines. CHP systems are most attractive to entities that have a need for electric power and thermal energy, such as food and chemical processing plants or large manufacturing operations. CHP is a system that utilizes energy resources more efficiently than traditional industrial boiler options which also require a steam/heat consumer to purchase electricity from the grid. See Figure 8-1 for a depiction of how fuel units are more efficiently utilized by CHP than by traditional boiler systems.

[xcvi] 21CEP Working Groups include: Capacity Needs Forum Update, Energy Efficiency, Alternative Technology, and Renewables. CHP is addressed by the Alternative Technology Team.

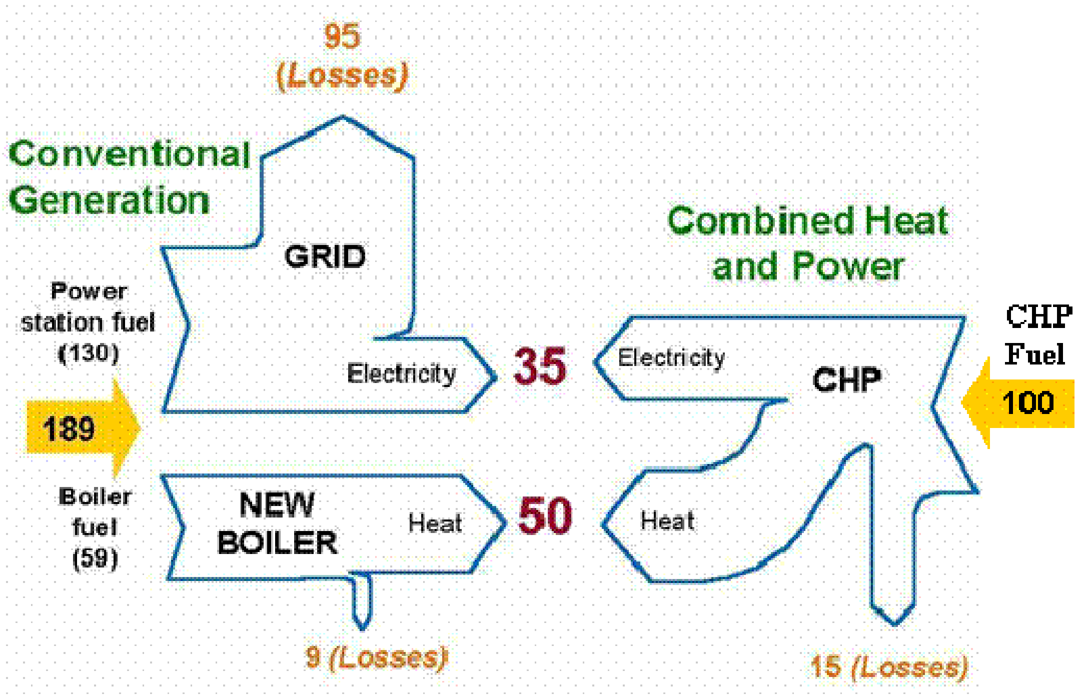


Figure 8-1. Diagram Comparing CHP to Traditional Boiler.[204]

Arkansas, California, Connecticut, Massachusetts, New Jersey, and New York[205] (among others) have considered or implemented state incentive programs to increase electric generation from CHP. More than 78 sites in the state of Michigan produce and consume on-site electricity by employing CHP technologies.[206] These sites are managed by entities such as the University of Michigan, General Foods Corporation, General Motors, and the Ford Motor Company. These large capacity sites (considered first-tier CHP candidates in this study) employ CHP systems for a variety of reasons, chief of which is its cost-savings.

The 21CEP CHP Working Group sought to identify second- and third-tier CHP candidates; such candidates have relatively smaller steam demand or boiler capacity resulting in less cost-effective CHP system options. The group identified reasons that second- and third-tier candidates were not already utilizing CHP, as well as strategies to help these potential adopters employ CHP technologies.

The MCCP team considered a variety of state tax incentive strategies that could induce the adoption of CHP as a source of energy in Michigan. A production tax credit (PTC) could go to CHP operators based on a percentage of the kilowatt hour (kWh) electricity generation potential of each particular system. An investment tax credit (ITC) could go to investors in CHP technologies based on capital, operations, and management costs associated with each kWh of potential generation in the system. The MCCP team assumed the PTC would go to third-party implementers such as electric utilities while the ITC would go to boiler owners.

The primary tax incentive policies considered for CHP were the PTC and ITC. To a lesser extent, the team considered accelerated depreciation options and, ultimately, focused on incentives with greater potential for influencing CHP utilization.[xcvii]

Over the course of developing the CHP Tax Incentive strategy, a variety of policy iterations emerged. The original policy scenarios were to include a tax credit to offset capital costs of CHP at three different levels ($0.015/kWh, $0.05/kWh, and $0.07/kWh). The levels were chosen based on: (1) conservative estimates of incentives that might attract second- and third-tier candidates,[xcviii] (2) estimates of average costs per kilowatt hour for developing CHP systems,[207] and (3) average estimated capital costs of other renewable energy sources.[xcix]

In assessing the effects of a CHP PTC or ITC in Michigan, the REMI model was unable to distinguish between the two incentives. The model was capable of showing the effects of a state subsidy for CHP technologies at the levels previously described. Detailed stakeholder input determined that incentives at the $0.07/kWh level were too high to be realistic options for the state. Given further limitations of the model, combined with stakeholder insights, the MCCP team analyzed an incentive at the $0.05/kWh level at a variety of utilization capacities for determining the potential Megawatt hour (MWh) generation levels that would serve as inputs into MCCP models.[c] To understand the total effect of the subsidy on the state's economy as opposed to the total effect of electricity and fuel savings on the state's economy, the MCCP team also modeled the economic impacts of implementing 180 MW worth of CHP without a state subsidy.

GHG model inputs were derived from the work of the 21CEP CHP Working Group. The Working Group gathered data on Michigan's large, medium, small, very small, and commercial boilers from the Michigan Department of Environmental Quality, Michigan Air Emissions Reporting System (MAERS). (See Appendix M.1 for the 21CEP final report section including discussion of CHP.) From this data, the Working Group calculated an updated total MW generation capacity available in the state. After determining the state could realistically capture a 25% rate of market penetration from total CHP generation potential,[ci] the group estimated an achievable generation potential of approximately 180 MW from Michigan's existing boilers (see Table 8-1). This is a conservative estimate: in July 2005, the Alternative Generation Working Group of the Michigan Capacity Needs Forum identified 547 MW of potential generation in the state[208]. Additionally, a 2003 report prepared by the Midwest CHP Application Center stated Michigan's total market potential for electricity production from Buildings CHP to be at least 2,400 MW.[209]

[xcvii] State depreciation rates are considerably less relevant to a cost-benefit analysis of CHP technology than are federal rates.

[xcviii] These estimates came from a variety of inputs from stakeholders throughout the project.

[xcix] The original Michigan Public Service Commission Capacity Needs Forum estimated $0.07/kWh required by renewable energy sources. The team looked at the seven cent level as an upper limit on its study scope.

[c] Study results showed this subsidy level is too high. However, the level represented a mid-point between the subsidy levels recommended by MCCP stakeholders.

[ci] 25% penetration rate takes into consideration the following factors: (1) existing boilers may be old and will not be operating long enough (no less than 10 years) to justify capital investments in CHP-type modifications; (2) manufacturing operations are slowing down in the state and, thus, some of the plants reflected in the state inventory will no longer be operating; (3) new facilities have higher efficiencies and, thus, produce less steam for the same type of steam/electricity demand; and (4) facilities need to have a year-round steam load to be attractive to CHP adopters.

Table 8-1. CHP MWh and Installations (kW) Potential from Michigan Industrial Boilers.

Note: MMBTUHR represents Million British Thermal Unit Hour.

Facilities w/Boilers	Avg. Hrly Boiler MMBTUHR		CHP kW Potentials at Varying Degrees of Market Penetration		
		Pentration:	100%	50%	25%
		Heat Rate: (BTU/ KW)*	*25,787*	*25,787*	*25,787*
		Avg. MW/Boiler			
Large Boilers	56.60	**4.6**	160,337	80,168	40,084
Medium Boilers	19.50	**1.5**	113,217	56,608	28,304
Small Boilers	7.40	**0.6**	10,127	5,064	2,532
Very Small Boilers	8.53	**0.8**	25,994	12,997	6,499
Commercial	13.42	**1.2**	21,919	10,959	5,480
Other Boilers (has a fair amount of coal)	30.37	**1.8**	85,549	42,774	21,387
Optimal CHP kW Potential:			417,143	208,572	104,286
Subtotal Boiler CHP Design kW at 135% of Avg Output:			**563,143**	**281,572**	**140,786**
Other Facilties w/o Boilers					
Ethanol Facilities			25,000	12,500	6,250
Steel Facilities			100,000	50,000	25,000
Cement Kilns			25,000	12,500	6,250
Subtotal			**150,000**	**75,000**	**37,500**
Total CHP Potential			**713,143**	**356,572**	**178,286**

8.2 GHG Model

The majority of estimated GHG emission reductions result from decreasing fossil fuels consumed by existing boilers. Secondary contributions to reduced GHG emissions result from decreasing utility demand for electricity from state-regulated and non-regulated utilities. This displacement occurs by replacing existing boilers and, to a lesser extent, steel facilities, ethanol facilities, and cement kilns with CHP systems running on natural gas (NG).

The MCCP team calculated total net GHG emissions reductions associated with adopting CHP technology by taking into account the following three factors:

(1) Reduction of electricity demand of utilities,

(2) Reduction of existing on-site emissions from boilers, and

(3) Additional emissions from new CHP systems.

In general, net GHG emissions were calculated by determining the displaced utility level fossil fuel electricity generation (MWh), the reduced fossil fuel usage at the facility (MBtu), and any new fossil fuel usage (MBtu of natural gas) associated with the implementation of a CHP. These reductions and increases are translated into MMTCE and netted against each other to determine an overall GHG reduction number. The processes for determining outputs for each of the three factors are discussed in more detail below.

The model calculated overall GHG savings out to the year 2025, with a policy implementation date of 2007. The team calculated cumulative GHG emissions reductions up to and including the year 2015, and cumulative GHG emissions reductions up to and including the year 2025. See Appendices M.2-M.7 for GHG model calculation results for existing boilers for all boiler sizes.

The MCCP team assumed total in-state CHP MW generation capacity to be 180 MW. The team converted 180 MW to net change in utility and on-site energy consumption and translated those energy savings into carbon-equivalent emissions subtracted from Michigan's boiler emissions output.

Three CHP utilization levels were used to determine three scenarios of total MWh production potential for newly implemented CHP systems. These three utilization-based levels of MWh translated to reductions in demand on utilities and new on-site electricity generation by CHP.[cii] The theoretical upper limit of capacity (i.e. *full* CHP utilization) indicated 8760 hours of operation per year; *majority* utilization indicated 6570 hours of operation per year; and *partial* utilization indicated 4380 hours of operation per year. Year-round, full capacity operation using 8760-hour operating time resulted in a total potential of 1,576,800 MWh. Three-quarters capacity operation using 6570-hour operating time resulted in a total potential of 1,182,600 MWh. Half-time capacity operation using a 4380-hour operating time resulted in a total potential of 788,400 MWh. A sample set of calculations is shown in Table 8-2.

[cii] Levels of reductions in demand on displaced boilers and other facilities were calculated using 21CEP projections of 25% reduction in fuel consumption.

Table 8-2. Relationship between Utilization Scenarios and Model Factors.

Reduction of Grid Emissions		**Reduction of Boiler Emissions**		**New CHP Emissions**	
	Total Annual MMTCE	*Sum of the Large, Medium and Small Boilers*			**Total Annual MMTCE**
180 (MW) running 8760 hrs	**0.384**	**MMTCE**	**0.258**	**180 (MW) running 8760 hrs**	**0.277**
		Sum of the Very Small, Commercial and Other Boilers			
180 (MW) running 6570 hrs	**0.288**	**MMTCE**	**0.134**	**180 (MW) running 6570 hrs**	**0.208**
		Total (MMTCE)	**0.392**		
180 (MW) running 4380 hrs	**0.192**			**180 (MW) running 4380 hrs**	**0.138**

Note: Reduction of Boiler Emissions reflects 25% of total emissions from boilers in the state.

8.2.1 Reducing Utility Level Demand

The MCCP team apportioned displaced utility energy generation among two non-renewable fuels at a ratio of 88% coal and 12% NG. These percentages reflected the relative contributions to load growth in 2004 among coal and natural gas. MCCP modeling assumed that nuclear generation stays constant over time. The MCCP team assumed no GHG emissions for nuclear sources.

Regarding utility level emissions, the MCCP team calculated GHG emissions reductions by reducing annual utility electricity sales (and subsequent non-renewable fuel consumption) by fuel type. The MCCP team converted these displaced sales figures (in MWh) to million metric tons of carbon equivalent (MMTCE). The MCCP team assumed: (1) transmission and distribution losses of 9%, including power plant efficiencies using various fuels from EPA data (coal = 0.379, natural gas = 0.488); and (2) emissions factors for each of the GHGs (see table 8-3). Michigan currently imports around 10% of its electricity.[210] However, the MCCP team has not made any specific adjustments for this portion of Michigan's electricity. See Appendices M.11-M.13 for calculations of GHG emissions from removing 180 MW of electricity generation from utility operations at the three modeled CHP operating scenarios.

Table 8-3. Utility Fuel Emission Factors.

Emission Factor	CO2 (lb C/MBTU)	CH4 (Mton/BBTU)	N2O (Mton/BBTU)
Coal	57.29	0.001	1.403 E-03
Natural Gas	31.91	0.00095	9.496 E-05

Each of the three main greenhouse gasses (CO_2, CH_4, and N_2O) were individually considered, given distinct relationships to carbon and distinct Global Warming Potential (GWP) (CO_2, CH_4, and N_2O = 1, 21, and 310, respectively).

Total MWh generated by CHP were converted to billion BTU, then to emissions in million tons, and then to MMTCE. Table 8-4 represents a sample set of calculations using CO_2 as an example. This following format was also used for CH_4 and N_2O, however converting short tons of CH_4 and N_2O to MMTCE also included respective GWP allocations.

Table 8-4. Sample Set of Fossil Fuel Energy Conversion Calculations Using CO_2 as Sample GHG.

GHG	Source	Total MWh Potential	Percent contribution to total FF source	MWh Considered	Power Plant and T&D Losses (MBTU)	Units Conversion (BBTU)	Emission Factor (lbsC/ MBTU)	Emissions (tons)	Emissions (MMTCE)
CO_2	Coal *utility*	30,000	0.88	30,000 * .88 = 26400	26400 MWh * T&D/ Power Plant Efficiency	MBTU * .001	57.29	BBTU * Emission Factor * 1000/2000	Short tons * 1/1.1023/ 1000000
CO_2	Natural Gas *utility*	30,000	0.12	30,000 * .12 = 3600	3600 MWh * T&D/ Power Plant Efficiency	MBTU * .001	31.91	BBTU * Emission Factor * 1000/2000	Short tons * 1/1.1023/ 1000000

Table 8-5 shows results for all three utilization scenarios modeled for savings experienced by reducing demand of utility generated electricity.

Table 8-5. GHG Model Results: Reducing Utility-Generated Electricity.

FF	180 (MW) running 8760 hrs	CO_2	CH_4	N_2O	Total Annual MMTCE	10 Yr Cum	20 Yr Cum
Coal	Full Utilization	0.357	7.88E-05	0.002			
Natural Gas	Full Utilization	0.021	7.90E-06	1.17E-05			
Totals		0.378	8.67E-05	0.002	**0.38**	3.04	6.83
FF	**180 (MW) running 6570 hrs**	**CO2**	**CH4**	**N2O**	**Total Annual MMTCE**	**10 Yr Cum**	**20 Yr Cum**
Coal	Majority Utilization	0.268	5.91E-05	0.001			
Natural Gas	Majority Utilization	0.016	5.93E-06	8.75E-06			
Totals		0.283	6.5E-05	0.001	**0.29**	2.28	5.12
FF	**180 (MW) running 4380 hrs**	**CO2**	**CH4**	**N2O**	**Total Annual MMTCE**	**10 Yr Cum**	**20 Yr Cum**
Coal	Half Utilization	0.178	3.94E-05	0.0008			
Natural Gas	Half Utilization	0.011	3.95E-06	5.84E-06			
Totals		0.189	4.34E-05	0.0008	**0.19**	1.52	3.42

8.2.2 Reducing Existing On-Site Boiler Emissions

As with GHG emissions calculated for reducing electricity generation demand, these emissions are also converted from BBTU to MMTCE via their respective GWP. However, where utility fuel consumption considered Coal and Natural Gas only, on-site boiler emissions reductions also account for reductions in other fossil fuels, such as residual and distillate oil. See table 8-6 for a complete list of emissions factors and combustion efficiencies used in these calculations. Additionally, on-site fuel consumption data from the MAERS database was given in the corresponding units for the following fuels: tons coal, thousand gallons residual oil, thousand gallons distillate oil, and million cubic feet natural gas. Table 8-7 shows the conversion factors used to determine MBTU (and BBTU) equivalents. Of the total reported fuel consumption by Michigan boilers and other facilities, the MCCP team calculated on-site emissions reductions by eliminating emissions that result from 25%[ciii] of total current fuel consumption. This proportion is directly correlated to the total 180 MW generation potential as calculated by the 21CEP and does not change as a result of operating utilization of new CHP facilities. See Table 8-1 for a summary table of the MAERS database.

Table 8-6. Emission Factors and Combustion Efficiency (On-Site Boilers).

Emission Factor	**CO_2** (lbC/MBTU)	**CH_4** (Mton/BBTU)	**N_2O** (Mton/BBTU)
Coal	57.29	0.001	1.403E -03
Natural Gas	31.91	0.00095	9.496E-05
Other Petroleum	46.62788	0.003	0.0006
Combustion Efficiency			
Coal	0.99	0.99	0.99
Natural Gas	0.995	0.995	0.995
Other Petroleum	0.99	0.99	0.99

Table 8-7. Fuel Heat Content Values.

Fuel	**Heat Content**	**Units**
Coal:	24	MMBTU/ton
Distillate Oil:	140	MMBTU/1000 gallons
Residual Oil:	150	MMBTU/1000 gallons
Natural Gas:	1050	MMBTU/M cubic feet

8.2.3 Emissions from New CHP Systems

The MMTCE from the addition of new CHP systems were calculated using the methodology described above. Fuel consumed by new CHP systems was assumed

[ciii]Reductions of 25% follow the 21CEP assumption that 180MW modeled is 25% of total MW generation potential in the state.

to be 100% natural gas. Emissions factors of all three GHGs using natural gas are shown in Table 8-6. For on-site emissions calculations, the MCCP team used a natural gas heat rate of 12,759.64 BTU/kWh. This heat rate represents an average of the heat rates attained when consuming natural gas by each of the existing types of boilers (large, medium, small, and very small[civ]) and other facilities to be replaced. See Appendices E, F, and G for specific GHG model calculations at each of the three MWh utilization scenarios.

8.3 Economic Model

To determine the impact of providing incentives for CHP technology installation, the MCCP team used the Energy 2020 model and the REMI Inc. Policy Insight model. The CHP policy primarily affects the utility industry, as the CHP reduces electricity demand. Implementation of the technology affects electricity demanded from utilities, industry's electricity and fuel costs, fuel imports to the utilities from outside the state, and industry capital costs. A long-term savings potential exists for both the commercial and industrial sectors through on-site electricity generation (often referred to as Distributed Generation) and reduced reliance on utilities. The five major industries contributing to CHP-based generation (and, thus, primarily considered by the economic model) are:

- Automotive/Transportation (43% of total potential).
- Mining/Metal Forming (18% of total potential).
- Pulp/Paper (15% of total potential).
- Chemical/Pharmaceutical (10% of total potential).
- Food Processing (9% of total potential).

8.3.1 Energy 2020

Based on annual energy savings from using CHP, the Energy 2020 model calculated the reduction of future energy generation needed as a result of changes in energy demand for industrial and commercial operations. The baseline projection is a business-as-usual scenario with no tax incentives and no increase in CHP adoption rate. Results of these changes in energy generation in the state were used as inputs into the REMI model and to compare the base-case scenario of energy consumption against the policy scenario.

8.3.2 REMI Assumptions

Results from the Energy 2020 model were input into the REMI model. The following section explains the economic REMI model input variables and rationale, the variable impacts, and the economic sectors affected by subsidizing the adoption of distributed CHP generation. The following is a list of REMI inputs determined by the MCCP team as a result of information provided by the Energy 2020 model.

[civ]Boiler size based on Design Capacity: Large=greater than 100,000 MMBTUH; Medium=25-100,000 MMBTUH; Small=20-25,000 MMBTUH; Very Small=Less than 25,000 MMBTUH (determined by MPSC 21[st]CEP CHP Working Group).

Input Variables and Rationale

- Decreased amount of Production Costs for the Motor Vehicle, Primary Metal, Paper, Chemical, and Food Manufacturing sectors to model the reduced spending on electricity in these sectors due to CHP implementation.
- Reduced amount of Exogenous Final Demand in the Utility sector to model the decreased electricity sales due to CHP implementation.
- Decreased amount of Exogenous Final Demand for Petroleum, Coal Product Manufacturing to model the reduced coal sales due to decreased electricity demand.
- Decreased amount of Production Costs for the Utility sector to model the reduced cost due to reduced electricity production.
- Increased amount of Exogenous Final Demand for Electrical Equipment Manufacturing to model the purchases of CHP equipment by implementing industries.
- Decreased amount of Government Spending on all programs by the state government to model the subsidy the government pays to implementing industries.

Impacts of Model Variables

- Decreased amount of Production Costs for the Motor Vehicle, Primary Metal, Paper, Chemical, and Food Manufacturing sectors have positive impacts on employment and gross state product.
- Reduced amount of Exogenous Final Demand for the Utility sector has negative impacts on employment and gross state product.
- Reduced amount of Exogenous Final Demand for the Petroleum, Coal Product Manufacturing sector has negative impacts on employment and gross state product.
- Decreased amount of Production Costs for the Utility sector has positive impacts on employment and gross state product.
- Increased amount of Exogenous Final Demand for the Electrical Equipment Manufacturing sector has positive impacts on employment and gross state product.
- Decreased amount of Government Spending at the state level has negative impacts on employment and gross state product.

Economic Sectors Impacted

- Sectors positively impacted by the policy include Motor Vehicle, Primary Metal, Paper, Chemical, and Food Product Manufacturing, Wholesale and Retail Trade, and the General Service.
- Negatively impacted sectors include the Construction Sector and Utilities.

The CHP scenario of implementing 180 MW without a state subsidy affects the same sectors of the economy except state government spending. Capital expenditures are higher for the industrial and commercial sectors implementing CHP, and, thus, overall economic impact reflects a combination of those expenditures, reductions in revenues at the utility level, and savings in energy expenditures at the facility level.

8.4 Results and Discussion

By 2025, GHG modeling of the implementation of 180 MW of CHP indicates a reduction of 8.9 Million Metric Tons GHG emissions. This ranks relatively high among the other strategies studied throughout this project. Further exploration into variations of state incentives, such as PTC and ITC, should be conducted to fully understand the potential adoption-rates of CHP and its full GHG reduction and economic potential.

The following results, shown in Table 8-8, were calculated for the CHP incentive. Cumulative economic figures represent the average change to both employment and gross state product in Michigan for the years 2015 and 2025.

8.4.1 Stakeholder Response

During Forum I, MCCP stakeholders rated Tax Incentive strategies as a very high priority for this project. Valuing existing in-state efforts to address GHG emission related issues, specifically with respect to reducing energy consumption, the MCCP team viewed tax incentives related to CHP as highly relevant to the needs and interests of its stakeholders. Despite addressing certain tax-incentive options in the state, this is not an exhaustive analysis of other tax incentive options in the state. The results of this study should not serve as disincentive to CHP adoption; rather, they should serve as an example of emissions reductions and MW generation potential, including the associated costs that can be shared by the state and third-party investors, or as some combination of different incentive levels.

Stakeholder response to this policy reflected a concern that too much state government capital would be required to meet the desired MWh generation potential of in-state CHP systems. The MCCP team intended to show potential investment costs to a particular entity investing in the adoption of CHP and, therefore, does not advocate for the state spending almost 1% of its total budget on CHP.

Table 8-8. Modeling Results.

Scenario	Average in 2015	Average in 2025	Cumulative by 2015	Cumulative by 2025
MMTCE Reduced				
180 MW (8760 hr/yr)			3.96	8.9
180 MW (6570 hr/yr)			2.71	6.09
180 MW (4380 hr/yr)			1.98	4.45
Change in Gross State Product (millions of 2000 dollars)				
$0.05/kWh (8760 hr/yr)	-49.5	-12.2	-445	-230
$0.05/kWh (6570 hr/yr)	-44	-13.6	-400	-260
$0.05/kWh (4380 hr/yr)	-38.5	-15.1	-350	-290
Change in Employment				
$0.05/kWh (8760 hr/yr)	-587	-49	-5280	-930
$0.05/kWh (6570 hr/yr)	-511	-81	-4600	-1540
$0.05/kWh (4380 hr/yr)	-435	-112	-3910	-2140
Change in Gross State Product (millions of 2000 dollars)				
No Subsidy (8760 hr/yr)	26.8	-23.2	-480	-440
No Subsidy (6570 hr/yr)	-49.3	-20.8	-440	-390
No Subsidy (4380 hr/yr)	10.4	-20.5	-350	-380
Change in Employment				
No Subsidy (8760 hr/yr)	-326	29.4	-2940	560
No Subsidy (6570 hr/yr)	-315	-21.4	-2830	-410
No Subsidy (4380 hr/yr)	-305	-74.7	-2750	-1420

8.4.2 Summary of Findings and Considerations

The 21 CEP CHP working group determined that, despite lack of explicit data or inventories of Michigan CHP MW generation potential, the Michigan DEQ MAERS database would be sufficient to estimate total achievable MW generation potential by CHP in the state. The Michigan DEQ MAERS data is the result of state law that requires submittal of emission information from all manufacturing commercial and institutional establishments.[211] Despite its being mandatory that all such entities produce public annual reports on source emissions for criteria pollutants, the database still contains incomplete and inaccurate information. Inaccuracies result from non-participating boiler operators not reflected in the state's total capacity and from incomplete or out-of-date information recorded by participating boiler operators. MW potential was calculated by analyzing the total fuel consumption by each boiler size class and estimating average kW utilization and steam production from assumed capacity and efficiency levels for each size class of boiler in the database.

The model output, representing 180 MW of electricity generation by CHP without a state subsidy, shows a minor overall effect on the state's economy as opposed to providing a subsidy. While the majority of the results are still slightly negative, the non-subsidy adoption of CHP begins to show positive effects on state GSP and employment as a result of on-site energy savings. Without a subsidy drawing down state resources, the on-site energy cost savings from CHP eventually become large enough to offset the large initial capital outlay required to implement CHP systems. (Note: Using data provided by the Midwest Combined Heat and Power Application Center, the MCCP team calculated CHP Gas Turbine systems to include installation costs between $800 and $1,500/kW, and Operating and Maintenance costs between $.005/kWh and $.008/kWh.) The timeframe of the MCCP study is not long enough to show the years in which CHP without a subsidy turns into net positive impacts on the economy. Benefits of CHP systems should be analyzed considering a longer timeline than the timeline utilized in this study. Given this consideration, the MCCP team expects an introductory state subsidy to partially offset initial capital outlay, for installing new CHP systems would result in net positive impacts on the state in the earlier years of adoption.

The majority of the economic impacts of the subsidy are attributed to high levels of spending by the state government. The numbers were negative in the early years of the study because of the large outlay from state government funds allocated to CHP subsidies. More than half of the job loss in the early years came directly from state government resources allocated to CHP subsidies instead of other programs. Later years had positive employment impacts but they were not enough to make up for the initial losses See Appendix M.14 for CHP scenario outputs for each of the years.

In addition, state-funded subsidies should not be the sole mechanism for encouraging the adoption of CHP but should be combined with reducing economic, political, and infrastructural barriers to CHP utilization. Those barriers include back-up and standby rates which contribute to making additional CHP projects[cv] in the state cost prohibitive.[212]

[cv]Those projects not already implemented due to cost effectiveness.

Providing tax incentives or subsidies for CHP will not necessarily remove the largest barrier to CHP adoption. (Back-up and standby rates are rates charged for unplanned electricity consumption due to black-outs or maintenance events when on-site electricity generation is not available, including a charge from the utilities for maintaining the capacity to meet emergency or unplanned electricity needs.)

Individual CHP adopters will have different costs of implementing CHP systems, and, generally, a one- to two-year lag time for a CHP project to go from concept to functionality.[213] Investment costs will vary based on:

- Current energy and/or steam demands of adopter.
- Current energy costs to adopter.
- Ability to sell power to the grid (current barriers include: transmission and interconnection infrastructure and fees and electricity prices).
- Changes in the regulatory nature of the energy market.

Other considerations not captured by this study:

- As adoption and utilization of CHP grow on all scales, projections in the state's energy capacity needs may be considerably reduced; technological innovations may reduce the capital investment, operations, and management costs of CHP systems; and emerging energy markets may better incorporate market demands for CHP-generated electricity.
- Third party investors may emerge in response to growing capacity to sell retail power to the grid.

By 2025, Michigan can experience a reduction of 6.09 MMTCE by generating up to 180 MW of power through CHP systems instead of from utilities. Economic modeling for a state subsidy of $0.05/kWh given to CHP adopters to achieve the full 180 MW was a burden on the state, resulting in negative economic impacts. Similarly, implementing 180 MW of CHP power in the state without a subsidy resulted in slightly negative impacts. However, given the uniqueness of Michigan's quasi-unregulated utility sector, the variety of electricity rates, and substantial standby and back-up fees, the state still needs to consider providing incentives for adopting CHP. These incentives do not necessarily need to be as high as $0.05/kWh. Further exploration into variations of state incentives, such as production and investment tax credits, should be conducted to fully understand potential adoption rates and the range of CHP's potential impacts.

IV. Conclusion

1. Summary of Results

The MCCP demonstrated that enacting policies to reduce GHG emissions can positively affect Michigan's economy. Enacting a set of state-level GHG emission reduction policies has the potential to reduce the state's GHG emissions by 84 MMTCE by 2025, while increasing GSP by an average of $380 million per year, and increasing state employment by an annual average of 3,400 job-years. Table IV.1 displays the cumulative GHG emission reductions and economic impacts that could be realized by implementing a subset of the MCCP policies. The MCCP team screened the complete set of nine policies and excluded those policies with results that could potentially overlap. The resulting subset included the following six policy scenarios described in detail in previous sections of this report:

- **Renewable Portfolio Standard**: *MCCP RPS* (20% renewable by 2025).
- **Renewable Motor Fuel Standard**: *Cellulose and Corn Based Ethanol Supply* (25% RFS by 2025).
- **Carbon Sequestration**: *10% Magland Planted with Conifers* (CRP funding).
- **Appliance Efficiency Standards**: *SB 1333* (Introduced by Senator Brater).
- **Building Codes**: *MCCP 2006* (IECC 2006 and DOE Insulation recommendations according to climate zones).
- **Combined Heat and Power Incentives**: *180 MW, 6,570 hr/yr* ($0.05/ kWh state subsidy).

Table IV.1. Cumulative Impacts of a Subset of MCCP Policies (2007-2025).

	GHG Emission Reductions	Avg. Annual Δ GSP, $	Avg. Annual Δ Job-Years
MCCP Policies	84 MMTCE	380 Million	3,400

Note: All GHG reductions refer to policy-specific BAU scenarios.

Table IV.1 and Figure IV.1 present the contributions of each of the selected policies to the cumulative GHG emission reductions of 84 MMTCE by 2025. The MCCP 2006 RPS scenario drove the largest displacement of GHG emissions at 39.9 MMTCE. This policy would raise the level of renewable electricity sold to Michigan utility customers from the current level of approximately 3% to 20% by 2025. Next, the RFS scenario of 25% renewable motor fuels by 2025 dramatically reduced GHG emissions by 13.2 MMTCE in the transportation sector by shifting a proportion of motor fuel usage from petroleum-based fuels to bio-based fuels. Carbon Sequestration exhibits similar results through the planting of conifers on marginal agricultural land. The MCCP Building Codes scenario, which applies only to new residential construction, and the Appliance Efficiency Standard, based on Senator Brater's bill (SB 1333), each contribute approximately 7.1 MMTCE in GHG emission reductions. Finally, the CHP scenario, based on a state subsidy of $0.05/kWh, produced GHG reductions of 6.09 MMTCE.

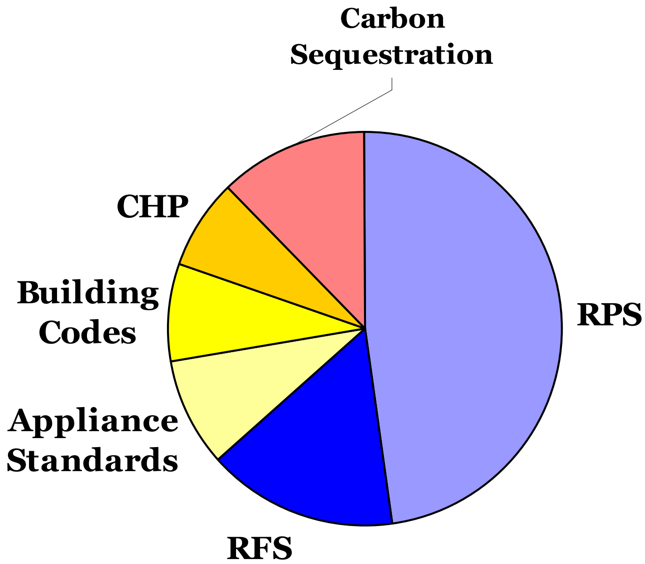


Figure IV.1. Cumulative GHG Emission Reductions (MMTCE) from a Subset of MCCP Policies (2007 – 2025).

Figure IV.2 presents the contributions of the selected policies in the previously identified subset to the $380 million average annual increase in Michigan's GSP. The RFS scenario's 25% contribution by 2025 provides the majority of the average annual increase in Michigan's GSP.

Figure IV.3 presents the contributions of each of the selected policies in the previously identified subset to the average annual increase in Michigan's employment of 3,400 Job-Years. Similar to the GSP results, the RFS scenario contributes the most to the average annual increase in job-years, followed by the RPS and Building Codes scenarios.

The MCCP results show that by focusing on energy efficiency, fuel switching, carbon sequestration, and renewable energy, the state can realize economic benefits. MCCP modeling indicated that the combined economic effects of these policies are a net positive for the state. Only two policies, Carbon Sequestration and Combined Heat and Power Incentives, contributed negative economic effects.

For each policy, benefits and costs vary within and across sectors. While average annual impacts are mostly positive, some individual policies produced negative GSP and employment changes within some years of the modeled time-period. Individual policy results from the GHG and economic modeling are presented in Table IV.2. Output from the Energy 2020 model was used as input for the REMI model, which provides output in the form of job-years. Job-years is distinct from jobs and indicates an average increase in employment in reference to a baseline on a year-by-year basis. For example, 100 job-years is equivalent to either 10 jobs lasting 10 years or 100 jobs lasting one year.

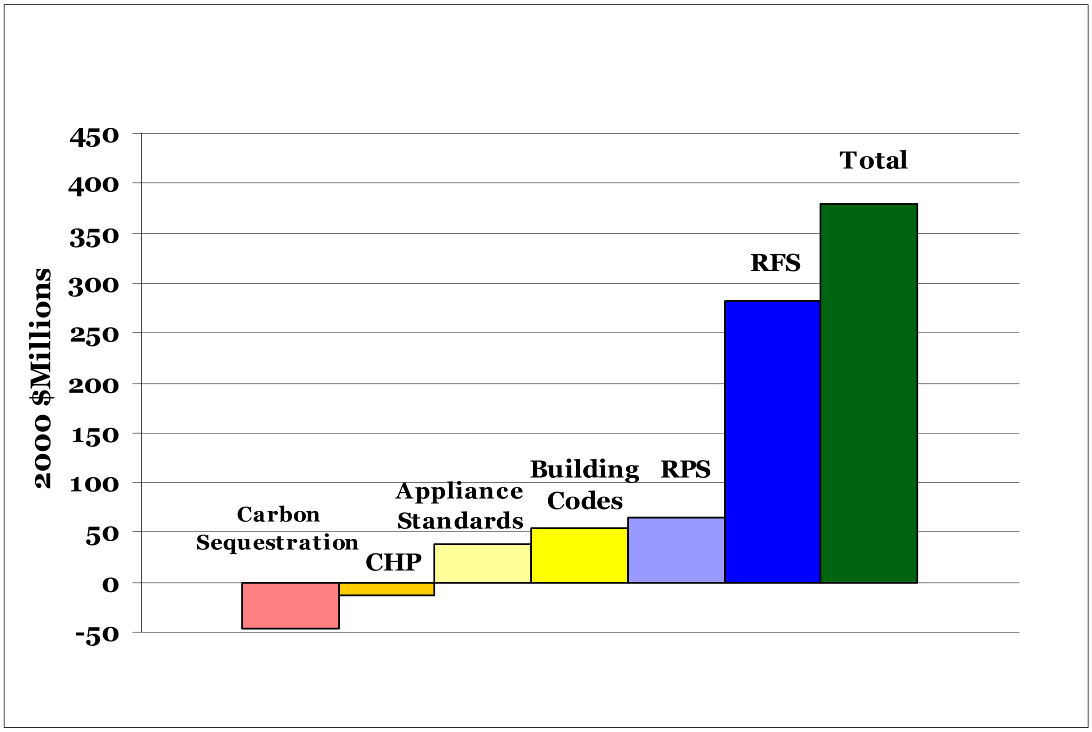


Figure IV.2. Average Annual Changes in Gross State Product from a Subset of MCCP Policies (2007-2025).

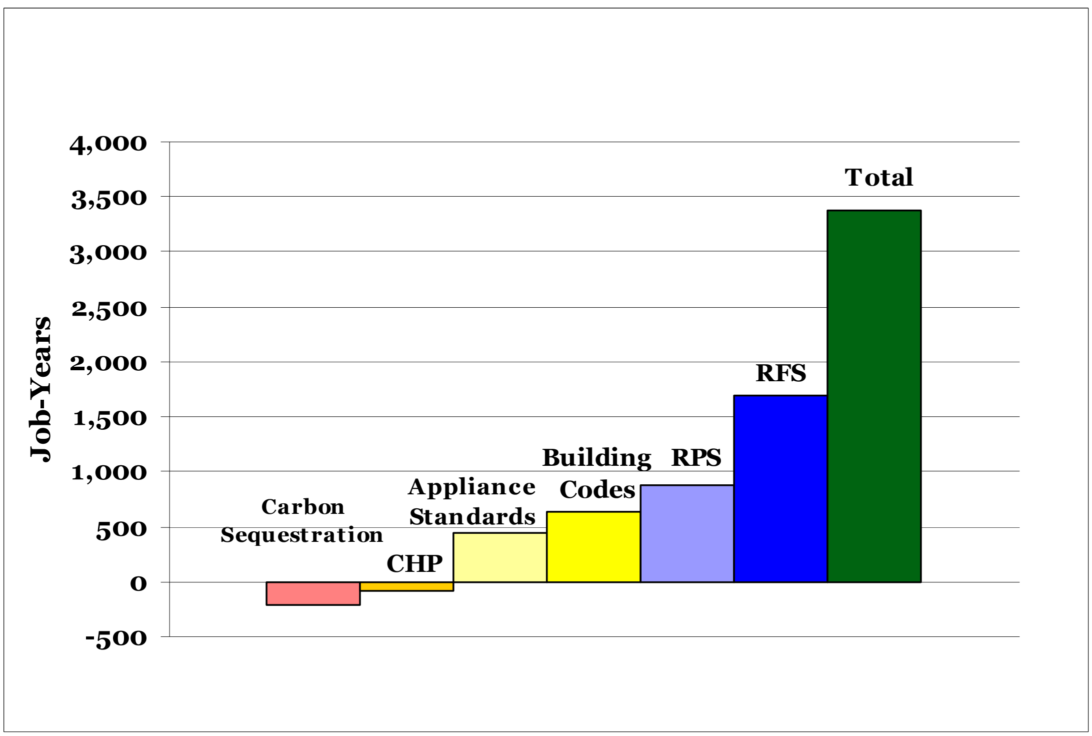


Figure IV.3. Average Annual Changes in Employment from a Subset of MCCP Policies (2007-2025).

Table IV.2. Individual Policy Results: GHG Reduction Potential and Economic Effects (2007-2025).

Policy	Cumulative GHG Savings (MMTCE)	Avg. Annual Δ GSP (2000 $Millions)	Avg. Annual Δ Job-Years
RPS: MCCP RPS (20% renewable by 2025)	**39.9**	**64.6**	**881**
RFS: Cellulose- and Corn-Based Ethanol Supply	**13.2**	**283**	**1,700**
Carbon Sequestration: 10% Magland (CRP)	**10.3**	**-46.7**	**- 212**
Ethanol PTC: Corn Baseline II + Cellulosic	**8.45**	**504**	**2,970**
Appliance Standards: SB 1333	**7.35**	**38.3**	**437**
Building Codes: MCCP 2006	**6.83**	**54**	**644**
CHP - 180 MW, 6,570 hr/yr ($0.05/kWh)	**6.09**	**-13.6**	**-81**
Fuel-Switching: B20 Mandate for Buses	**0.13**	**4.48**	**31**

Note: Negative numbers are primarily due to large government subsidies.
Note: All GHG reductions are in reference to policy-specific scenarios.

2. Context

The *Michigan Greenhouse Gas Inventory 1990 and 2002* indicated that total statewide GHG emissions increased 9% from 57.4 MMTCE in 1990, to 62.6 MMTCE in 2002. In 2002, 33% of Michigan GHG emissions resulted from the production of electricity in the state, 26% from the transportation sector, and 17% from industrial operations.[cvi] The MCCP findings show that the modeled policies represent a wide range of GHG emission reduction potentials.

If state GHG emissions continue to grow by 9% every 12 years (consistent with the Inventory's findings), then Michigan's GHG emissions in 2025 are predicted to be 74.6 MMTCE. In the year 2025, the GHG reductions resulting from the subset of policies (RPS, RFS, Appliance Standards, Carbon Sequestration, CHP, and Building Codes) amounts to 8.9 MMTCE. By implementing the aforementioned subset of MCCP policies, the state could reduce emissions to approximately 65.7 MMTCE, reducing projected GHG emission levels by 12% in the year 2025 (Figure IV.4).

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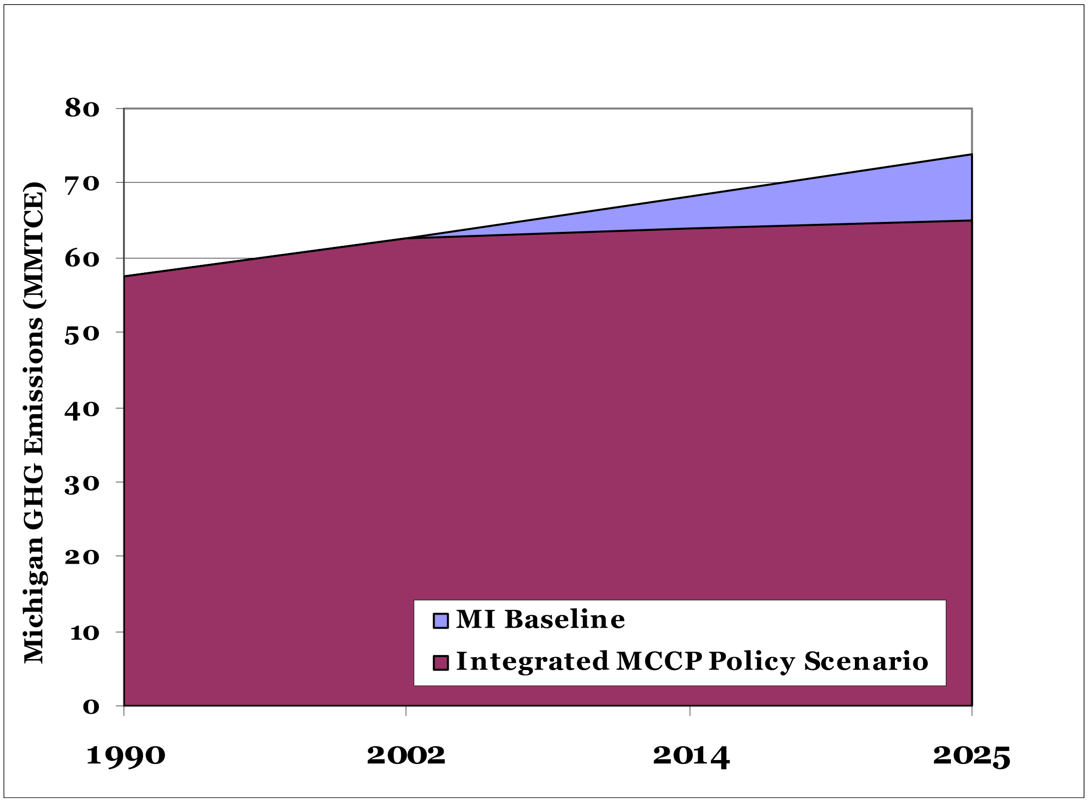

Note: GHG emissions are based on a 12-year growth rate of 9%, as calculated in the *Michigan Greenhouse Gas Inventory 1990 and 2002*.

Figure IV.4. Baseline Michigan GHG Emissions (1990-2025).

The modeled policies only slow the overall growth rate of the state's GHG emissions and are not sufficient to reduce emissions below 2002 levels. Thus, these policies represent only a first step toward stopping the growth of the state's annual GHG emissions. The state will have to take bolder and more far-reaching actions to significantly reduce emissions and to help avoid the adverse consequences of global climate change; simply implementing the MCCP policies is not enough.

3. Stakeholder Input

Throughout the development of the MCCP, the team committed to incorporating the input, concerns, and expertise of Michigan stakeholders. The MCCP team worked with over 150 regional professionals representing the industrial, commercial, higher education, government, and non-profit sectors to develop policy options and parameters for MCCP modeling. These stakeholders identified and prioritized a specific set of strategies for the MCCP investigation and overall modeling process from an initial set of over 70 strategies (as listed in Appendix A). The Michigan stakeholders participated throughout MCCP providing feedback on modeling parameters and results.

Despite representing a range of GHG-reducing options, the MCCP strategies do not represent the full spectrum of policy options. For example, this study did not model the effects of more stringent fuel economy standards imposed on the transportation sector, nor did it consider the benefits of retrofitting existing Michigan buildings to become more energy efficient. If the MCCP team and stakeholders had not considered political feasibility as one of the primary criteria in selecting potential strategies, the team could have investigated and modeled more aggressive GHG-reduction policies.

4. Policy Options

As of September 2006, 29 states had developed State Action Plans (also referred to as Climate Action Plans) specifically targeting GHG emissions reductions. Michigan has yet to develop its own State Action Plan. A major objective of the MCCP was to serve as a starting point for Michigan to understand the various impacts of proactive mechanisms for reducing emissions. The MCCP results serve to inform Michigan leaders about potential paths for the state to become a leader in climate change policy in the Midwest. A responsible economic development strategy for Michigan should position the state to respond to the impacts of impending federal policies intended to reduce GHG emissions. Whether such policies take the form of a mandatory cap-and-trade system, taxes on GHG emissions, or other mechanisms, aggressive action will stimulate and encourage clean energy technology innovations and efficiency improvements that can provide significant economic benefits to the state. By taking immediate action, Michigan could begin to realize the economic benefits generated by GHG reduction policies.

MCCP economic modeling did not account for a future price of carbon, and MCCP considers reported results to be conservative estimates for the economic benefits of these policies in a carbon-constrained world. The Chicago Climate Exchange has been operating a voluntary carbon-trading market since 2003, where carbon prices range from $3.67 -$18.33/MTCE.[cvii] Under this price scenario, the cumulative MCCP GHG emission reductions (84 MMTCE) would be roughly valued between $308 million and $1.54 billion by trading the carbon offsets that these policies produce. While, it was not possible for the MCCP team to model a price of carbon due to the uncertainty of future climate legislation, various federal climate bills provide perspective on the range of potential future carbon prices. The US Department of Energy's Energy Information Administration analyzed proposed bills and predicted future (2025-2030) carbon prices ranging from $52-$180/MTCE.[cviii]

Michigan will need to implement innovative and far-reaching policies to achieve significant reductions in GHG emissions, minimize economic risks, and take advantage of economic opportunities presented by a carbon-constrained world. Starting now can help the state prepare for likely federal action, allow it to assume a leadership position, and stimulate the economy in the process. The policies outlined above can guide the state forward. The MCCP team has demonstrated that environmental improvements can be achieved while creating positive economic outcomes for the state.

[cvii]Chicago Climate Exchange prices have ranged from $1.00-$5.00/metric ton of CO_2-equivalent since the exchange's founding in 2003. Historical prices retrieved Mar. 2007 from: http://www.chicagoclimatex.com/trading/marketData.html.
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Appendix A. Long List of Potential Strategies Considered During Forum I

1. Tailpipe GHG Standards
2. Tax Credit for Alternative Vehicles Technologies Incentives for Production and R&D
3. Feebate Program based on Vehicle Fuel Efficiency
4. Flexible Fuel Initiatives
5. Alternative Fuel Infrastructure/Flexible Fuel Initiatives
6. Gas Tax
7. Low GHG-Fuel Standards
8. Hydrogen Infrastructure Support
9. Eco-driving Training Program
10. Vehicle Inspection and Maintenance Program
11. Mass Transit Enhancement and Development
12. Institution of HOV/Carpool Lanes in High-Density Regions
13. Rideshare Programs
14. Develop Carshare Programs
15. Telecommuting and Live-Near-Your-Work Programs
16. Bike and Pedestrian Infrastructure
17. Parking Pricing/Limitations
18. Vehicle Miles Traveled Tax
19. Brownfield Redevelopment Initiatives
20. Mixed-use Zoning
21. Standards for Clean Diesel
22. Anti-Idling Measures
23. Truck to Train Mode Shift
24. Diesel to Electric Train Conversion
25. Promote More Efficient Airplane Engines
26. Airport Ground Equipment Fuel Switching
27. Tax Incentive Programs
27.a) Fuel Switching
27.b) Process Shifts Away from GHG Emission
27.c) Cogeneration
27.d) Innovative Design; Research and Implementation
27.e) Carbon Capture

27.f) Efficient Production Processes
27.g) Revenue-neutral Tax Incentives
28. Process Energy Efficiency/Cogeneration
29. Participation in Voluntary Programs
30. Renewable Energy
31. Emissions Trading
32. International Programs
33. Soil Management
33.a) Conservation Tillage
33.b) Crop Rotation
33.c) Improve Nitrogen Fertilizer
34. Farm Operations Efficiency
34.a) Improve Farm Efficiency
34.b) Biogas Recovery Systems
34.c) Less Intensive Animal Agriculture Practices
35. Biogas Recovery Systems
36. Biomass for Electricity
37. Biofuels
38. Carbon Sequestration
38.a) Reforestation
38.b) Afforestation
39. Forest Land Preservation
40. Sustainable Timber Harvesting
41. Promote Use of Durable Wood Products
42. Urban Tree Planting Programs
43. Promote Landfill Gas Recovery
44. Expand Recycling Programs
45. Renewable Portfolio Standard/Clean Energy Portfolio
47. Capacity Needs Planning
48. Integrated Resource Planning
49. Production Tax Credit for Renewables/Net Metering
50. Property Tax Exemptions
51. Systems Benefit Charge
53. Distributed Energy

54. Restructure Market Incentives
56. Emissions Trading (Cap and Trade, Chicago Climate Exchange)
57. Leadership in Energy and Environmental Design (LEED) or Energy Star Buildings
58. Revise Building Codes
58.a) Residential
58.b) Commercial
58.c) Industrial
58.d) Schools/Universities
59. Weatherization Programs
60. Energy Audits
61. Energy-Efficient Mortgages
62. Demand-Side Management
63. Promoting Energy Star Appliances
64. Education Programs for Green Building
65. Michigan State Pension funds in Green Investing
66. Promoting Local Food Consumption
67. Encouraging Eating Lower on the Food Chain
68. Energy Efficiency for State Buildings
69. State Vehicle Fleet Standards
70. Green Power Purchase Requirements
71. State GHG Registry
72. Designation of CO_2 as Air Pollutant

Appendix B. Forum I and II Stakeholder Organizations

American Council for an Energy Efficient Economy
Cascade Engineering
Clear the Air
Consumers Energy
Council of Great Lakes Industries
Daimler Chrysler Corporation
Decker Energy International
Delphi
DTE Energy
Duke Energy
Ecology Center
Electric Cooperative Association
Energy Conversion Devices
Environment Michigan
Ford Motor Company
General Motors
Great Lakes Renewable Energy Association
Haworth
Herman Miller
Holcim
Indigo Financial Group
Johnson Controls
Kenetex Management Solutions
Mackinaw Power
MI Allied Poultry Industries
MI Corn Office
MI Department of Agriculture
MI Department of Environmental Quality Air Quality Division
MI Department of Labor and Economic Growth Energy Office
MI Department of Labor and Economic Growth/Bureau of Construction Codes/Building Division
MI Department of Labor and Economic Growth/Bureau of Construction Codes/Plan Review Division
MI Department of Natural Resources Forest, Mineral and Fire Management
MI Farmers Union
MI Governor’s Office
MI House of Representatives
MI Interfaith Power and Light
MI Pork Producers Association
MI Public Service Commission
Michigan Dept of Agriculture
Michigan Environmental Council
Michigan Manufacturing Technology Center
National Environmental Trust
National Wildlife Federation Great Lakes Office
Newman Consulting Group
Next Energy

Noble Environmental Power
Oakland Community College
Public Interest Research Group in Michigan
Shepherd Advisors
Small Business Association of Michigan (SBAM)
Steelcase
Sustainable Research Group
The Nature Conservancy-Michigan
Third Planet Wind Power
United Steelworkers
University of Michigan
Urban Options
Visteon
WARM Training
Wolverine Power Cooperative

Appendix C. Slides from Forum I and Forum II

Note: Some slides shown at Forum II have been updated to reflect more accurate modeling results.

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

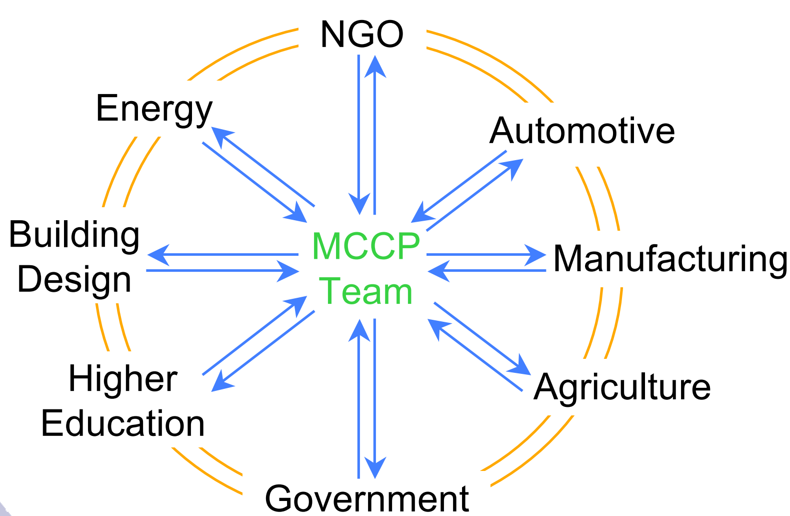
Forum I

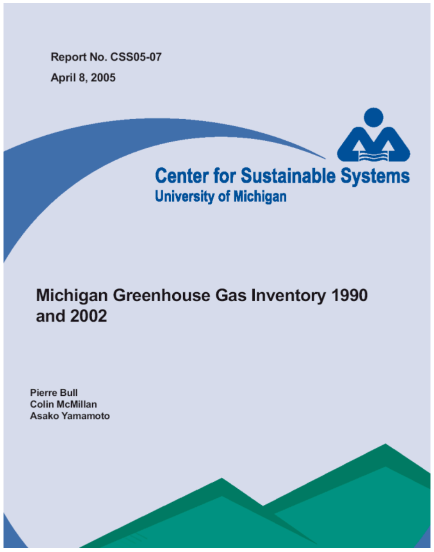
January 31, 2006

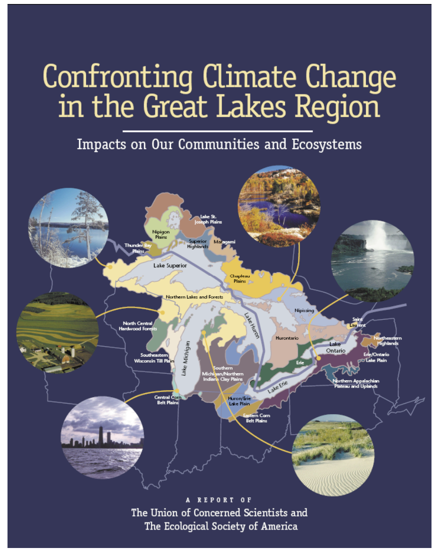
Center for Sustainable Systems
University of Michigan

Michigan at a Climate Crossroads

Welcome and Introductions



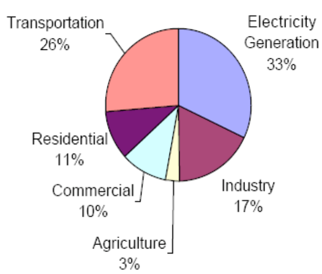




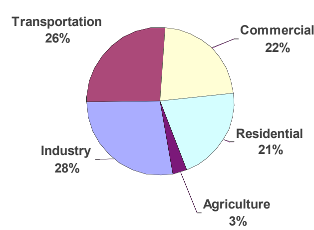
Michigan GHG Inventory

Emissions Sector Breakdown

IPCC Category	Emissions (MMTCE) 1990	Emissions (MMTCE) 2002	Percent Change (1990 to 2002)	Percent of Total Emissions 1990	Percent of Total Emissions 2002
Energy	50.16	54.25	8.2%	87.4%	86.7%
Industrial Processes	1.79	3.06	70.9%	1.6%	2.5%
Agriculture	1.92	1.87	-2.7%	2.0%	1.6%
Waste	3.55	3.40	-4.2%	6.6%	5.8%
Total	**57.42**	**62.59**	**9.0%**	**100%**	**100%**

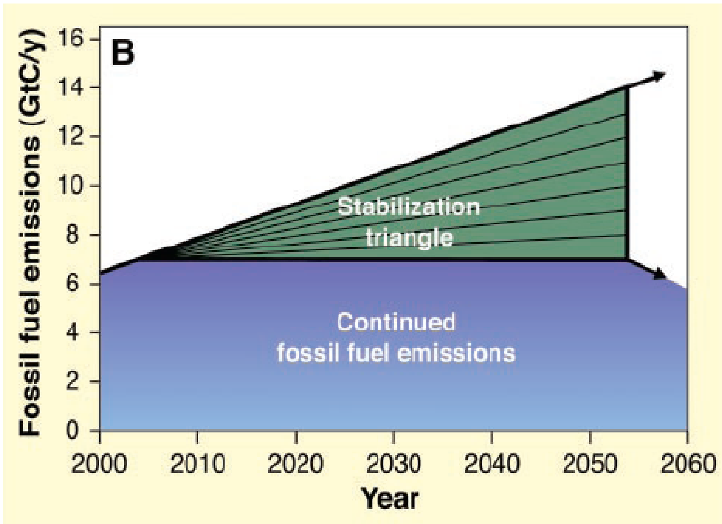


2002 GHG Emissions



2002 GHG Emissions with Electricity

Stabilization Wedges



U.S. State GHG Reduction Goals

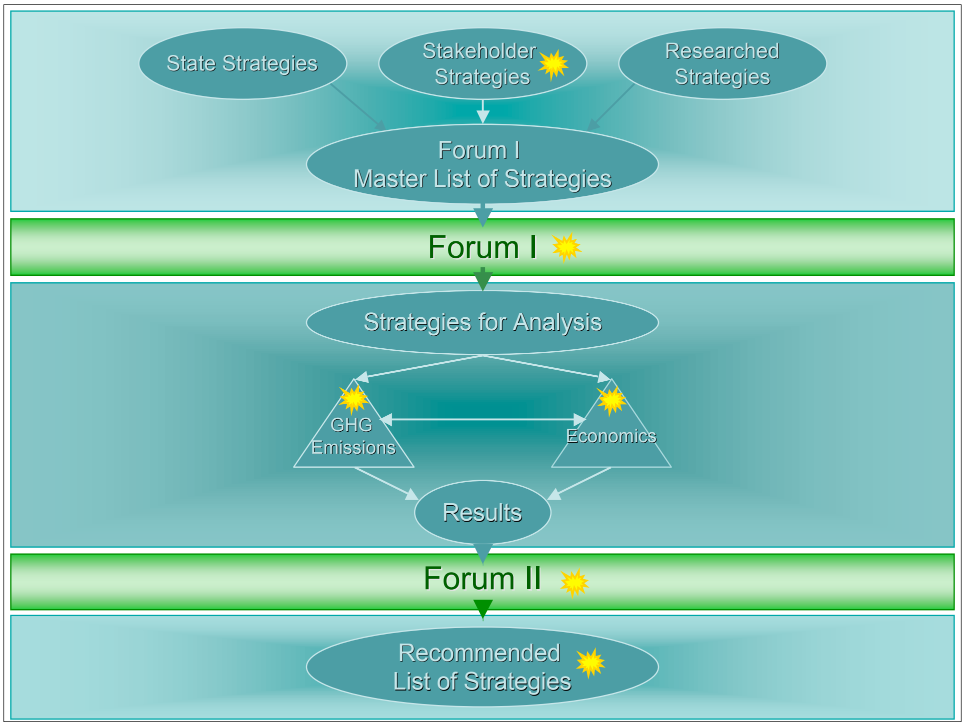
- California – 11% below current levels over the next five years, 25% by 2020, and 80% by 2050
  - Executive order of the governor
- New Mexico – 2000 levels by 2012, 10% below 2000 levels by 2020, and a 75% reduction below 2000 levels by 2050
  - Executive order of the governor
- Connecticut – 1990 levels by 2010, 10% below 1990 levels by 2020, eventually reaching the long-term reduction goal of 75%.
  - State Law SB 712
- Ohio – 65% to 85% reduction in current levels by 2100
  - OH Climate Road Map (state of the science goal)
- Kentucky – List of Proposed Policy Strategies that would result in emissions at 1990 levels
  - Climate Action Plan proposal

MCC Project Goal

Examine and recommend to the state government strategies for reducing greenhouse gas emissions in Michigan that will most optimally position the state in a future with further carbon restrictions.

Potential Outcomes

- Present creative and innovative methods for addressing GHG emissions
- Position the state to successfully navigate a carbon constricted world
- Reduce absolute GHG emissions
- Create jobs with businesses and industries that are less carbon intensive
- Contribute to the development of regional and national climate policy



Parameters of Analysis

- GHG Emission Reduction Potential
  - Percent reduced from baseline (1990, 2002, BAU)
  - Total in-state reduction
  - Total global reduction from MI manufactured products
- Economic Indicators
  - Per Gross State Product
  - Job growth potential

"Preliminary modeling indicates that just eight policies that were analyzed in detail can achieve almost half of the Governor's 2020 targets while increasing Gross State Product by about $60 billion and creating over 20,000 new jobs."

- *Managing Greenhouse Gas Emissions in California*
The Climate Change Center at UC Berkeley

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Forum I

January 31, 2006

10:45 am Session

Professor Barry Rabe

Lessons from Other States

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Forum I

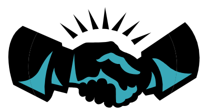
January 31, 2006

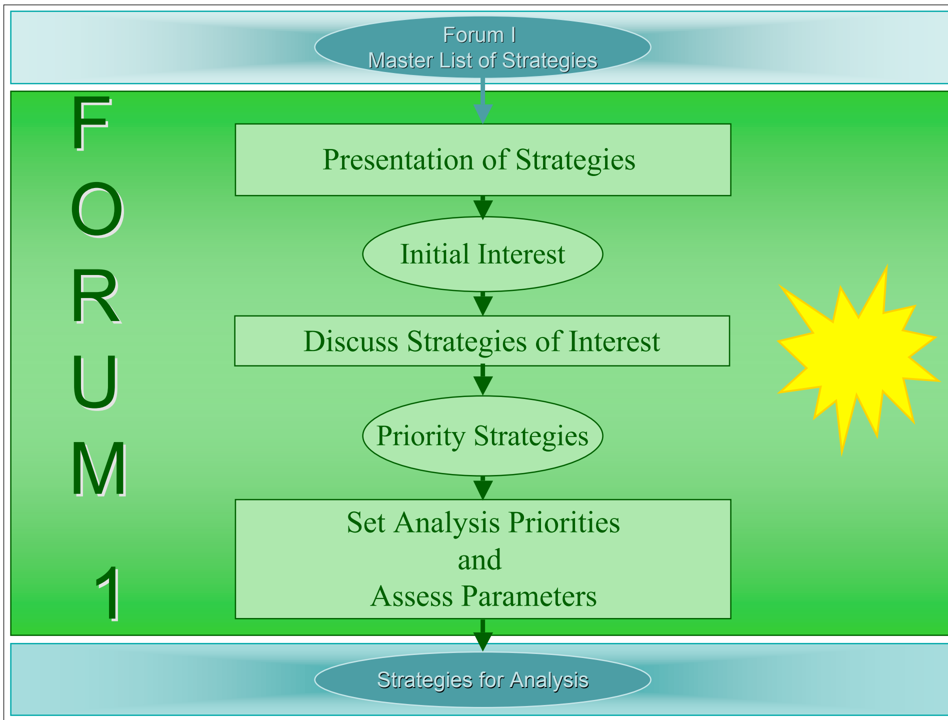
11:00 am Session

Forum I Guidelines and Objectives

Forum I Guidelines

- Review and Approve





Overview of Strategies (Grouped by Targeted Sector)

- Results of Questionnaire
- Definitions for Specific Strategies
- Examples from other states
- Existing programs in Michigan

- (The MCCP team does not advocate any specific strategy. Rather, we are interested in gaining a better understanding of the potential strategies that Michigan can use as it faces a carbon-constrained world.)

Indicate interest in specific strategies

- Review Strategies Posted around the room
- Identify two strategies in each sector that you wish to discuss further
- Indicate interest by placing sticker adjacent to that strategy

Initial Interest

- How well does this strategy enhance your organization's ability to reduce GHG emissions?
- What short term and long term implications does this strategy have regarding economic development and jobs?
- How well does this strategy reduce statewide/global GHG emissions?
  - And position the state to successfully navigate a carbon constrained world?
- What potential does this strategy have regarding implementation in Michigan?

Discuss Specific Strategies

- Why is this strategy important for the group to discuss?
- Of the strategies you are most interested in, what more would you like to know?

Priority Strategies

- Which strategies are of high priority? (Please indicate using three green stickers provided)
- What strategies should CSS develop in-depth analysis of?

Develop Priority List for Further Analysis

- Recommendation for strategy parameters.

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Forum I

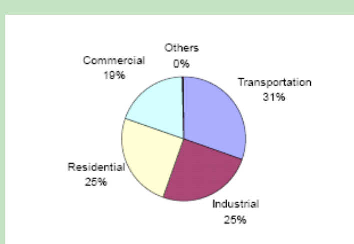
January 31, 2006

11:15 am Session

Presentation of Strategies and Questionnaire Results

Transportation

- Passenger Vehicles (Vehicle, Fuel, Driver)
- Freight
- Aviation
- Vehicle Miles Traveled (VMT) Reduction



Transportation Strategies

Vehicle Technology

1. Tailpipe GHG Standards
2. Tax Credit for Alternative Vehicle Technology
3. Feebate Program based on Vehicle Fuel Efficiency

Fuel

4. Flexible Fuel Initiatives
5. Alternative Fuel Infrastructure
6. Gas Tax
7. Low GHG-Fuel Standards
8. Hydrogen Infrastructure Support

Driver

9. Eco-driving Training Program
10. Vehicle Inspection and Maintenance Program

Transportation Strategies

VMT Reduction

11. Mass Transit Enhancement and Development
12. Institution of HOV/Carpool Lanes in high density regions
13. Rideshare Programs
14. Develop Carshare Programs
15. Telecommuting and Live-Near-Your Work Programs
16. Bike and Pedestrian Infrastructure
17. Parking Pricing/Limitations
18. Vehicle Miles Traveled Tax
19. Brownfield Redevelopment Initiatives
20. Mixed-use Zoning

Freight

21. Standards for Clean Diesel
22. Anti-Idling Measures
23. Truck to Train Mode Shift
24. Diesel to Electric Train Conversion

Aviation

25. Promote More Efficient Airplane Engines
26. Airport Ground Equipment Fuel Switching

Transportation Supporting Information

Alternative Vehicle Technologies (AVT)

- Advanced Internal Combustion Engine (ICE)
- Diesel ICE
- ICE Hybrid Electric Vehicle (HEV)
- Diesel HEV
- Fuel Cell (FC)

Alternative Fuels

- Ethanol (EXX, where XX is the percent of mix)
- Biodiesel
- Fischer-Tropsch Diesel (FT-Diesel)
- Compressed Natural Gas (CNG)
- Liquefied Petroleum Gas (LPG)
- Hydrogen (H2)

Vehicle

Promote and support development and commercialization of alternative vehicle technologies.

- Tailpipe GHG Standards
  - CA LEV II – Emission Standards for CO_2
    – Advanced Technology Vehicle Program
  - Adopted or being considered for adoption in several states
- Tax Credit for Incremental Cost of Purchase or Retrofit
- Feebate Program based on Vehicle Fuel Efficiency

Fuel

Promote and support development and distribution of alternative fuels.

- Flexible Fuel Initiatives
- Alternative Fuel Infrastructure
  - Tax Incentives for construction, reconstruction or acquisition of Alternative Fuel refueling stations
- Gas Tax
  - $0.17/gallon on E85 v. $0.203/gallon on conventional
- Adopt Standards for Low GHG-Fuel Types
  - Ethanol and biodiesel meeting ASTM standards

Fuel

Promote and support development and distribution of alternative fuels.

- Hydrogen Infrastructure Support
  - Hydrogen Highway
    - Build a network of refueling stations
    - Ensure H2 vehicles are commercially available
    - Incorporate H2 vehicles in state fleet
    - Safety standards and permitting for H2 refueling stations
    - Incentives to encourage green sources of H2 production
  - Michigan Hydrogen Infrastructure Initiatives
    - Michigan NextEnergy Authority

Driver

- Eco-driving Training Program
- Vehicle Inspection and Maintenance Program
  - Efficient Tire and Inflation
  - Annual tail pipe emission inspections

VMT Reduction

- Mass Transit Enhancement and Development
  - SEMCOG – 2030 Regional Transportation Plan
    - Ann Arbor to Detroit Rapid Transit Study
  - Grand Rapids – The Citizen's Agenda for Transit
- Institute HOV/Carpool Lanes in high density regions
- Rideshare Programs
  - Promote/Expand MichiVan Commuter Van Pools
- Develop Carshare Programs in high density regions
- Telecommuting and Live-Near-Your Work Programs
- Bike and Pedestrian Infrastructure
  - SW MI Non-motorized Project Planning (MDOT)
- Parking Pricing/Limitations
- Vehicle Miles Traveled Tax
  - Toll Roads, Insurance per mile

VMT Reduction

Smart Growth Initiatives

- Brownfield Redevelopment Initiatives
  - Brownfield Grant and Loan Program (2004 – SB805)
  - Michigan Land Use Institute – 2006 recommendations
- Mixed-use Zoning
  - Planned Unit Developments – Mixed Land Use/Open Space Preservation - (2004 – HB4666, 4667, 4668)
  - Program for working with 1,800 local governments to move towards traditional neighborhood developments

Freight

- Standards for Clean Diesel
  - Low Black Carbon Fuels – Ultra Low Sulfur Fuel (ULSF)
  - Federal Requirement for ULSF – June 2006
- Anti-Idling Measures
  - Truck Stop Electrification w/Enforcement Programs
- Truck to Train Mode Shift
  - MI Rail Loan Assistance Program (MDOT)
- Diesel to Electric Train Conversion
  - Electricity Production Methods?

Aviation

- Promote more efficient airplane engines
- Airport Ground Equipment

Manufacturing and Industry

•Industry in Michigan

•Potential Strategies

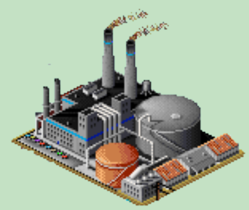
Survey Results

Current Programs and Initiatives

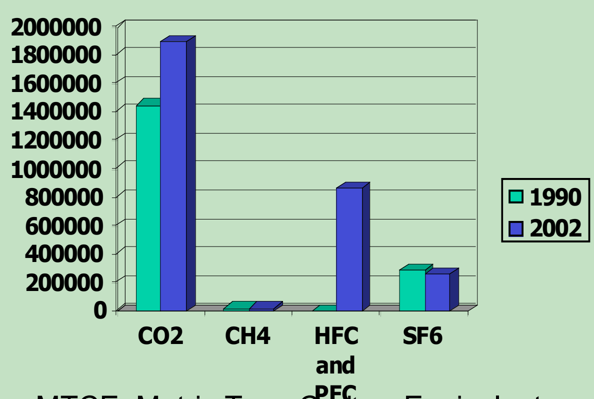
Programs and Initiatives in Other States

Major Industry in Michigan

- Manufacturing: Transportation equipment, machinery, fabricated metal, office furniture, plastics
- Iron and Steel Production
- Cement Manufacture
- Lime Manufacture
- Limestone and Dolomite Use
- Semiconductor Manufacture
- Magnesium Casting
- Electric Power Transmission and Distribution Systems
- Pulp and Paper



Industrial Process Greenhouse Gas Emissions: 1990 and 2002

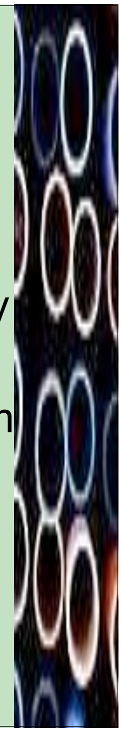


MTCE: Metric Tons Carbon Equivalent

Source: Michigan Greenhouse Gas Inventory, 2005, Center for Sustainable Systems

Potential Strategies

- 27. Tax Incentive Programs
- 28. Alternative Processes and Energy Efficiency
- 29. Participation in Voluntary Program
- 30. Renewable Energy
- 31. Emissions Trading
- 32. International Programs



Tax Incentive Programs

- Fuel Switching
  - Use of less carbon intensive fuels
- Process shifts away from GHG emission
- Cogeneration
- Innovative Design; Research and Implementation
  - Lightweight automotive materials

Tax Incentive Programs

- Carbon Capture
- Efficient Production Processes
  - Leakages, continuously adjusting variable speed motors
- Revenue-Neutral Tax Incentives
  - i.e.: Decrease payroll taxes, increase electricity taxes.

Alternative Processes and Energy Efficiency

- Water Conservation
- Carbon Capture
- CO_2 in cement production
- HFC's in cooling systems
- Energy Efficient Procurement Practices
- Recycling
- Energy Efficiency Audits

Participation in Voluntary Programs

- Join EPA's Climate Leaders
- *U.S. EPA voluntary SF_6 reduction program:* Major Magnesium facilities in Michigan (from 1999 to 2002, SF_6 output from Industry reduced by 10.8%)

Renewable Energy

- Green Power Purchasing
- On-Site Generation

Emissions Trading

- Cap and Trade - Industry-Specific Cap and Trade in Europe
- Offsets
- Trading and complying under the EU Emission Trading Directive

International Programs

- Participate in Joint Implementation and Clean Development Mechanism projects globally (JI/CDM)
- International Emissions Trading Association

Agriculture, Forestry & Waste Management



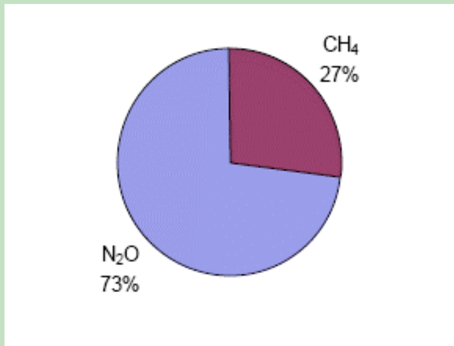
Agriculture, Forestry and Waste Management Strategies

Agriculture
- 33. Soil Management
- 34. Farm Operations Efficiency
- 35. Biogas Recovery Systems
- 36. Biomass for Electricity
- 37. Biofuels

Forestry
- 38. Carbon Sequestration
- 39. Forest Land Preservation
- 40. Sustainable Timber Harvesting
- 41. Promote Use of Durable Wood Products
- 42. Urban Tree Planting Programs

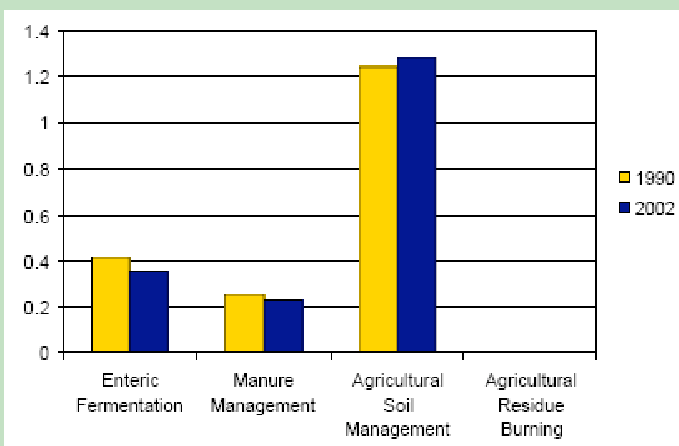
Waste Management
- 43. Promote Landfill Gas Recovery
- 44. Expand Recycling Programs

Agriculture Emissions by Gas (Carbon-Equivalent Adjusted) in 2002



Source: MI GHG INVENTORY 1990 and 2002

Agriculture Emissions Categories in 1990 and 2002 (MMTCE)



Source: MI GHG INVENTORY 1990 and 2002

Agriculture Strategies
Soil Management Incentives

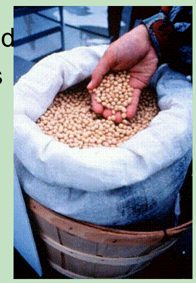
- Conservation Tillage
  - Low till or no till agriculture saves diesel fuel and helps reduce soil erosion
- Crop Rotation
  - Improves the overall efficiency of nitrogen uptake and utilization in the soil
- Improve Nitrogen Fertilizer Efficiency
  - Reduces CO_2 associated with fertilizer manufacturing
  - Reduces emissions of N_20

Agriculture Strategies
Farm Operations Efficiency

- Improve Farm Efficiency
- Biogas Recovery Systems
  - Anaerobic digester with biogas capture and combustion to produce electricity, heat or hot water
- Less Intensive Animal Agriculture Practices
  - Consumers willing to pay premium for sustainably produced products

Agriculture Strategies
Biomass

- Biomass for Electricity
  - Renewable organic matter
  - Used for electricity production, cogeneration of heat and power, space heating and transportation fuels
- Biofuels
  - Energy crops like switch grass, sugar beets, soy and corn can be converted into alternative fuels such as methanol, ethanol and biodiesel
  - Potential to use brownfield sites for crops

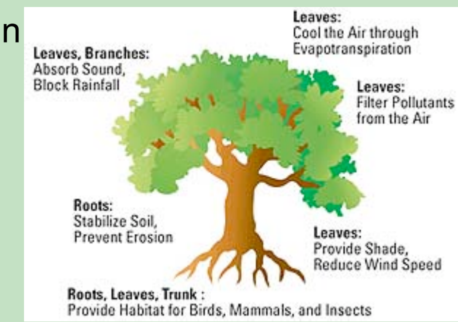


Forestry Strategies

- Carbon Sequestration
  - Reforestation
  - Afforestation
- Forest Land Preservation
- Sustainable Timber Harvesting

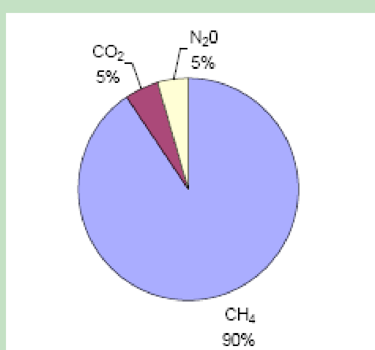
Forestry Strategies

- Promote Use of Durable Wood Products
  - Serve as long-term storage for CO_2
- Urban Tree Planting Programs
  - Reduces air-conditioning use
  - Heat Island Mitigation



Waste Management

Distribution of Waste Emissions by GHG Type (Carbon-Equivalent Adjusted) in 2002



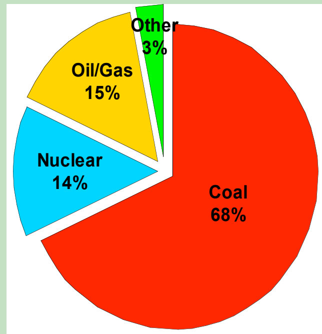
Source: MI GHG INVENTORY 1990 and 2002

Waste Management Strategies

- Promote Landfill Gas Recovery
  - Landfill gas can be captured, converted and used as an energy source
- Expand Recycling Programs
  - Statewide recycling programs (NJ)
  - Increase wood fiber products recycling

Michigan Electricity Generation and Building Energy Use

Electricity Generation



Current Generation Mix in Michigan

Lower GHG Options

- Combined Heat and Power Facilities
- Renewable Energy Development
- Integrated Gasification Combined Cycle
- Landfill Gas Combustion

Electricity Generation Strategies

- 45. Renewable Portfolio Standard
- 46. Clean Energy Portfolio Standard
- 47. Capacity Needs Planning
- 48. Integrated Resource Planning
- 49. Production Tax Credit for Renewables
- 50. Property Tax Exemptions
- 51. Systems Benefit Charge
- 52. Plant Switching/Fuel Switching
- 53. Distributed Energy
- 54. Restructure Market Incentives
- 55. Net Metering
- 56. Emissions Trading

Building Strategies

- 57. Leadership in Energy and Environmental Design (LEED) or Energy Star Buildings
- 58. Revise Building Codes
  - Residential
  - Commercial
  - Industrial
  - Schools/Universities
- 59. Weatherization Programs
- 60. Energy Audits
- 61. Energy Efficient Mortgages

Energy Planning

- Capacity Needs Planning- prioritize renewables and energy efficiency measures
- Integrated Resource Planning- require utilities to assess future generation needs and include renewables and energy efficiency

Generation Source

- Plant Switching/Fuel Switching- Using low emission plants first, develop low emission plants for replacement
- Distributed Energy- Reduce need for use of transmission lines, line losses

Tax Strategies

- Production Tax Credit- tax credit for every KWh produced
- Property Value Tax Exemption- no property tax on the added value from renewable energy development
- Systems Benefit Charge/Public Benefit Fund- fee added to customer electricity bills for energy programs

Additional Strategies

- Restructure Market Incentives (Pricing)- ex. Based on time of day
- Net Metering- allows small generators to use energy on site and sell excess into the grid
- Emissions Trading- market system utilizing renewable energy credits
- Fuel Mix and Emissions Disclosure
  - Already exists in Michigan

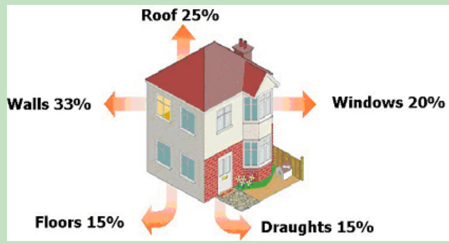
Building Energy

Building Types

- Residential
- Commercial
- Industrial
- Schools/Universities

Building Energy Efficiency

- Insulation
- Water Heating
- Roofing
- Lighting
- HVAC



Source:
http://www.salford.gov.uk

Building Energy Strategies

- Leadership in Energy and Environmental Design (LEED) or Energy Star Buildings
- Revise Building Codes
- Weatherization Programs
- Energy Audits
- Energy Efficient Mortgages

Education, Outreach, & Government Strategies

- 62. Demand-Side Management
- 63. Promoting Energy Star Appliances
- 64. Education Programs for Green Building
- 65. Socially Responsible Investing
- 66-67. Food Consumption Initiatives
- 68. Energy Efficiency for State Buildings
- 69. State Vehicle Fleet Standards
- 70. Green Power Purchase Requirements
- 71. State GHG Registry
- 72. Designation of CO_2 as Air Pollutant

Demand-Side Management

- Encourage citizen energy conservation:
  - reducing energy consumption
  - increasing energy efficiency
  - shifting energy demand to off-peak hours

Seattle City Light

– Commitment to meet all load growth with conservation and renewable energy (2000)

– DSM efforts: energy audits, weatherization grants, incentives & technical assistance to small businesses

Promoting Energy Star Appliances

- Small Business Association of Michigan currently operates a small business Energy Star promotion program
- Use SBAM as a model, and expand promotion to citizens, government agencies, nonprofit organizations, and others.

Education Programs for Green Building

- Training contractors, architects, builders, and operators about green building processes.
- BUILT SMART[SM] certification (Seattle City Light)
- Establishing student training programs
  - Example: Mascaro Sustainability Initiative (Univ. of Pittsburgh Engineering School)
  - Seven $55,000 seed grants to start academic programs in green engineering

Socially Responsible Investing

- Encourage individual and institutional investors to screen portfolios for companies that:
  - Produce few GHG emissions
  - Are substantially reducing GHG emissions

Food Consumption Initiatives

- Encourage consumption of local foods
  - Reduces transportation emissions
  - Strengthens local economies
- Encourage eating less meat and animal products
  - Energy savings from eating lower on the food chain

Energy Efficiency for State Buildings

- This strategy would require all buildings that are either owned, funded, or leased by the state to meet an energy efficiency standard.
- California requires 20% reduction (below 2003 levels) in state building energy use by 2015.

State Vehicle Fleet Standards

- This strategy would require vehicles in state government fleets to meet a specified fuel economy standard.
- California's emissions reduction standards require a ~30% GHG reduction by model year 2016.
- Connecticut requires 40 mpg fleet average.

Green Power Purchase Requirements

- State government and universities required to purchase a percentage of its electricity from "green power" programs.
- Pennsylvania (1999) 5%; doubled to 10% (2003)
- New Jersey (1999) 10%
- Chicago (2001) 10%
  - increases to 20% this year (2006)
- Maryland (2002) 20%
  - at least half from solar and wind.

Additional Potential Strategies

- Establish a registry to document existing GHG emissions
  - NH, WI, CA have registries
  - Michigan discussing Great Lakes regional registry
- Designate CO_2 as an air pollutant.

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Forum I

January 31, 2006

12:15 pm Lunch

Dean Rosina Bierbaum

Indicate Initial Interest in Strategies

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Forum I

January 31, 2006

1:15 pm Session

Strategy Discussion and Feedback

Facilitated by: Professor Tom Lyon and Professor Jonathan Bulkley

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Forum I

January 31, 2006

2:20 pm Break

Indicate Strategy Priorities for Analysis

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Forum I

January 31, 2006

2:45 pm Session

Set Priorities and Discuss Parameters

Facilitated by: Professor Tom Lyon

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Forum I

January 31, 2006

3:45 pm Wrap-up

Next Steps

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Forum II

October 25, 2006

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Forum II

October 25, 2006

9:00 am Session

Welcome and Introductions

Michigan at a Climate Crossroads

Project Team

- ❖ Mike Edison – MS/MBA
- ❖ Kate Elliott – MS/MBA
- ❖ Bernie Fischlowitz-Roberts – MS/MPP
- ❖ Rachel Permut – MS/MBA
- ❖ Sarah Popp – MS
- ❖ Andy Winkelman – MPP

Michigan at a Climate Crossroads

Forum II Goals

- ❖ Presentation of policy results and preliminary analysis of GHG emissions reductions and economic impacts
- ❖ Gathering stakeholder feedback on polices, modeling results, and implications
- ❖ Exploration of where and how the study's results can be most effectively applied to best position the state in a carbon-constrained world

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Forum II

October 25, 2006

9:15 am Session

General Overview, Project Goals and Results

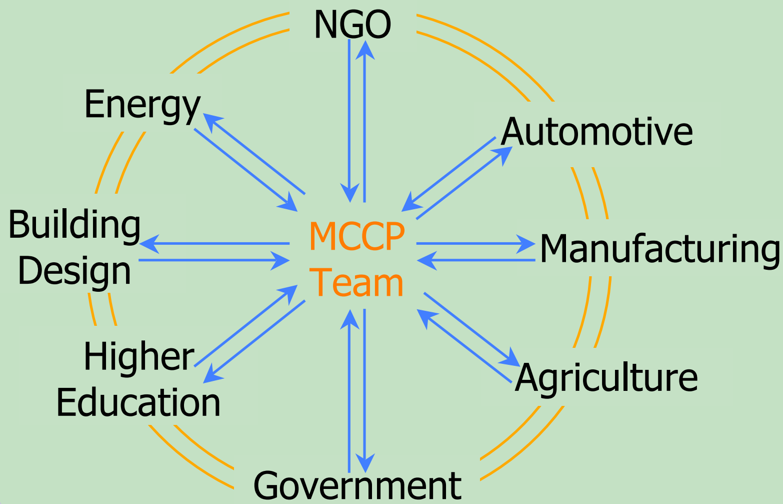
Purpose Statement

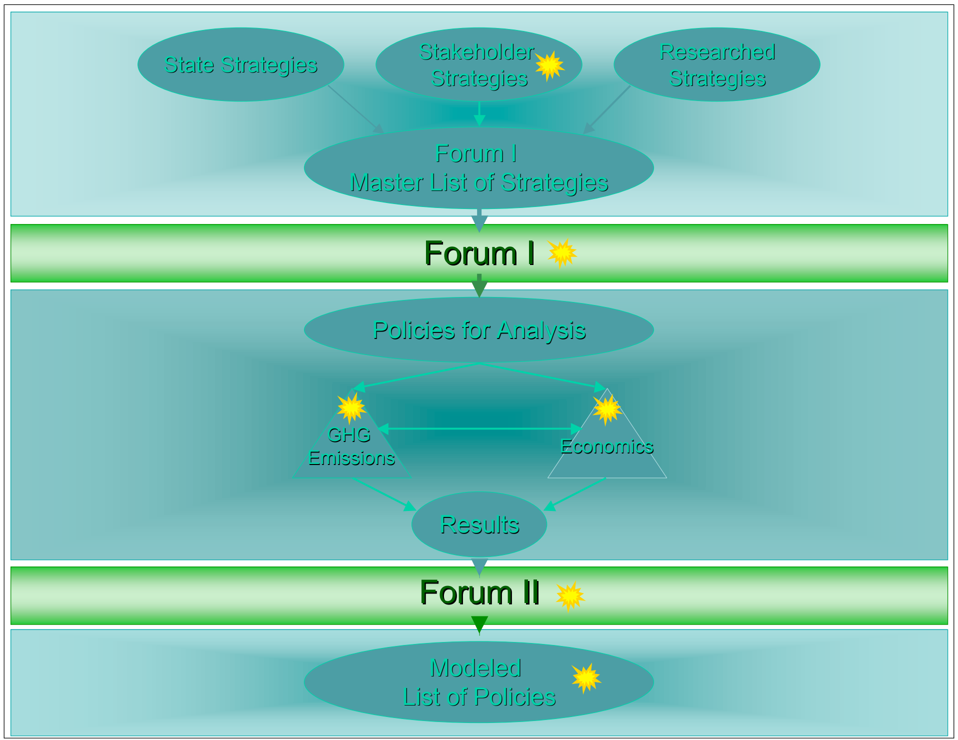
To determine the *greenhouse gas emissions reduction potential* of state policies selected by a multi-stakeholder collaborative and the effect of the policies on the state economy in terms of *gross state product and jobs*.

Target Strategies

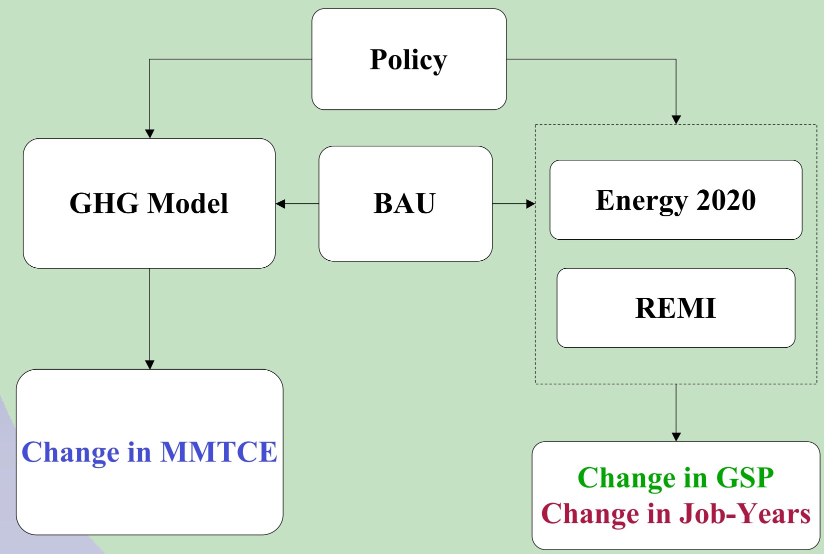
1	Renewable Portfolio Standard
2	Demand-Side Management
3	Alternative Fuels
4	Carbon Sequestration
5	Building Codes
6	Mass Transit
7	Production Tax Credit for Renewables
8	Tax Credit for Alternative Vehicles Technologies
9	Tax Incentive Programs/Cogeneration

Stakeholder Input throughout project development:





Modeling the Policies



GHG and Economic Results
Best Case Scenario by 2025

Policy	Cumulative GHG Savings (MMTCE)	Avg. Annual GSP (2000 $Millions)	Avg. Annual Jobs-Years
MCCP RPS	39.9	64.6	881
RFS w/ Cellulosic Ethanol	13.2	283	1,700
Carbon Sequestration	10.3	-46.7	-212
Ethanol PTC	8.45	504	2,970
Appliance Standards	7.35	38.3	437
MCCP Building Codes	6.83	54	644
Combined Heat and Power	6.09	-13.6	-81
Mass Transit – Fuel-Switch	0.13	4.48	31

Context: The Big Picture

- **62.59 MMTCE**: Michigan Annual GHG Emissions (2002, MI GHG Inventory)
- Estimated 9% growth in Michigan's GHG emissions every 12 years
  - Resulting 2025 emissions: **74.36 MMTCE**
- **65.5 MMTCE:** 2025 GHG emissions after implementing a subset of MCCP policies
  - MCCP policies combined will result in savings of **8.86 MMTCE** in 2025,12% of projected BAU emissions in 2025

Greenhouse Gas Modeling Methodology

Greenhouse Gases Modeled

- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxide (N_2O)

Modeling Tool: Microsoft Excel

Modeling Methodology

Activity **X** Pollutant Emission Factor **=** Pollutant Emission Rate **X** GWP Factor **=** MMTCE

MMTCE – Million Metric Tons of Carbon Equivalent
GWP – Global Warming Potential

- CO2 = 1
- CH4 = 21
- N2O = 310

Greenhouse Gas Modeling Methodology

Activity		*Emission Factor*		*Emission Rate*		*GWP Factor*		*Emissions*
Tons of Coal Burned	X	metric ton CO_2 per ton of coal	=	metric ton of CO_2	X	1 MTCE/ MT CO_2	=	MMTCE
Vehicle Miles Traveled	X	metric ton N_2O per VMT	=	metric ton of N_2O	X	310 MTCE/ MT N_2O	=	MMTCE
MMBtu Heat Loss from Building	X	metric ton CH_4 per MMBtu of Heat	=	metric ton of CH_4	X	21 MTCE/ MT CH_4	=	MMTCE

Greenhouse Gas Modeling Methodology

Model Input Creation

- Identify activity associated with policy, e.g.:
  - RPS: MW electricity generation
  - RFS: Gallons of Alternative Fuel
- Develop baseline activity levels
- Develop policy derived activity levels
- Research appropriate GHG emission factors for activity

Model Calculation Option 1:

- Calculate net affect of policy from baseline at the activity level
- Calculate net GHG emissions associated with policy

Model Calculation Option 2:

- Calculate GHG emissions associated with baseline activity
- Calculate GHG emissions associated with policy activity
- Calculate net GHG emissions associated with policy

Regional Economic Models, Inc. (REMI) Policy Insight Model

- Developed in 1980
- General Equilibrium Model - combining features of Input-Output and econometric models
- Regional scope: national, state, or sub-state regions
- MCCP: state of Michigan as one region
- Calibrated with Bureau of Economic Analysis data for Michigan
- Baseline is created by projecting trends into the future
- Divides the state economy into 70 sectors (NAICS codes)
- Allows the user to manipulate hundreds of different policy input variables
- Primary output variables: Changes to Employment and Gross State Product

REMI

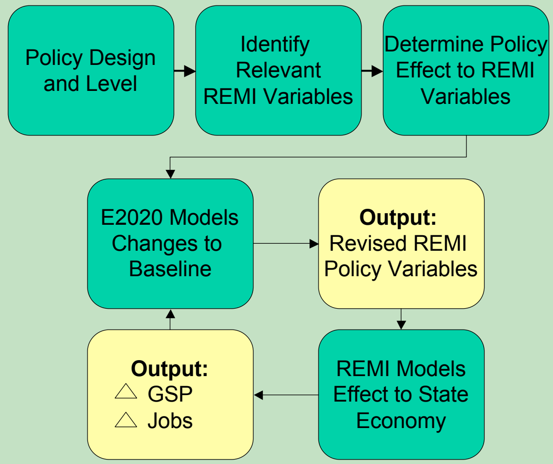
Century

Energy 2020

- Developed by Systematic Solutions, Inc.
- Model designed specifically for modeling changes to the energy sector
- Covers electric utilities, transportation, extraction industries, and related regulatory agencies
- Calibrated to the state of Michigan using historical data and REMI's baseline forecast
- The future baseline was then modified to match the Capacity Needs Forum (CNF) projections

ENERGY 2020
Energy Solutions for the 21st Century

Modeling the Policies



REMI

ENERGY 2020
Energy Solutions for the 21st Century

Strengths and Weaknesses

- Works very well for policies that mandate change, especially for the electricity sector
  - RPS, Building Codes, DSM
- Works well for transportation policies
  - Mass Transit, Renewable Fuel Standard, Ethanol Production
- Weaker performance with subsidy policies
  - CHP, Renewable Production Tax Credit, Alternative Vehicles
- Did not take into account future climate change legislation
  - Too many variations in structure and timing of potential policies
  - Difficult to determine how much of the economic impact was from national legislation versus state policies
  - In general, any national legislation would support the economic viability of these policies (i.e., Carbon Sequestration)

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Forum II

October 25, 2006

10:15 am Session

Policy Presentations and Modeling Results

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Renewable Portfolio Standard

Renewable Portfolio Standard

Policy: Requires regulated electric utilities to obtain specified percentages of their electricity from renewable sources by given dates, with intermediate targets.

Purpose: Promote expanded electricity generation from renewable sources and reduce GHG emissions in the state.

- ***Michigan Sustainable Energy Coalition (MSEC) RPS***:
  8% renewable by 2015
- ***Michigan at a Climate Crossroads (MCCP) RPS***:
  10% renewable by 2015, and 20% renewable by 2025

Qualifying renewable resources include: existing renewables, new wind, solar, geothermal, biomass, landfill gas, and hydro (no pump storage).

Renewable Portfolio Standard

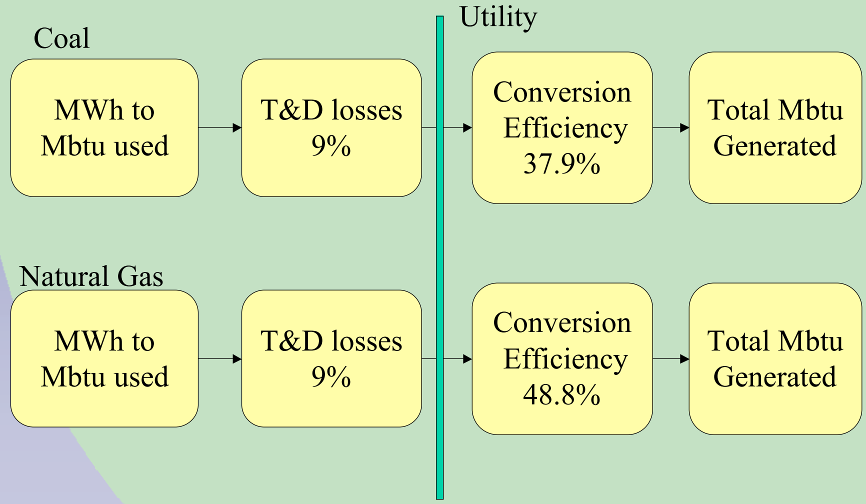
GHG Modeling Methodology

Model Inputs: 2004 Electricity Sales Data and MI Regulated Utility Fuel Mixes

Baseline Assumptions

- Projected annual rate of demand growth: 1.10% (CNF)
- Transmission & Distribution losses: 9% (EIA)
- Power plant conversion efficiencies from U.S. EPA data
- Michigan-specific emissions factors from DOE-EIA
- Kept generation from nuclear, hydro, oil, landfill gas, & wood constant
- Annual growth of renewables: 1.10% (biomass, wind, solar)
- Remaining demand met by coal (88%) and natural gas (12%)

GHG Modeling Methodology for Electric Utilities



Renewable Portfolio Standard

GHG Modeling Methodology

RPS Policy Assumptions

- ❖ New renewables allocated to wind (87%), biomass (12%), solar (1%)
- ❖ Remaining demand not fulfilled by renewables met by coal (88%) & natural gas (12%)
- ❖ Net emissions calculated by multiplying fuel-specific emission factors by difference in sales of each fuel between Baseline and RPS cases

Renewable Portfolio Standard

Economic Modeling Methodology

- Two economic scenarios:
  - No change in renewable energy industries in the state occurs
  - RPS brings more renewable energy industries into Michigan

Effects

- Utility Sector Production and Fuel Costs: decrease for renewables relative to fossil fuels
- Utility Capital Costs (per MW generated): increase for renewables relative to fossil fuels
- Electricity Prices: increase initially during construction of new renewables, then drop below baseline
- Consumer Spending: changes in household expenses for electricity

Renewable Portfolio Standard

Policy Results

Cumulative Greenhouse Gas Emission Reductions		
	MMTCE by 2015	MMTCE by 2025
MSEC RPS	6.37	20.05
MCCP RPS	7.73	39.86

Average Annual Economic Effects		
	Change in GSP (millions 2000 fixed $)	Change in Job-Years
MSEC RPS	144	1,390
MCCP RPS	64.6	881

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Renewable Energy Production Tax Credit

Renewable Energy Production Tax Credit

Policy: Incentivize renewable energy development with a $0.015 tax credit, max $4,000 over 10 years..

Purpose: Encourage renewable energy development

GHG Model Methodology

Assuming 0.5% increase in renewables annually above baseline

Economic Model Methodology

N/A

Policy Results

2.14 MMTCE cumulative reductions

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Building Codes

Building Codes Strategy

Mandatory Residential Energy Codes

Policies:

1) Adopt 2004 International Residential Code
2) Adopt R-values proposed by MCCP

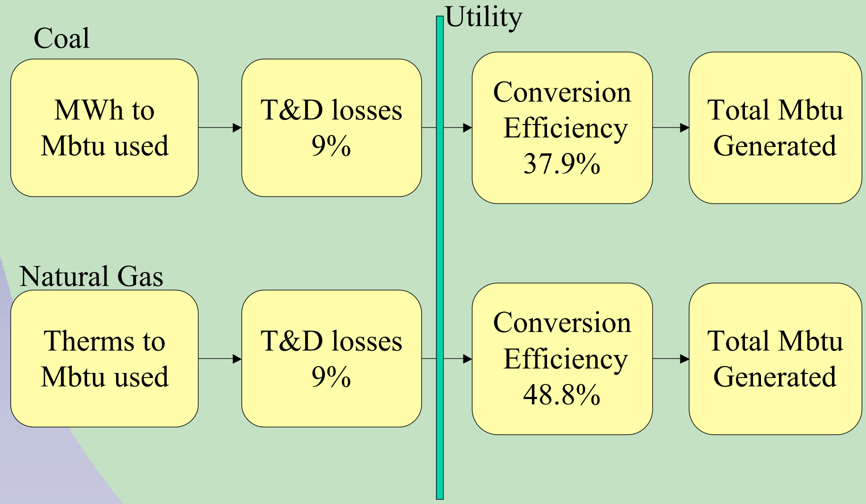
Purpose: Reduce residential energy usage by increasing efficiency of building envelopes.

Highest Regional R-Values Under Different Codes

R-values actually modeled vary by IECC region

	Current	IRC	MCCP
Walls	R-19	R-21	R-26
Floor	R-30	R-21	R-30
Roof	R-38	R-49	R-49
Basement	R-5	R-19	R-19

GHG Modeling Methodology for Electric Utilities



Building Codes Strategy

Mandatory Residential Energy Code

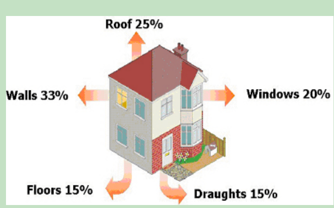
GHG Modeling Methodology

Home Energy Saver

❖Used Lawrence Berkeley Lab's **Home Energy Saver** model to determine the effects of different R-values in homes of different sizes in different climate regions within Michigan

❖Number of homes of each size and climate weighted based on past five years U.S. Census Data for new home starts in each county

❖Used DOE-EIA Michigan-specific utility emission factors



Building Codes Strategy

Mandatory Residential Energy Codes

Economic Modeling Methodology

- 2% increase in home prices from energy efficiency additions

Effects

- Consumer Utility Bills: reduction from increased efficiency
- Consumer Spending: reallocated to other consumer expenditures
- Construction Industry: reduced from capital expenses in utility sector
- Utility Sector: reduced expenditures on fuel and capital expenses

Building Codes Strategy

Mandatory Residential Energy Code

Policy Results

Cumulative Greenhouse Gas Emission Reductions		
	MMTCE by 2015	**MMTCE by 2025**
IRC 2004	1.01	3.85
MCCP 2006	1.35	5.51

Average Annual Economic Effects		
	Change in GSP (millions 2000 fixed $)	**Change in Job-Years**
IRC 2004	18.8	200
MCCP 2006	54	644

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Demand Side Management

Demand Side Management Strategy

Appliance Efficiency Standard

Policy: Mandatory State Appliance Efficiency Standard based on SB 1333 (Sponsor: Senator Brater)

Purpose: Reduce state energy consumption by increasing appliance efficiency

Included Appliances	
1. Bottle type water dispensers	9. Metal halide lamp fixtures
2. Commercial boilers (gas)	10. Pool heaters (natural gas)
3. Commercial hot food holding cabinets	11. Portable electric spas
4. Compact audio products	12. Residential furnace (electricity)
5. DVD Players and recorders	13. Residential boilers (natural gas)
6. Liquid immersed distribution transformers	14. Single voltage external AC-DC power supplies
7. Medium voltage dry type distribution transformers	15. State regulated incandescent reflector lamps
8. Walk-in fridges and freezers	

Demand Side Management Strategy

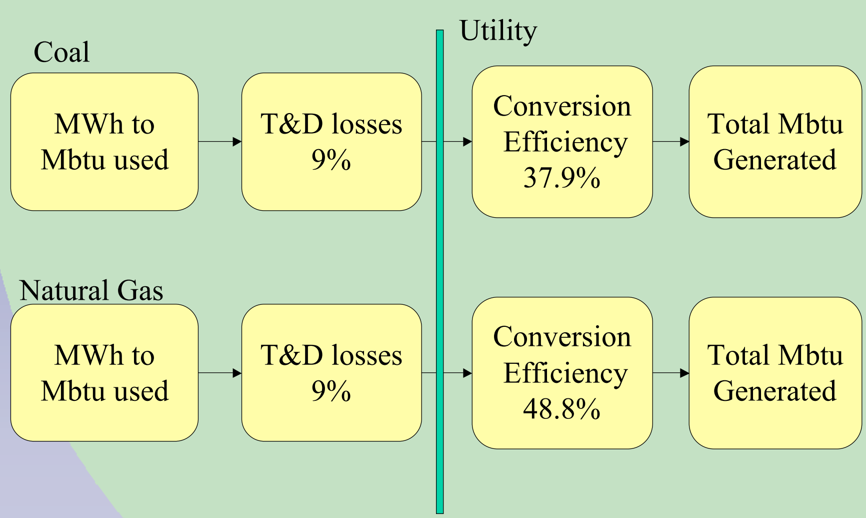
Appliance Efficiency Standard

GHG Modeling Methodology

Calculate reductions in energy demanded of the grid and reductions in on-site natural gas consumption for each projected appliance purchased in the state over the model timeframe.

- ❖ Energy savings calculated using ACEEE data
- ❖ Emissions reductions reflect graduated purchases of appliances with higher efficiencies based on appliance life cycles
- ❖ Michigan-specific utility emission factors used for both electricity and natural gas (data from EIA DOE)

GHG Modeling Methodology for Electric Utilities



Demand Side Management Strategy

Appliance Efficiency Standard

Economic Modeling Methodology

❖Appliance efficiency standards affects in-state purchasing and in-state sales of regulated appliances.

Effects

❖Utility production costs: Reduced as a result of lower production

❖Consumer energy costs: Reduced as a result of lower energy demand

❖Utility sales: Reduced as a result of lower demand

❖Consumer spending: Redistributed as a result of energy savings

Demand Side Management Strategy

Appliance Efficiency Standard

Policy Results

Cumulative Greenhouse Gas Emissions Reductions		
	MMTCE by 2015	**MMTCE by 2025**
Mandatory Standard	**--**	**7.35**

Average Annual Economic Effects by 2025	
Change in GSP (millions 2000 fixed $)	**Change in Job-Years**
38.3	**437**

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Tax Incentives/ Cogeneration

Tax Incentives

Combined Heat and Power

Policy: Subsidy provided on a per kWh basis for new CHP systems

Purpose: To capture MW generation potential from Distributed Generation

- ❖Developed in line with the 21st Century Energy Plan estimations of MW generation potential in Michigan (approximately 180 MW/ year)

21st Century Energy Plan

Model Scenarios:

- ❖$.015/kWh subsidy
- ❖$.05/kWh subsidy
- ❖$.07/kWh subsidy

Tax Incentives

Combined Heat and Power

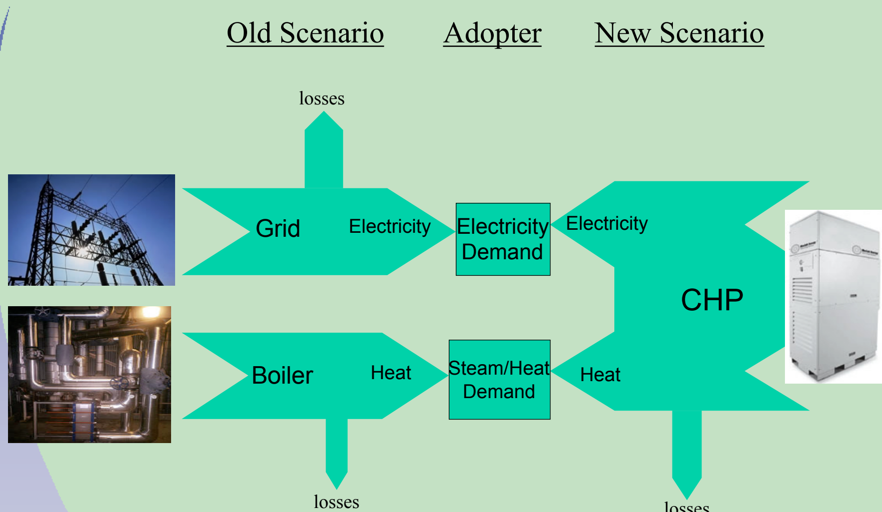
GHG Modeling Methodology

Activity

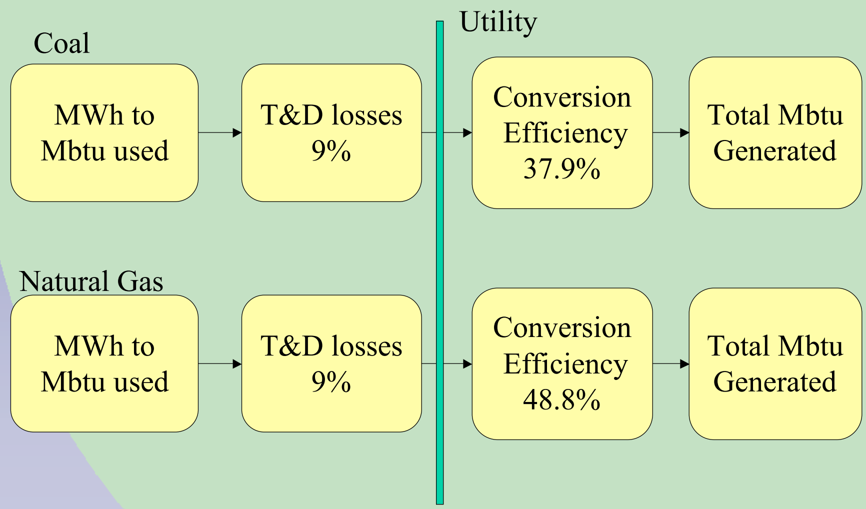
❖Reduce electricity demanded of the grid
❖Reduce emissions resulting from existing boilers
❖Increase natural gas consumption from new CHP systems.

Operating Capacity

❖Full-time operation (8,760 hr/yr)
❖Part time operation (5,840 hr/yr)
❖Half-time operation (4,380 hr/yr)



GHG Modeling Methodology for Electric Utilities



Tax Incentives

Combined Heat and Power

Economic Modeling Methodology

Commercial, Industrial and other sectors adopt CHP based on current levels of steam and electricity consumption

Effects

❖Five major industries contribute to estimated MW potential:
- •Automotive/Transportation (43%)
- •Mining/Metal Forming (18%)
- •Pulp/Paper (15%)
- •Chemical/Pharmaceutical (10%)
- •Food Processing (9%)

❖Utility production costs: Reduced
❖Utility sales: Reduced
❖Consumer energy costs: Reduced
❖State expenditure: Increased

Tax Incentives

Combined Heat and Power

Policy Results

Cumulative Greenhouse Gas Emissions Reductions		
	MMTCE by 2015	**MMTCE by 2025**
180 MW, 8760 hr/yr	**3.96**	**8.9**
180MW, 6570 hr/yr	**2.71**	**6.09**
180 MW, 4380 hr/yr	**1.98**	**4.45**

Average Annual Economic Effects by 2025		
Assumed 6,570 hr/yr	**Change in GSP (millions 2000 fixed $)**	**Change in Job-Years**
$.05/kWh	**-13.6**	**-81**
No Subsidy	**-20.8**	**-21.4**

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Carbon Sequestration

Carbon Sequestration Strategy

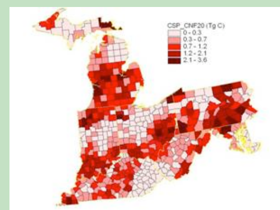
Afforestation of Marginal Agricultural Lands

Policy: Cost-sharing incentive for non-industrial private landowners to establish afforestation projects on marginal agricultural lands

Purpose: Offset carbon emissions using afforestation projects on marginal agricultural lands

Model Scenarios:

- ❖1% of marginal agricultural lands afforested with conifers
- ❖10% of marginal agricultural lands afforested with conifers



Carbon Sequestration Strategy

Afforestation of Marginal Agricultural Lands

GHG Modeling Methodology

Activities:

❖Identified acres of available maglands according to a Midwest Regional Carbon Sequestration Partnership report. Maglands defined as:

- oSeverely-eroded prime cropland
- oNon-eroded marginal cropland
- oSeverely-eroded marginal cropland
- oSeverely-eroded pastureland
- oNon-eroded marginal pastureland
- oSeverely-eroded marginal pastureland
- oBarren land

MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

❖Staggered conifer plantings over 10 years

GHG Emissions Factors:

❖Chicago Climate Exchange dense planting sequestration rates for conifer above-ground biomass (0.98 – 1.37 MTCE/yr/acre)

Carbon Sequestration Strategy

Afforestation of Marginal Agricultural Lands

Economic Modeling Methodology

Total cost to implement afforestation projects includes soil preparation, tree planting and site maintenance

Effects

❖Forestry sector output increases as a result of new tree planting projects

❖State government spending increases due to the cost of implementing the cost-share program

❖Changes in the farm sector to compensate farmers participating in the cost-share program

Carbon Sequestration Strategy

Afforestation of Marginal Agricultural Lands

Policy Results

Cumulative Greenhouse Gas Emission Reductions		
	MMTCE by 2015	**MMTCE by 2025**
1% Afforestation w/ white spruce	**0.28**	**1.03**
10% Afforestation w/ white spruce	**2.81**	**10.3**

Average Annual Economic Effects		
	Change in GSP (millions 2000 fixed $)	**Change in Job-Years**
1% Afforestation – CRP funding	**- 4.67**	**- 21.1**
10% Afforestation – CRP funding	**- 46.7**	**- 212**

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Mass Transit

Mass Transit Enhancement Strategy

Mandatory Use of B20 in Urban Transit Buses

Policy: Mandate use of biodiesel (B20) in all diesel-powered urban public transit buses.

Purpose: Promote use of Michigan-produced biodiesel

Included Urban Transit Agencies	
Ann Arbor Transit Authority	Kalamazoo Metro Transit
Battle Creek Transit	Lake Erie Transit - Monroe
Bay Metro Transit Authority	Macatawa Area Express - Holland
Blue Water Transportation Authority	Muskegon Area Transit System
Capital Area Transportation Authority	The Rapid - Grand Rapids
Detroit Department of Transportation	Saginaw Transit Authority Regional Services
Flint Mass Transportation Authority	Suburban Mobility Authority for Regional Transportation
Jackson Transit Authority	University of Michigan Transit Services *

Mass Transit Enhancement Strategy

Mandatory Use of B20 in Urban Transit Buses

GHG Modeling Methodology

Activities:

- ❖ Projected future diesel and B20 fuel use by urban transit authorities (gallons)
- ❖ Converted projected fuel use to miles, based on transit bus fuel economy

GHG Emission Factors:

- ❖ U.S. Department of Energy/ U.S. Department of Agriculture Well-to-wheel emission factors for diesel and B20 (g CO_2/ miles traveled)

Mass Transit Enhancement Strategy

Mandatory Use of B20 in Urban Transit Buses

Effects

❖Construction sector firm sales increase due to building a new 5 million gallons per year biodiesel refinery

❖Decrease in demand for petroleum products

❖Increase in electrical equipment manufacturing due to a new biodiesel refinery

❖Increase in industry sales for the chemical sector

❖Increase in agricultural inputs. Represented by intermediary inputs to the chemical sector

Mass Transit Enhancement Strategy

Mandatory Use of B20 in Urban Transit Buses

Policy Results

Cumulative Greenhouse Gas Emission Reductions		
	MMTCE by 2015	**MMTCE by 2025**
DOE/ DOA Emission Factors	**0.06**	**.13**

Average Annual Economic Effects		
	Change in GSP (millions 2000 fixed $)	**Change in Job- Years**
Mandatory B20 Use	**4.48**	**31.2**

Michigan at a Climate Crossroads:

Strategies for Guiding the State in a Carbon Constrained World

Alternative Vehicle Technology & Alternative Fuels

Transportation Strategies

Tax Credit for Alternative Vehicle Technology

Policy: Five year (2007-2011) state funded automobile consumer tax credit for eligible alternative vehicle technologies

- Light Duty Car Average Credit: $500 - $10,500
- Light Duty Truck Average Credit: $1,500 - $9,500

Purpose: Promote development and commercialization of alternative vehicle technologies

Alternative Technologies	
Compressed Natural Gas Bi-fuel	Electric-Gasoline Hybrid
Compressed Natural Gas ICE	Fuel Cell Hydrogen
Electric-Diesel Hybrid	Liquefied Petroleum Gas Bi-fuel
Ethanol-Flex Fuel ICE	Liquefied Petroleum Gas ICE
Ethanol ICE	Fuel Cell Methanol
Electric Vehicle	Methanol-Flex Fuel ICE
Fuel Cell Gasoline	Methanol ICE

Transportation Strategies

Tax Credit for Alternative Vehicle Technology

GHG Modeling Methodology

well-to-wheel analysis

Activity

- VMT by new AVT and VMT by displaced conventional vehicles

DOE AER: Baseline Vehicle Sales 2007 - 2025 → Market Share By LD Vehicle Type → Econ Modeling: Increased AVT Market Share → EPA Vehicle Age VMT Profile → **Policy Affected VMT by Vehicle Type**

Emission Factor

- GREET: WTW grams per VMT for a mix of LDC and LDT

Transportation Strategies

Tax Credit for Alternative Vehicle Technology

Economic Modeling Methodology

Sticker price reduction, from baseline, of alternative vehicle technologies

Effects

- ❖ Vehicle Adoption: Increases for AVT compared to conventional vehicles
- ❖ Demand for Petroleum Products: Reduced
- ❖ Demand for Chemical Sector: Increases; acting as a surrogate for agriculture and biorefining
- ❖ State Government Spending: Increases per AVT purchased

Transportation Strategies

Tax Credit for Alternative Vehicle Technology

Policy Results

- ❖ Economic modeling still being developed to properly capture the adoption of AVT due to tax subsidy
- ❖ Reference Scenario: Tax Credit results in a 5% increase in market share of AVTI in each of the five modeled years (2007 – 2011)
- ❖ ~30,000 new AVTI above baseline (~50,000) purchased
- ❖ At a cost of approximately $45,000,000 per year to the state

Cumulative Greenhouse Gas Emission Reductions		
	MMTCE by 2015	**MMTCE by 2015**
AVT Incentive	**0.31**	**0.51**

Transportation Strategies

Alternative Fuels

Policy: Ethanol Production Tax Credit

- $0.05 per gallon of ethanol, up to 15-million gallons per year, produced at a **corn** based biorefinery, with an annual capacity of less than 60 million gallons. The PTC is limited to three years of operations.
- $0.125 per gallon of ethanol, up to 15-million gallons per year, produced at a **cellulosic** biorefinery. There is no limit on the size of the facility and the PTC is limited to ten years of operations.

Purpose: Promote the growth of the Michigan ethanol supply to the alternative fuels market.

Model Scenarios:

- Michigan baseline I corn ethanol production: 5-plants, 250-million gal/yr capacity by 2010
- Michigan baseline II corn ethanol production: Baseline I + 4 new plants, 260-million gal/yr capacity by 2012
- Corn PTC: Baseline I + 4 new 60-million gal/yr facilities by 2010
- Cellulosic PTC: One new production scale facility, 100-million gal/yr capacity

Transportation Strategies

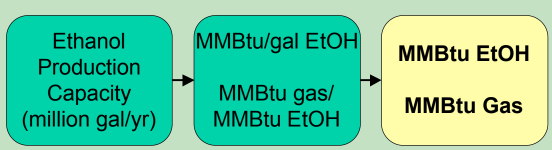
Ethanol Production Tax Credit

GHG Modeling Methodology

well-to-pump analysis

Activity

- MMBtu of ethanol supplied to the pump and MMBtu of petroleum gasoline displaced at the pump



Emission Factor

- GREET: WTP grams per MMBtu of fuel

Argonne NATIONAL LABORATORY

Transportation Strategies

Ethanol Production Tax Credit

Economic Modeling Methodology

Modeled Scenario:

- 9-corn ethanol facilities (510 million gal/yr) with 1-cellulosic ethanol facility (100 million gal/yr)

Effects

- Firm Spending: Increases due to capital costs associated with new ethanol production
  - Corn Ethanol from 2005 - 2010
  - Cellulosic Ethanol from 2009 – 2010
- Demand for Petroleum Products: Reduced
- Demand for Chemical Sector: Increases; acting as a surrogate for agriculture and biorefining
- State Government Spending: Increases $1.875 million per year for cellulosic EtOH

Transportation Strategies

Ethanol Production Tax Credit

Policy Results

Cumulative Greenhouse Gas Emission Reductions		
	MMTCE by 2015	MMTCE by 2015
Baseline I: Corn 250 mil gal/yr	1.27	2.67
Corn PTC: 240 mil gal/yr above Baseline I	0.78	2.13
Baseline II: Corn 510 mil gal/yr	2.27	5.21
Cellulosic PTC: 100 mil gal/yr	1.22	3.24

Average Annual Economic Effects		
	Change in GSP (millions 2000 fixed $)	**Change in Job-Years**
Baseline II + Cellulosic PTC	504	2,970

Transportation Strategies

Renewable Fuel Standard

Policy: Renewable Fuel Standard for Statewide Motor Fuels

- ❖ Beginning in 2010, 10% of motor fuels (on a volume basis) sold in the state produced from renewable sources. Each subsequent year an additional 1% of fuels sold produced from renewable sources until 25% of fuels are renewable in 2025.
- ❖ Eligible fuels include the ethanol in E85 and reformulated gasoline and biodiesel.

Purpose: Promote the production, distribution and use of alternative fuels and alternative vehicles.

Model Scenarios:

- ❖ Ethanol used to meet the RFS standard produced from corn feedstock
- ❖ Ethanol used to meet the RFS standard produced from cellulosic feedstock

Transportation Strategies

Renewable Fuel Standard

GHG Modeling Methodology

well-to-wheel analysis

Activity

- ❖ VMT by powered by renewable fuels meeting RFS and VMT powered by displaced conventional fuels
- ❖ Eligible Fuels: Ethanol in E85 and RFG and Biodiesel

Emission Factor

- ❖ GREET: WTW grams per LDV VMT fueled by renewable fuel

Transportation Strategies
Renewable Fuel Standard

Economic Modeling Methodology

Modeled Scenarios
- E85 and Conventional Gas at price equilibrium (equal $/mi traveled)
  - only applies to ethanol in E85 used to meet standard
- E85 set at a higher cost per mile traveled

Effects
- Demand for Petroleum Products: Reduced
- Demand for Chemical Sector: Increases; acting as a surrogate for agriculture and biorefining
- Consumer Spending – Oil/Gas: Increases for the higher E85 cost per mile scenario
- Consumer Spending – Other: Decreases

Transportation Strategies
Renewable Fuel Standard

Policy Results

Cumulative Greenhouse Gas Emission Reductions		
	MMTCE by 2015	MMTCE by 2025
Corn Scenario	1.28	6.51
Cellulosic Scenario	0.78	13.2

Average Annual Economic Effects		
	Change in GSP (millions 2000 fixed $)	**Change in Job-Years**
E85/CG Price Equilibrium	283	1,700
E85 Higher Price Per Mile	361	1,230

Michigan at a Climate Crossroads

Breakout Session I

11:15 am – 12:00 pm

A. Mass Transportation – Crowfoot Room
B. Combined Heat and Power – Sophia B. Jones Room
C. Building Codes – Pendleton Room

Framing Questions:

- What is your feedback on the modeling approach and results?
- Is this an effective policy, why or why not?
- How and where can the results be most effectively applied?

Michigan at a Climate Crossroads

Lunch

12:00 pm – 12:30 pm

Michigan at a Climate Crossroads

Breakout Session II

12:30 pm – 1:15 pm

A. Alternative Fuels – Wolverine Room
B. Appliance Efficiency – Pendleton Room
C. Renewable Production Tax Credit – Sophia B. Jones Room

Framing Questions:

- What is your feedback on the modeling approach and results?
- Is this an effective policy, why or why not?
- How and where can the results be most effectively applied?

Michigan at a Climate Crossroads

Breakout Session III

1:20 pm – 2:05 pm

A. Alternative Vehicles – Sophia B. Jones Room
B. Carbon Sequestration – Wolverine Room
C. Renewable Portfolio Standard – Pendleton Room

Framing Questions:

- What is your feedback on the modeling approach and results?
- Is this an effective policy, why or why not?
- How and where can the results be most effectively applied?

Appendix D. REMI Variable Definitions

Input Variables

The input variables for the model fall into the following six categories.

1) **Output Block**: The Output Block linkages in the model determine local demand for components of personal consumption which depends on real income, for investment demand which depends on relative factor prices and anticipated economic activity, and for government demand which is influenced by the size of the local population. These demands are translated into industry demand which also depends on the interstate and international exports.

2) **Labor and Capital Demand Block**: The Labor and Capital Demand Block is affected by local Output. However, labor and capital utilization is also determined by Labor Productivity. This in turn depends, in part, on the relative costs of all of the factors of production.

3) **Population and Labor Supply Block**: The Population and Labor Supply Block includes policy variables that directly affect Migration, Participation Rates, Special Populations, Birth and Survival Rates, and Occupational Supply.

4) **Wage, Price, and Profit Block**: The Wage, Price, and Profit Block includes policy variables that directly affect wage rates, the cost of doing business, fuel costs, consumer, housing and land prices, as well as industry prices.

5) **Market Shares Block**: The Market Shares Block includes policy variables that directly affect industries' shares of local and export markets. The share of local markets can be increased by increasing the Regional Purchase Coefficients, which represent the proportion of local demand that is supplied locally. The proportion of national and international markets can be changed using the Export Market Share and Import Market Share variables. These shares can be changed for individual industries or for the entire set of private industries at once.

6) **Fiscal Calibration Block**: The Fiscal Calibration Category includes policy variables that can adjust state and local government revenue and expenditures. The model incorporates the most recent Census of Governments data to obtain the revenue and expenditure amounts for every state government and for the county governments using state averages. Government tax and revenue policy changes must be input as policy variables in the first five blocks.

Within each of these blocks are a number of sub-categories, with these sub-categories further divided into the policy variables. Specific policy variables can be defined in several different ways; the primary ways are by sector and by share or amount. When the individual variables are described below, the key in parentheses will be added to show how the variables can be defined.

Definition by Sector (Sect):
The REMI model divides the state of Michigan's economy into 66 different sectors. For some variables, it is possible to define the variable for each sector individually. For example, you may want to know what the effect would be of increasing the price of electricity for vehicle manufacturing by 10%. The 66 sectors are listed below.

Forestry
Agriculture
Oil/gas extraction
Mining (except oil/gas)
Support activities for mining
Utilities
Construction
Wood product mfg.
Nonmetallic mineral production mfg.
Primary metal mfg.
Fabricated metal product mfg.
Machinery mfg.
Computer/electronic product mfg.
Electrical equipment/appliance mfg.
Motor Vehicle mfg.
Transportation equip (exc. motor veh.)
Furniture/related product mfg.
Miscellaneous mfg.
Food mfg.
Beverage/tobacco prod. mfg.
Textile mills
Textile product mfg.
Apparel mfg.
Leather/Allied product mfg.
Paper mfg.
Printing/Related support activity
Petroleum/coal product mfg.
Chemical mfg.
Plastics/rubber mfg.
Wholesale trade
Retail trade
Air transportation
Rail transportation
Water transportation
Truck transp./couriers/messsengers
Transit/ground passenger transp.
Pipeline transport
Scenic/sightseeing transp./supply
Warehousing/storage
Publishing (exc. Internet)
Motion picture/sound recording
Internet service/data processing
Broadcasting (exc. internet)/telecomm
Monetary authority
Security/communication/contracts
Insurance carriers
Real estate
Rental/leasing services
Professional/technical services
Management of Companies/Enterprises
Admin/support services
Waste management/remediation
Educational services
Ambulatory health care services
Hospitals
Nursing/Residential care facilities
Social assistance
Performing arts/spectator sports
Museums
Amusement/gambling/recreation
Accommodations
Food services/drinking places
Repair/Maintenance
Personal/laundry services
Membership associations/orgs.
Private households

Definition by Industrial or Commercial Enterprises (I/C):
Instead of dividing the economy into the 66 sectors listed above, some variables only make the distinction between industrial and commercial enterprises.

Consumer Spending (CS):
Consumer spending options include:
Vehicles and Parts, Computers and Furniture, Other Durables, Food and Beverages, Clothing and Shoes, Gasoline and Oil, Fuel Oil and Coal, Other Non-durables, Housing, Household Operation, Transportation, Medical Care, Other Services.

Definition by Share/Amount (S/A)
Definition by Share Only (S)
Definition by Amount Only (A):
Most variables allow you to express the policy in either a change in the share (percentage), the amount (absolute value), or both. This is true when the variable applies to a single sector or to the whole economy. For example, you could express the variable as an increase in the price of electricity of 10% or the equivalent dollar amount, and this can be applied to an individual sector or to the entire state.

Individual Variables by Policy Blocks and Sub-Categories:
(Underlined are final variables)

- **Output Block**
  1) **Industry Output**: It is important to distinguish between Demand and Output. For policy variables which affect demand, only the proportion of demand that is usually supplied by each area in the model (i.e. its market share) times the new demand results in additional output. Industry output changes are often made to show the effect on a local economy of a policy that will lead to the opening of a new business. However, these studies are often based on the premise that all of the increased output will be exported from the area and, therefore, will not compete with existing firms. This is a valid premise only in certain cases. So, unless a valid reason exists, a new firm should be added as Firm Sales so that any displacement of local firms will be accounted for. If, for example, a firm that was going to produce tennis balls relocated to this county, it could safely be assumed that all of the output would go to exports. However in a more general case, when a new retail store goes into business, it is not reasonable to assume that all of the retail activity of the new store would represent exports. In fact, a good deal of the retail activity in the new store might go to local markets and thus be at the expense of the preexisting stores in the area. If all of the activity was at the expense of existing stores, then the new store would have no net effect on local output. For the special cases (e.g. tennis balls) where no displacement will occur, use the Industry Sales policy variable. In some cases, there may be reason to think that a change in the activity (such as a strike) in an industry will not have an effect on the wage rate for that industry. In this case, the endogenous wage response for the industry may be shut off using Nullify Wage Rate Induced by Sales (amount).

     a) Firm Sales – (Sect), (S/A): The Firm Sales policy variable assumes that the firm entering or leaving the home area (or expanding or contracting in the home area) will change the share for home area by augmenting or diminishing that region's share by a percentage/amount that allows for the displacement or augmentation of the sales of other firms competing with the firm in question in the home or multiregional markets in the model. The future sales of the firm in question will be dependent on the rate of growth of the industry in the base line and any changes in its competitiveness in the markets served by that firm.

b) Industry Sales/International Exports – (Sect), (S/A): The policy variable assumes the industry in the area changes its exports to the rest of the world by the percentage/amount that is input and that the sales amount remains constant over the forecast period.

c) Government Output
   i) State and Local Government Output – (S)
   ii) State Government Output – (S)
   iii) Local Government Output – (S)
   iv) Federal Civilian Government Output – (S)
   v) Federal Military Government Output – (S)

d) Farm Output – (S): The Farm Employment (share) policy variable changes the level of farm Employment in the local area by the proportion or percentage of local farm employment entered. The Farm industry is assumed to be exogenous in the REMI model. Therefore, all farm demand is imported, and all farm production is exported. Intermediate purchases from the Farm sector are not included in the model's inter-industry transactions.

e) Nullify Investment Induced by Industry Sales/International Exports – (Sect), (A): Nullify Investment Induced by Sales (amount) eliminates the endogenous effect of Sales (amount) on investment. It is used to override the model's default investment response when specific information concerning investment decisions is known.

f) Nullify Intermediate Inputs Induced by Industry Sales/International Exports – (Sect), (A): Nullify Intermediate Inputs Induced by Sales (amount) eliminates the endogenous effect of Sales (amount) on intermediate inputs. It is used to override the model's default intermediate input response when specific information concerning material inputs is known.

g) Industry Sales/International Exports without Employment, Investment, and Wages – (Sect), (A): The Sales (International Exports) without Employment, Investment, and Wages (amount) policy variables change industry output by the amount entered without any direct effects on Employment, Investment, and the Wage Bill. It is used to override the model's default responses when specific information concerning production changes and the associated employment, investment, and wage and salary disbursement changes are known. You may enter these concepts exogenously using the Employment (number), Wage Bill (amount), and any of the Investment policy variables.

2) Commodity Access Index – (Sect), (S): This policy variable is for changing the access of this good or service by industry so that through better choice of inputs they will be more (or less) productive than they would have been in the face of more (or less) choice of the service or goods in question.

3) Industry Value Added: This section includes the policy variable that directly affects Industry Value Added. This variable must be used in conjunction with

Intermediate Demand (amount) so that any direct change in value added is offset with an equal and opposite change in intermediate demand.

a) Value Added with no effect on Sales or Employment – (Sect), (A): The Value Added with No Effect on Sales or Employment (amount) policy variables change the Industry Value Added of the specified industry by the dollar amount entered. It is used to change the value added characteristics of a particular industry when modeling an atypical firm.

4) Industry Demand: It is important to distinguish between Demand and Output. For policy variables which affect demand, output in all of the supplying regions will change by the amount of their market share times the change in demand. Since the model does not know the source of demand and apportions it to the demand sources, it is advisable to use the Employment by Sector instead of the Employment by Demand Source in the results section.

a) Exogenous Final Demand – (Sect), (A): Local Demand (amount) policy variables change the total Demand in the specified industry. For policy variables which affect demand, only the proportion of demand that is usually supplied locally is added to local production. The remainder of the amount that you enter is assumed to be produced elsewhere and imported to the area.

b) Intermediate Demand – (Sect), (A): The Intermediate Demand (amount) policy variables changes the level of Intermediate Demand facing the specified industry by the amount entered. They are used to change the default assumptions about intermediate activity when modeling an atypical firm.

5) Disposable Income: This section includes policy variables that affect the different components of disposable income. You change most of them by dollar amount or percentage. The total wage bill is also used in the calculation of disposable income, although wage policy variables are considered separately.

a) Proprietor and Other Labor Income – (Modified Sect - 23 sectors), (S/A): The Proprietor and Other Labor Income (amount) policy variables change personal income originating from specific industries (23 major sectors) by the amount entered.

b) Transfer Payments – (S/A): This policy variable changes the total amount of Transfer Payments going to all recipients by the dollar amount or proportion entered.

c) Contributions to Social Insurance – (S/A): This policy variable changes the amount of total Contributions to Social Insurance (Social Security) by the dollar amount or proportion entered.

d) Dividends, Interest, and Rent – (S/A): This policy variable changes the amount of total Dividends, Interest and Rent earned by residents by the dollar amount or proportion entered.

e) Residence Adjustment – (S/A): The Residence Adjustment policy variable changes the total Residence Adjustment in a region by the amount or proportion entered. The Residence Adjustment is used to convert place-of-work income (wage and salaries, other labor income, and personal contributions for social insurance reported by place of work) to a place-of-residence basis. A negative Net Residence Adjustment denotes a flow of income out of the local region as a result of commuting behavior, while a positive Net Residence Adjustment denotes the opposite. Use the Residence Adjustment (amount) policy variable to change the flow of income in to or out of a region because of commuters. A positive dollar value for this policy variable will increase Personal Income in the region.

f) Personal Taxes – (S/A): The Personal Taxes policy variable changes total Personal Taxes in the region by the dollar amount or proportion entered. Personal Taxes include federal, state, and local income taxes, and deductibility is not taken into account. Therefore, the amount entered is the net change in income tax payments. A change in State and Local personal tax payments will NOT directly affect government spending in the region.

6) **Consumer Spending**: This section includes policy variables that affect the different components of Consumer Spending. Changes in the Consumer Spending by Residents variables are associated with local Consumption and Real Disposable Income. These variables alter commodity-specific demand. Changes in the Consumer Spending by Non-Residents variables are associated with visitors' commodity-specific purchases. These variables automatically alter the Industry Demand associated with the commodity expenditure change. The effects show up as adding an exogenous change to current levels of industry demand without directly changing consumption induced output and employment.

a) Consumer Spending – (CS), (S/A): The Consumer Spending by Non-Residents policy variable converts the commodity-based dollar amount or proportion entered into changes in industry Demand using the Personal Consumption Expenditures (PCE) Bridge Matrix. They enter the model as exogenous changes in industry demand. These variables are used to alter tourist or other non-resident expenditures when specific information concerning the spending patterns is known.

b) Consumption Reallocation – (S/A): The Consumption Reallocation by Residents policy variable is used in conjunction with one or more of the Consumer Spending by Residents variables to reallocate the change in resident spending to all other consumption categories by the dollar amount or proportion entered. This variable is used when commodity-specific information regarding the reallocated spending is not known.

c) Total Consumer Spending – (S): The Total Consumer Spending by Residents (same share all types) policy variable directly changes the local Consumption of all commodities by the proportion or percentage entered. This variable is used to alter implied savings.

7) **Government Spending**: This section includes policy variables that affect the different components of Government Spending. The federal government's civilian and military spending on employment in the local area are exogenous to the model and are maintained at a fixed share of the corresponding total national values. Federal military procurement is allocated according to each local area's representation in the industries in which the federal military spending takes place. Changes in federal civilian and federal military spending cannot be implemented directly for a sub-national region. This is true because there is no pattern of federal spending within different regions around the nation, thus it is difficult to model the role which federal spending plays in the average region. Such spending changes must be entered through Industry Output and/or Employment. The expenditures of state and local government are both dependent on relative population, nationally predicted state and local government expenditures, and take into account an adjustment for regional differences. Changing state and local government spending is very similar to changing spending in a consumption sector in that the initial spending change entered is converted into direct changes in Industry Demand.

a) Government Spending – (State, Local, or State and Local), (S/A): The Government Spending policy variable converts the change in State and Local Government Spending entered into Industry Demands using the Technical Coefficients Matrix. This variable is used to increase or decrease general public expenditures associated with a particular simulation.

b) Government Spending including Non-Pecuniary – (State, Local, or State and Local), (A): The Government Spending including Non-Pecuniary (Amenity) Aspects (amount) policy variable assigns the dollar amount entered to both the Amenity Term and State and Local Government Spending. The State and Local Government Spending change is converted into Industry Demands using the Technical Coefficients Matrix. The Amenity change enters the Non-Pecuniary (Amenity) Aspects (amount) policy variable. This variable is used if a change in state and local government spending is likely to result in a change in services normally provided to the local community, leading to a change in the perception of the amenities previously associated with living in the area.

8) **Investment Spending**: This section includes policy variables that affect the different components of Investment Spending. Investment Spending is similar to the other components of aggregate demand, because it represents a flow of economic activity (i.e., billions of 1992 dollars of construction per year). However, it is different, because it is the only one out of the four final-demand components that is a function of the difference between an actual and a desired stock, rather than a flow variable. This process, which drives investment, is called the stock adjustment process. The driving force behind investment is the optimal capital stock less the actual stock of capital. The actual stock of capital is the stock of capital at the end of last year less depreciation. The speed with which this gap is filled is the adjustment speed estimated for all states in the United States simultaneously. Any regional differences in capital preference are also taken into account. In the generalized model, there are four types of investment to be considered: residential, nonresidential, equipment investment, and changes in business inventories. In a model with disaggregated industries, it is necessary to allocate demand for investment to the industries supplying the investment goods and carrying out the construction.

a) Investment Spending – (Residential, Non-Residential, and Producer's Durable Equipment), (S/A): The Investment Spending policy variables convert the dollar amount entered into changes in Industry Demand using the technical coefficients from the Input/Output Matrix. These variables are used to change general Investment Spending for the region, especially in conjunction with the Nullify Investment Induced by Employment (number) and Nullify Investment Induced by Sales (amount) policy variables. Any changes to Non-Residential Investment will also automatically flow into Producer's Durable Equipment. If this is not expected, it is necessary to put in a negative change to producer's durable equipment to offset an increase in non-residential investment, or vice-versa.

b) Total Investment Spending – (S): The Total Investment Spending (share) policy variable directly changes total local Investment across all fixed investment categories by the proportion or percentage of total investment entered. This variable is used to change total general Investment Spending for the region.

c) Residential Capital – (S/A): The Residential Capital policy variable directly changes the actual Residential Capital Stock by the dollar amount or proportion entered.

d) Non-Residential Capital – (S/A): The Non-Residential Capital policy variable directly changes the actual Non-Residential Capital Stock by the dollar amount or proportion entered. Since Capital is a stock, this change should only be entered for one year to avoid changing the stock commutatively year after year.

- **Labor and Capital Demand Block**

1) Employment: This section includes policy variables that affect the different components of Employment. The policy variables for employment are often used as an alternative to introducing additional dollars of output. Much like the Industry Output-policy variables, the user must choose between Firm Employment and Industry Employment. One consideration is whether it is expected that the real output will remain constant each year (in this case, use Nullify Output Demand Growth Based on Productivity Growth (number) and the employment will drop each year as productivity increases) or whether the output is expected to grow each year enough to absorb 100 employees even as the output per employee grows (in this case, do not use Nullify Output Demand Growth Based on Productivity Growth (number)). Also, Nullify Wage Rate Induced by Employment (number) can be used if there is a reason to believe that the usual endogenous wage response to the exogenous employment changes should be suppressed.

a) Firm Employment – (Sect), (S/A): As the productivity of labor changes in the forecast, the sales associated with this employment change are assumed to change proportionally. The amount or proportion change in employment converted into sales is input into the model.

b) Industry Employment (Industry Sales/International Exports) – (Sect), (S/A): As the productivity of labor changes in the forecast, the sales associated with this employment change are assumed to change proportionally. The amount or proportion change in employment converted into sales is input into the model.

c) Government Employment
   i) State and Local Government Employment – (S/A)

   ii) State Government Employment – (S/A)

   iii) Local Government Employment – (S/A)

iv) Federal Civilian Government Employment – (S/A): Federal government employment in a local area is a fixed proportion of government employment in the nation. The Civilian Employment policy variable changes the level of local Employment in the federal civilian sector by the amount or proportion entered.

v) Federal Military Government Employment – (S/A): Federal government employment in a local area is a fixed proportion of government employment in the nation. The Military Employment policy variable changes the level of local Employment in the federal military sector by the amount or proportion entered.

d) Farm Employment – (S/A): Farm employment in a local area is estimated as a fixed share of National farm employment based on the last year of history. The Farm Employment policy variable changes the level or proportion of local Employment in the farm industry. The Farm industry is assumed to be exogenous in the REMI model. Therefore, all farm demand is imported, and all farm production is exported. Intermediate purchases from the Farm sector are not included in the model's inter-industry transactions.

e) Nullify Investment Induced by Employment (Industry Sales/International Exports) – (Sect), (A): The Nullify Investment Induced by Employment (International Exports) (number) policy variables eliminate the endogenous effect of Employment (International Exports) (number) on Investment. It is used to override the model's default investment response when specific information concerning investment decisions is known.

f) Industry Employment without Output Demand Growth Based on Productivity Growth – (Sect), (A): The Output based on fixed Q/E-Employment (Number) policy variable maintains a constant level of Output each year despite the Employment change. As such, employment will drop each year as productivity increases. It is used when it is expected that real exogenous output will remain constant each year.

g) Nullify Intermediate Inputs Induced by Employment (Industry Sales/International Exports) – (Sect), (A): The Nullify Intermediate Inputs Induced by Employment (International Exports) (number) policy variables eliminate the endogenous effect of Employment (International Exports) (number) on Intermediate Inputs. It is used to override the model's default intermediate input response when specific information concerning material inputs is known.

2) Labor Access Index – (Sect), (S): Labor Access Index increases labor productivity over time as greater access gives both employers and employees a better opportunity to match the particular requirements of each job and the particular characteristics of each employee.

3) Productivity: Both total Factor Productivity and Labor Productivity concepts are used in the model. When factor productivity is increased, the same Output can be produced using both less labor and less capital. When labor productivity is increased, the same output can be produced using less labor, and businesses will substitute labor for capital. For both productivity variables, Relative Profits will increase for national industries and Relative Industry Sales Price should fall for regional industries.

a) Factor Productivity – (Sect), (S): The Factor Productivity (share) policy variables change the level of Factor Productivity in the specified industry by the proportion or percentage entered. It is used when output per unit of factor input is expected to change without substitution between those factors of production.

b) Factor Productivity, All Industries – (S): The Factor Productivity, All Industries (share) policy variable changes the level of Factor Productivity in all private non-farm industries by the proportion or percentage entered. It is used when output per unit of factor input is expected to change for all industries without any substitution between those factors of production.

c) Labor Productivity – (Sect), (S): The Labor Productivity (share) policy variables change the level of Labor Productivity in the specified industry by the proportion or percentage entered. It is used when output per unit of labor is expected to change, and will result in substitution between the factors of production.

- **Population and Labor Supply Block**

1) Migration: This section includes policy variables that affect the different components of Migration. Migration comprises one source of the change in a region's population in response to either economic, amenity or political conditions. The population in the region, in conjunction with labor force participation rates, determines the Labor Supply. The four components of net migrants are International Migrants, Retired Migrants, Former Military Personnel and Their Dependents reentering the civilian population, and Economic Migrants. All but economic migrants are exogenous to the economic sectors of the model.

a) Economic – (S/A): This section includes policy variables that affect the different components of Economic Migration. The endogenous component of the model's net migration concept is economic migration. Economic migrants are defined as persons less than 65 years of age who move in response to differential changes in inter-regional expected income and quality of life aspects. Expected income takes into account the real after-tax wage rate - relative to the National value, and the relative employment opportunity. The latter can be interpreted as the probability of getting a job and is a function of Employment in the area held by residents and the size of the Labor Force. A consumer index that endogenously predicts changes in the availability of consumer choice on the quality of life is also included.

b) Retired (ages 65-100) – (S/A): Retired migrants are defined as persons 65 years of age or over who relocate. Retired migrants by single-year age cohort and race are first calculated as a residual between predicted surviving population by the cohort algorithm versus known five-year age cohort levels from 1984-1998. The average rate of retired migration is calculated for two cohorts from the group 65 years of age or over. The rates are then defined from single-year cohorts relative to the region's population in that cohort (if retired migrants over the period were negative), and relative to the national population in the cohort (if retired migrants over the period were positive). The population model is then rerun over history with the retired migrants predicted by the above methodology. The retired migration rates are carried forward into the forecast period. Finally, survival rates are applied to the retired migrants and adjusted to reflect an average of one-half year of residence.

c) International (ages 0-64) – (S/A): This section includes policy variables that affect the different components of International Migration. International migration is assumed exogenous to the region and is based on each region's share of the nation's international immigrants by race. Net international migration, by race, for the US is obtained from the Census' Current Population Reports for recent history (beginning in 1981). The Statistical Abstract provides an early history (1971-1980). Racial detail is obtained by assigning a racial category to each country of origin available in Immigration and Naturalization Service (INS) data, and then reconciling to the total from the Statistical Abstract data.

2) **Participation Rates (ages 16 -100) – Divided by racial groups – (S/A):** This section includes policy variables that affect the different age/gender/race components of Labor Force Participation Rates.

3) **College Population (ages 15-34) – Divided by racial groups – (S/A):** This section includes policy variables that affect the different components of the College Population. Special populations such as college students or prisoners are a problem for the cohort survival part of any demographic model. If a region has several thousand 15-34 year olds due to the presence of a college or university, this population will "grow old" in the area even though it is known that the great majority of these students eventually leave the area shortly upon graduation. The same concept is true for prisoners. In addition to the demographic consequences, failure to identify college and prison populations may lead to erroneous labor force estimates since prisoners do not participate in the labor force at all and college students participate at a reduced rate. The model has incorporated a procedure to deal with student populations which appropriately adjusts the population downward for those areas with universities and upward for other areas. This procedure is a residual method, which calculates the special population by cohort and race as the difference between the 1970 population as advanced to 1990, and the 1990 population as reported by census. Regions with College Populations have a positive special population, which is subtracted from cohort survival. Regions that have no colleges tend to show a negative special population, representing people who are away from the area in a cohort pattern characteristic of young adults. The special populations are not aged with the rest of the population.

4) **Birth Rates (ages 10-49) – Divided by racial groups – (S/A):** Starting with 1971, predicted civilian births and deaths by cohort and race are adjusted to obtain total Birth and Survival Rates by race calculated from Vital Statistics data (1971-1990). For history years after 1990, the total births and deaths are targeted to Census data that has been adjusted to match BEA data. The adjustment to births and deaths in the last year of history is carried forward into the forecast period. In addition to predicting the civilian population, the number of military personnel and their dependents are also calculated. BEA Local Area Personal Income data provides regional military employment estimates. The number of military personnel is adjusted to account for the fact that the BEA concept for military employment includes the reserves and National Guard. Consequently, we alter the military concept by multiplying by an active to total state ratio to truly capture active military personnel. The proportion of military personnel that is male and female, and the number of male and female dependents, were

obtained from the Census. The age distribution by race of the military personnel and dependents was estimated using single-year and five-year cohort data also from the Census, based on 1995.

5) **Survival Rates (ages 0-100) – Divided by racial groups – (S/A):** This section includes policy variables that affect the different components of Survival Rates. Starting with 1971, predicted civilian births and deaths by cohort and race are adjusted to obtain total Birth and Survival Rates by race calculated from Vital Statistics data (1971-1990). For history years after 1990, the total births and deaths are targeted to Census data that has been adjusted to match BEA data. The adjustment to births and deaths in the last year of history is carried forward into the forecast period. In addition to predicting the civilian population, the number of military personnel and their dependents are also calculated. BEA Local Area Personal Income data provides regional military employment estimates. The number of military personnel is adjusted to account for the fact that the BEA concept for military employment includes the reserves and National Guard. Consequently, we alter the military concept by multiplying by an active to total state ratio to truly capture active military personnel. The proportion of military personnel that is male and female, and the number of male and female dependents, were obtained from the Census. The age distribution by race of the military personnel and dependents was estimated using single-year and five-year cohort data also from the Census, based on 1995.

6) **Occupational Supply/Training – (S/A):** This section includes policy variables that affect the different components of Occupational Supply. These variables work through occupational Wage Rates. An increase in supply reduces the wage. To use these variables appropriately, you must also consider changes in productivity associated with occupational training. Low-skilled occupations are not listed because an increase in training does not directly affect the wages for low-skilled occupations in this model. If training also increases the participation rate, this can be incorporated by using the Labor Force Participation Rate policy variables.

- **Wage, Price, and Profit Block**

1) **Production Costs**: We use relative terms to explain production costs for the region relative to the nation. The Delivered Price of a regional industry depends on Relative Production Costs. Relative production costs are derived from a hierarchical production function, and, therefore, depend on the relative cost of factor and material inputs. The relative factor cost of production is determined through a Cobb-Douglas specification of labor, capital and fuel, allowing substitutability among the factors as their individual costs change. Composite costs that included accessibility indexes are used for labor and goods and services inputs as well as wage rates and delivered costs are used in determining production costs.

   a) Production Costs – (Sect), (S/A): The Production Cost policy variables change the Relative Production Costs of the specified industry by the dollar amount or proportion entered. They are used when a specific policy will affect the cost of doing business in a region without directly changing the relative costs of factor inputs (labor, capital, and/or fuel).

   b) Production Costs, All Industries – (S): The Production Cost, All Industries (share) policy variable changes the Relative Production Costs of all private non-farm industries by the proportion or percent of total Output entered. It is used when a specific policy will affect the cost of doing business in a region without directly changing the relative costs of factor inputs (labor, capital, and/or fuel).

2) **Business Taxes and Credits**: This section includes policy variables which affect the different components of business taxes and credits. They are incorporated into the cost of capital equation.

a) <u>Corporate Profit Tax Rate – (Sect), (Share of Tax Base)</u>: The Corporate Profit Tax Rate (share of tax base) policy variables change the Corporate Profit Tax Rate of the specified industry by the proportion or percentage of the tax base entered. This is equivalent to a percentage point change in the baseline control forecast Corporate Profit Tax Rate.

b) <u>Corporate Profit Tax Rate, All Industries – (Share of Tax Base)</u>: The Corporate Profit Tax Rate, All Industries (share of tax base) policy variable changes the Corporate Profit Tax Rate of all private non-farm industries by the proportion or percentage of the tax base entered. This is equivalent to a percentage point change in the baseline control forecast Corporate Profit Tax Rate.

c) <u>Equipment Tax Rate – (Share of Tax Base)</u>: The Equipment Tax Rate (share of tax base) policy variable changes the value of the Equipment Tax Rate by the share of the tax base entered. This is equivalent to a percentage point change in the baseline control forecast Equipment Tax Rate.

d) <u>Property Tax Rate – (Share of Tax Base)</u>: The Property Tax Rate (share of tax base) policy variable changes the Property Tax for all industries by the share of the tax base entered. This is equivalent to a percentage point change in the baseline control forecast Property Tax Rate.

e) <u>Investment Tax Credit – (Share of Tax Base)</u>: The Investment Tax Credit (share of tax base) policy variable changes the Investment Tax Credit for equipment across all industries by the share of the tax base entered. This is equivalent to a percentage point change in the baseline control forecast Property Tax Rate.

f) <u>Equipment Life Time (years)</u>: The Equipment Life Time (years) policy variable changes Equipment Life Time used in the calculation of depreciation by the number of years entered. The number entered will be added to baseline Equipment Life Time.

g) <u>Structure Life Time (years)</u>: The Structure Life Time (years) policy variable changes Structure Life Time used in the calculation of depreciation by the number of years entered. The number entered will be added to baseline Structure Life Time.

3) **Fuel Costs**: This section includes policy variables that affect the different components of Fuel Costs. Relative "aggregate" fuel costs for a specific industry are based on the relative unit costs for three types of fuel and how the industry user manages these unit cost differences through their overall fuel mix. The equation for relative fuel costs is derived from a Cobb-Douglas function and therefore assumes possible substitution among fuels. The relative unit costs for each type of fuel is determined exogenously, but can be altered when one of the

policy variables is used to introduce a change. Changes may be entered for a specific industry or for one or two broad user classes: commercial and industrial.

a) Electricity Cost – (I/C), (S/A): The Electricity Fuel Cost (amount) policy variables change the Relative Fuel Cost of electricity to the specified user group by the dollar amount or proportion entered. They are used to change electric costs for regional industries, resulting in substitution between types of fuel. Electric rate changes for consumers are modeled by changing the Consumer Price of the electric share of the Household Operations commodity.

b) Electricity Cost for Individual Industries – (Sect), (S/A): The Electricity Fuel Cost for Individual Industry policy variable changes the electricity costs of the specified industry by the dollar amount or proportion entered. They are used to change electric costs for regional industries, resulting in substitution between types of fuel. Electric rate changes for consumers are modeled by changing the Consumer Price of the electric share of the Household Operations commodity.

c) Natural Gas Fuel Cost– (I/C), (S/A): The Natural Gas Fuel Cost policy variables change the Relative Fuel Costs of natural gas for the specified user group by the dollar amount or proportion entered. They are used to change natural gas costs for regional industries, resulting in substitution between types of fuel. Natural Gas rate changes for consumers are modeled by changing the Consumer Price of the natural gas share of the Household Operations commodity.

d) Natural Gas Fuel Cost for Individual Industries – (Sect), (S/A): The Natural Gas Fuel Cost for Individual Industry policy variable changes the natural gas costs of the specified industry by the dollar amount or proportion entered. They are used to change natural gas costs for regional industries, resulting in substitution between types of fuel. Natural Gas rate changes for consumers are modeled by changing the Consumer Price of the natural gas share of the Household Operations commodity.

e) Residual Fuel Cost – (I/C), (S/A): The Residual Fuel Cost policy variables change the Relative Fuel Costs of residual fuel (mainly residual fuel oil) for the specified user group by the dollar amount or proportion entered. They are used to change residual fuel costs for regional industries, resulting in substitution between types of fuel. Residual fuel rate changes for consumers are modeled by changing the Consumer Price of the residual fuel share of the Household Operations commodity.

f) Residual Fuel Cost for Individual Industries – (Sect), (S/A): The Residual Fuel Cost for Individual Industry policy variable changes the residual fuel costs (mainly residual fuel) oil of the specified industry by the dollar amount or proportion entered. They are used to change residual fuel costs for regional industries, resulting in substitution between types of fuel. Residual fuel rate changes for consumers are modeled by changing the Consumer Price of the residual fuel share of the Household Operations commodity.

4) Labor Costs (other than wages): This section includes policy variables that affect non-wage components of Labor Costs. For example, if unemployment or workman's compensation tax rates are increased, this will increase labor costs but not wage rates. In addition, a subsidy to labor use may reduce labor costs to the employer without changing the wage rates of workers.

a) Non-Wage Labor Costs (share of wage rate) – (Sect): The Non-Wage Labor Costs (share of wage rate) policy variables change the non-wage Labor Costs of the specified industry by the proportion or percentage of the average industry wage rate entered. These policy variables are used when a policy is expected to change the cost of labor to employers without changing wage and salary disbursements.

5) **Capital Cost**: This section includes policy variables that affect the different components of Capital Costs. The cost of capital equation calculates the implicit rental cost of capital. Changes in tax rates or regulation may affect this cost. Such changes can be implemented using the Business Taxes and Credits policy variables.

a) Capital Cost – (Sect), (S/A): The Capital Cost policy variables change the Capital Costs within the specified industry by the proportion or dollar amount entered. These policy variables are used when a policy scenario is expected to change the implicit rental cost of capital, thus resulting in substitution between capital and labor usage.

b) Cost, All Industries – (S): The Capital Cost, All Industries (share) policy variable changes the Capital Costs across all industries by the proportion or percentage of the dollar value of the total capital share of output entered. These policy variables are used when a policy scenario is expected to change the implicit rental cost of capital, thus resulting in substitution between capital and labor usage.

6) **Wages**: This section includes policy variables which affect the different components of Wages. A change in wage rates may occur due to a union settlement or a policy shift such as a change in the state minimum wage. It is also possible to change the wage bill as well as the wage rate. This may be necessary if particular employees in a policy simulation have earnings that are different than the average wage in the industry in which they are employed. For the individual private industries, this is done in employee units. Thus, if the wages for the employees to be added are 20 percent higher than they are in the industry in general, 0.2 must be added to the wage bill adjustment per employee. For the government and farm sectors, wage bill changes are made in dollar terms.

a) Wage Rate - (Sect), (S): The Wage Rate (share) policy variables change the average nominal Wage Rate within the specified industry by the Proportion or Percentage of average industry wage entered. These policy variables are used when a policy scenario is expected to change the wage rate for all employees in an industry, thus resulting in substitution between capital and labor usage.

b) State and Local Government Wage Rate - (S)

c) Wage Rate, All Industries – (S): The Wage Rate, All Industries (share) policy variable changes the average nominal Wage Rate across all industries by the proportion or percentage of the average regional wage entered. These policy variables are used when a policy scenario is expected to change the wage rate for all employees in all industries by the same percentage, thus resulting in substitution between capital and labor usage.

d) Wage Bill (employee equivalents) – (Sect): The Wage Bill (employee equivalents) policy variables change the Wage Bill within the specified industry by the number of employee equivalent units entered. This takes into account that employees in individual firms may have a different wage rate than REMI's calculated industry average. These variables are used to adjust the wage and salary disbursements associated with exogenous employment changes without changing the wage rate for all employees within a given industry.

e) Wage Bill – (Sect), (A): The Wage Bill (amount) policy variables change the Wage Bill within the specified industry by the dollar amount entered. This takes into account that employees in individual firms may have a different wage rate than REMI's calculated industry average wage. These variables are used to adjust the wage and salary disbursements associated with exogenous employment changes without changing the wage rate for all employees within a given industry.

f) State and Local Wage Bill – (A): The State and Local Wage Bill (amount) policy variable changes the State and Local Government sector Wage Bill by the dollar amount entered. This takes into account the presence of employees at particular state and local government worksites with a different wage rate than REMI's calculated average wage for the state and local government sector. This variable is used to adjust the wage and salary disbursements associated with exogenous employment changes without changing the wage rate for all employees in the State and Local government sector.

g) Federal Civilian Wage Bill – (A): The Federal Civilian Wage Bill (amount) policy variable changes the Federal Civilian Wage Bill by the dollar amount entered. This takes into account the presence of employees at particular federal civilian worksites with a different wage rate than REMI's calculated average wage for the federal civilian sector. This variable is used to adjust the wage and salary disbursements associated with exogenous employment changes without changing the wage rate for all employees in the Federal Civilian government sector.

h) Military Wage Bill – (A): The Military Wage Bill (amount) policy variable changes the Military Wage Bill by the dollar amount entered. This takes into account the presence of military sector employees with a different wage rate than REMI's calculated average wage for the military sector. This variable is used to adjust the wage and salary disbursements associated with exogenous employment changes without changing the wage rate for all employees in the Military sector.

i) Non-Farm Wage Bill – (A): The Non-Farm Wage Bill (amount) policy variable changes total non-farm Wage and Salary Disbursements by the dollar amount entered. This takes into account that employees in all non-farm firms may have a different wage rate than REMI's calculated industry average wage. This variable is used to adjust the wage and salary disbursements associated with exogenous employment changes without changing the wage rate for all employees in all non-farm (including public) sectors.

j) Farm Wage Bill – (A): The Farm Wage Bill (amount) policy variable changes the Farm Wage Bill by the dollar amount entered. This takes into accounting the presence of farm sector employees with a different wage rate than REMI's calculated average wage for the Farm sector. This variable is used to adjust the wage and salary disbursements associated with exogenous employment changes without changing the wage rate for all employees in the Farm sector.

k) Total Wage Bill – (S): The Total Wage Bill (share) policy variable changes total Wage and Salary Disbursements by the percentage or proportion of the total baseline forecast wage and salary disbursements entered. This takes into account that employees in all firms may have a different wage rate than REMI's calculated industry average wage. This variable is used to adjust the wage and salary disbursements associated with exogenous employment changes in all firms without changing the wage rate for all employees.

7) Prices (housing and consumers): Changing consumer prices is often an important part of a simulation. For example, prices might be raised to simulate a new sales tax or an increase in consumer electric rates. Housing price changes directly impact the real wage expected by migrants, but indirectly affect the regional economy through the effect on the Consumer Price Deflator. Since most local consumers own their own homes or pay rent, they do not respond immediately to changes in housing prices.

a) Housing and Land Prices – (S): The Housing and Land Prices (share) policy variable changes the Housing and Land Prices within a region by the proportion or percentage entered. The relative price of housing is estimated based on changes in relative population, and relative real disposable income. The housing price affects migration. The cost of land affects Capital Costs.

b) Consumer Expenditure Price Index (equivalent dollar amount): The Consumer Expenditure Price Index (equivalent dollar amount) policy variable changes the Consumer Expenditure Price Index through a conversion of the dollar amount entered. The dollar amount represents the change in consumer purchasing power. A positive dollar amount represents a LOSS in purchasing power (or increase in the price index), and vice-versa. This variable is used to simulate any policy that reduces real disposable income to consumers without changing relative commodity prices (or assuming a price elasticity of 0). The effect of increasing the price index by the equivalent of $100 will reduce purchasing power by the equivalent of $100 of real disposable income.

c) Consumer Expenditure Price Index – (S): The Consumer Expenditure Price Index (share) policy variable allows you to alter the Price Index of your run. The new index is based on the control forecast you have chosen, but modified by the percent or proportion of total consumption entered. A positive percentage represents a LOSS in purchasing power (or increase in the price), and vice-versa. This variable is used to simulate any policy that reduces real disposable income to consumers without changing relative commodity prices (or assuming a price elasticity of 0).

d) Consumer Price (equivalent dollar amount): The Consumer Price (equivalent dollar amount) policy variables change the Compensated Commodity Price within the specified consumption category through a conversion of the dollar amount entered. This dollar amount is equivalent to the change in purchasing power as a result of the price change. The dollar amount represents the change in consumer purchasing power. A positive dollar amount represents a LOSS in purchasing power (or increase in the price), and vice-versa. These variables are used to simulate any policy that effectively increases prices to consumers by specific commodity category.

e) Consumer Price – (S): The Consumer Price (share) policy variables change Compensated Commodity Price within the specified consumption category by the proportion or percentage of total category expenditures entered. This dollar amount is equivalent to the change in purchasing power as a result of the price change. The dollar amount represents the change in consumer purchasing power. A positive dollar amount represents a LOSS in purchasing power (or increase in the price), and vice-versa. These variables are used to simulate any policy that effectively increases prices to consumers by specific commodity category.

- **Market Shares Block**
  1) **Exports to Rest of World – (Sect), (S/A)**: This changes exports to the rest of the world by the amount specified.

  2) **Imports from Rest of World – (Sect), (S/A):** This changes exports from the rest of the world by the amount specified.

  3) **Foreign Export Costs – (Sect), (S)**

  4) **Foreign Import Costs – (Sect), (S)**

- **Fiscal Calibration Block**
  1) **State Revenues at State Average Rates – (S)**

  2) **Local Revenues at Adjusted State Average Rates – (S)**

  3) **State Expenditures at State Average Rates – (S)**

  4) **Local Expenditures at Adjusted State Average Rates – (S)**

Appendix E. Policy Fact Sheets

Renewable Energy Strategy
Policy Fact Sheet

POLICY

Implement a Renewable Portfolio Standard. Regulated electric utilities are required to obtain a specified percentage of their electricity from qualifying renewable energy sources. Utilities are required to meet their obligations with in-state generation. Qualifying renewable resources include: existing renewables, new wind, solar, geothermal, biomass, landfill gas, and hydro (no pump storage).

- Modeled Policies
  - Michigan Sustainable Energy Coalition Renewable Portfolio Standard of 8% by 2015, with intermediate targets of 4% by 2007, 5% by 2009, 6% by 2011, and 7% by 2013.
  - Michigan at a Climate Crossroads Project Renewable Portfolio Standard of: 20% by 2025, with intermediate targets identical to MSEC through 2011, 8% by 2013, 10% by 2015, and an increase of 1% per year for 2016 through 2025.
- Scenarios
  - Baseline scenario: Generation from nuclear, oil, hydro, landfill gas, and wood stay constant. Remaining renewable fuels grow at 1.10% annually. Demand not met by existing fuels and new renewables is apportioned to coal (88%) and natural gas (12%).
  - Coal Scenario: Baseline, plus a new 500 MW coal plant comes online in 2013.
  - Nuclear Scenario: Baseline, plus a new 1000 MW nuclear plant comes online in 2013.

RESULTS

Cumulative Greenhouse-Gas Emission Reductions

Scenario	*2015*	*2025*
MMTCE Reduced		
MSEC RPS	6.37	*20.1*
MCCP RPS	7.73	39.9

Average Annual Economic Effects

Scenario	*2015*	*2025*
Change in Gross State Product (millions of 2000 dollars)		
MSEC RPS	*15.2*	*144*
MCCP RPS	*20.6*	*64.6*
Change in Employment (job-years)		
MSEC RPS	*195*	*1,393*
MCCP RPS	*292*	*881*

These cumulative savings numbers represent the difference between the RPS scenarios and the business as usual (BAU) scenario over the period 2007-2025.

IMPLICATIONS AND CONSIDERATIONS

- The RPS policies generate the greatest GHG emission reductions of all strategies studied.

- Most GHG emission reductions are achieved by new renewable electric generation (primarily wind and biomass) displacing the development of future coal and natural gas plants.
- For each RPS policy, overall emissions savings were not changed with the addition of a new coal plant or a new nuclear plant.
- The construction sector realizes economic benefits by producing new renewable electric generating facilities. Positive economic impacts are of a greater magnitude if renewable energy industries have a greater presence in the state.
- Economic impacts decrease, and in-state GHG emissions increase, if utilities use out-of-state Renewable Energy Certificates (RECs) in place of in-state renewable generation.
- In 2025, MSEC RPS would reduce electric sector emissions by 1.46 MMTCE, or 5.5% below projected baseline, but substantially above current emissions. MCCP RPS would reduce emissions 4.52 MMTCE, or 17% below projected baseline, and about the same as current emissions. (Baseline assumed 1.1% annual increase of electric GHG emissions.)

MODEL PARAMETERS AND ASSUMPTIONS

Greenhouse-Gas Emission Reduction Model

- Baseline derived from MPSC data for regulated utility electricity sales in 2004, and utility-specific fuel mixes.
- Incorporates revised demand growth projections (1.10%/year) defined by the Capacity Needs Forum Projections updated during the 21st Century Energy Plan process.
- The 3% of electricity currently generated by regulated utilities from renewable sources will count toward meeting RPS requirements.
- Transmission and distribution losses are 9% (Energy Information Administration).
- Power plant conversion efficiencies of various fuels and emissions factors derived from US EPA data: Coal: 0.322; Natural Gas: 0.379; and Oil: 0.362. Emissions factors used: Coal: 57.29 lbs C/Mbtu; Natural Gas: 31.91 lbs C/Mbtu; and Oil, 57.56 lbs C/Mbtu. To account for efficiency increases of newer coal and natural gas plants, conversion efficiency for coal was modeled as 0.3791, and combined cycle natural gas as 0.488.
- Emissions calculations based on point of generation (except biomass, where emissions from combustion are offset by those from plant growth) resulting in zero calculated GHG emissions from renewable energy sources.
- Baseline scenario assumed:
    - Constant amount of electricity from nuclear, oil, hydro, landfill gas, and wood over time.
    - A 1.10% projected annual growth in remaining renewable sources, e.g., biofuel, biomass, wind, and solar. (Capacity Needs Forum revised demand growth estimates)
    - Remaining non-renewable fuels account for the portion of demand that is not met by existing fuels and new renewables. Non-renewables apportioned to coal (88%), natural gas (12%), and nuclear power (0%), based on relative contributions to load growth in 2004 among coal and natural gas.
- Additional assumptions used in the two RPS scenarios:
    - New renewables added to the mix were allocated among wind (87%), biomass (12%), and solar (1%), based on MSEC assumption.

- New renewables displaced coal and natural gas, according to the same proportions noted above (88% coal and 12% natural gas).

Economic Effects Model

- Two sets of economic analyses were run: no change in renewable energy industries in the state occurs and RPS brings more renewable energy industries into Michigan.
- Accounts for changes in:
  - Production costs and capital costs due to renewables coming online and future coal plants not being built.
  - Electricity prices for commercial and industrial sectors.
  - Demand for coal products, electrical equipment manufacturing, and construction.
  - Consumer spending for household operation due to electricity price changes, and reallocation to other types of spending.

Appendix Efficiency Strategy Policy Fact Sheet

POLICY

Mandate appliance-efficiency standards for in-state sales of specified set of new appliances.

- In June 2006, Michigan Senator Liz Brater introduced SB 1333, outlining state-mandatory appliance-efficiency standards.
- In general, mandated efficiency levels are more stringent than current federal efficiency levels.
- New efficiency levels vary for each product.
- Affected appliances include (from SB 1333):

Included Appliances	
Bottle-type water dispensers (.5% of total 2015 MWh savings)	Metal halide lamp fixtures (11.29% of total 2015 MWh savings)
Commercial boilers (gas) (.009% of total 2015 MWh savings)	Pool heaters (gas) (.008% of total v MWh savings)
Commercial hot food holding cabinets (.48% of total 2015 MWh savings)	Portable electric spas (.18% of total 2015 MWh savings)
Compact audio products (3.2% of total 2015 MWh savings)	Residential furnace (electricity) (45.61% of total 2015 MWh savings)
DVD Players and recorders (4.7% of total 2015 MWh savings)	Residential boilers (gas) (.46% of total 2015 MWh savings)
Liquid immersed distribution transformers (10.54% of total 2015 MWh savings)	Single voltage external ac-dc power supplies (9.26% of total 2015 MWh savings)
Medium-voltage dry-type distribution transformers (.67% of total 2015 MWh savings)	State-regulated incandescent reflector lamps (10.65% of total 2015 MWh savings)
	Walk-in fridges and freezers (6.58% of total 2015 MWh savings)

RESULTS

Cumulative Greenhouse-Gas Emission Reductions

Scenario	*2015*	*2025*
MMTCE Reduced		
SB 1333	1.75	7.35

Average Annual Economic Effects

Scenario	*2015*	*2025*
Change in Gross State Product (millions of 2000 dollars)		
All Appliances	16.0	38.3
Change in Employment (job-years)		
All Appliances	234	437

IMPLICATIONS AND CONSIDERATIONS

- By 2025, Michigan can experience a reduction of 7.35 MMTCE and average annual growth in GSP of $38.3 million.

- Cost/Benefit analysis of this strategy requires a longer period than modeled in this study, as a result of differences in product lifetimes and, thus, varying timeframes for in-state product turnover (e.g., a light bulb is replaced more frequently than a commercial boiler).
- Negative economic results for CHP implementation with a state subsidy can potentially be reduced by decreasing the level of the subsidy. Negative economic results for CHP implementation without a subsidy eventually become positive in the years outside of the modeling period. Additionally, negative economic results for both scenarios also can be driven in part by the standby and back-up rates, that may be relatively high in Michigan, charged to ratepayers.
- Other benefits of this strategy:
  - Consumer behavior adopting energy efficiency and saving practices may have implications for other energy-saving opportunities
  - As similar state and federal policies are implemented, compliant appliance manufacturers in Michigan will be well positioned to serve those new consumers.

MODEL PARAMETERS AND ASSUMPTIONS

Greenhouse-Gas Model

- Reductions in residential, commercial, and industrial-energy demands reduce energy consumption at the utility level by reducing electricity consumption.
- Emissions reductions calculated from on-site natural gas-consuming appliances are also included.
- Average energy savings for each product derived from ACEEE report, *"Leading the Way, Continued Opportunities for New State Appliance and Equipment Efficiency Standards."*
- State product sales projections based on average residential, commercial, and industrial square-footage, also derived from the ACEEE report, *"Leading the Way, Continued Opportunities for New State Appliance and Equipment Efficiency Standards."*

Economic Model

- Residential, commercial, and industrial sectors are affected by this policy (both by costs and prices).
- Results capture in-state manufacturing adjustment in general and are not specific to appliance manufacturing (captured by industry demand and sales in the model).
- Products in compliance may be imported from other states (captured by market share in model).
- Changes in consumer spending and consumer prices (captured by the model) that are redistributed as a result of savings on energy spending drive the positive economic effects of this policy.
- Changes in industry production costs (captured by the wage price and profit variables in the model) also drive the positive effects of this policy due to redistribution of spending.

Alternative Fuels Strategy
Policy Fact Sheet

POLICY
Mandate a 25% renewable fuels standard for in-state motor fuel sales.

- Beginning in 2010, RFS will require 10% of motor fuels sold (on a volume basis) in Michigan to come from renewable resources.
- RFS will increase 1% per year until 2025, resulting in 25% of motor fuel sold in the state supplied from a renewable resource by 2025.
- Eligible fuels:
    - E85: ethanol used in a 85% volumetric blend of ethanol and conventional gasoline (CG).
    - Reformulated Gasoline (RFG)/E10: ethanol used as an oxygenate in CG.
    - Biodiesel: blended in any proportion with conventional diesel from 20% (B20) to 100% (B100).

RESULTS
GHG Gas Scenarios:

- *Corn-Based Ethanol Supply*: ethanol required to meet the standard is supplied solely from a corn feedstock.
- *Cellulosic and Corn-Based Ethanol Supply*: early introduction of cellulosic technology (2009) and aggressive adoption (87% of ethanol market by 2025) allows increased cellulosic ethanol contribution.[1]

All Biodiesel used to meet RFS is modeled as a soybean-oil derived product.

Economic Modeling Scenarios:

- *CG/E85 Price Equilibrium*: E85 and CG at price equilibrium, a dollar per gallon equivalent on a miles per gallon basis.
- *Uncompetitive E85 Price*: E85 pegged at $0.10 per gallon less than CG, which is more expensive than CG on a miles per gallon basis.

There is no price difference between RFG and CG and biodiesel and conventional diesel.

Cumulative Greenhouse-Gas Emission Reductions

Scenario	*2015*	*2025*
MMTCE Reduced		
Corn Based Ethanol Supply	1.28	6.51
Cellulosic and Corn Based Ethanol Supply	0.78	13.2

Average Annual Economic Effects

Scenario	*2015*	*2025*
Change in Gross State Product (millions of 2000 dollars)		
CG/E85 Price Equilibrium	133	283
Uncompetitive E85 Price	165	361
Change in Employment (job-years)		
CG/E85 Price Equilibrium	920	1,700
Uncompetitive E85 Price	722	1,230

[1] Khosla, Vinod. *Biofuels; Think Outside the Barrel*. April 2006.

Presented results reflect net changes from business as usual starting January 1, 2007, and ending December 31, 2025.

IMPLICATIONS AND CONSIDERATIONS

- Under the RFS, biodiesel usage increases from 3,000,000 gallons in 2005, to 202,000,000 gallons in 2025. E85 usage increases from 149,000 gallons in 2005, to 1,775,000,000 gallons in 2025 (total motor fuel usage in a given year is approximately 6,700,000,000 gallons per year).
- With the RFS policy, there is a concern about the availability of vehicle technologies capable of consuming the required fuel.
- Market demand created for alternative fuels may result in short-term strains on both the state and national alternative fuel and agricultural production sectors.
- A 25% renewable motor fuel usage in 2025 displaces over 960,000,000 gallons of projected petroleum fuel. A cumulative reduction of petroleum fuel usage from 2007 through 2025 is approximately 9,150,000,000 gallons.

MODEL PARAMETERS AND ASSUMPTIONS

Greenhouse-Gas Emission Reduction Model

- Analysis performed on a "well-to-wheel" fuel life-cycle basis.
- GHG-emission reduction occurs by displacing conventional (petroleum gasoline and diesel) fuel-powered vehicle miles traveled (VMT) with renewable fuel powered VMT.
- Argonne National Lab's GREET Model used to generate vehicle-fuel specific GHG emission factors (grams pollutant per vehicle mile traveled).[2]
- GHG emissions from fuel usage and displacement associated with the RFS were modeled from light-duty passenger cars and trucks.

Economic Effects Model

- Models the effect of reducing petroleum demand and increasing demand for the chemical sector.
- Per REMI, the chemical sector acts as an acceptable surrogate to the combined agricultural and biofuel production industries associated with renewable fuel production.
- Modeled economic effects are primarily a result of shifting demand from a less regionally supported product class (petroleum production) to a more regionally supported product class (chemical production).
- The E85/CG price equilibrium scenario was modeled as a single dollar of reduced petroleum demand results in a single dollar increase in chemical demand.
- The higher E85 price scenario was modeled as a dollar reduction in petroleum demand resulted in an increase in chemical demand between $1.235 and $1.266, depending on model year.
- This additional demand in the chemical sector is translated to additional consumer spending on gas and oil and a reduction on other consumer spending.

[2] GREET: The Greenhouse-Gases, Regulated Emissions, and Energy Use in Transportation Model, v.1.7 (beta) http://www.transportation.anl.gov/software/GREET/ accessed April 2006.

Alternative Fuels Strategy
Policy Fact Sheet

POLICY

Provide tax credit for in-state ethanol (both corn and cellulosic) production.

- A price of $0.05 per gallon of ethanol, up to 15-million gallons per year, produced at a **corn**-based biorefinery, with an annual capacity of less than 60 million gallons. The production tax credit (PTC) is limited to three years of operations.[3]
  - *Modeled as four new 60-million gallon capacity refineries, accounting for 240 million new gallons of corn ethanol in the state.*
- A price of $0.125 per gallon of ethanol, up to 15-million gallons per year, produced at a **cellulosic** biorefinery. There is no limit on the size of the facility and the PTC is limited to 10 years of operations.
  - *Modeled as a single 100-million-gallon cellulosic full-scale production facility.*

RESULTS

GHG Modeling Scenarios include:

- Corn Baseline I: Production capacity of 250 million gallons per year (Mgal/yr).
- Corn Baseline II: Production capacity of 510 Mgal/yr.
- PTC-induced production capacity of 240 Mgal/yr above Baseline I.
- Cellulosic :Production capacity of 100 Mgal/yr from a herbaceous feedstock.

Economic Modeling Scenarios include:

- Corn Baseline II and Cellulosic facility

Cumulative Greenhouse-Gas Emission Reductions

Scenario	*2015*	*2025*
MMTCE Reduced		
Corn Baseline capacity of 250 million gal/yr	1.27	2.67
Corn PTC-driven capacity of 240 million gal/yr	0.78	2.13
Corn Baseline capacity of 510 million gal/yr	2.27	5.21
Cellulosic PTC-driven capacity of 100 million gal/yr	1.22	3.24

Average Annual Economic Effects

	2015	*2025*
Change in Gross State Product (millions of 2000 dollars)	447	504
Change in Employment (job-years)	3,050	2,970

Presented results reflect net changes from business as usual starting January 1, 2007, and ending December 31, 2025.

IMPLICATIONS AND CONSIDERATIONS

- By 2025, Michigan could experience a reduction of 0.18 metric tons of GHG emissions for each $1 invested in the program, based on cellulosic ethanol production.

[3] The US Energy Policy Act 2005 (EPACT) redefined a small ethanol producer from 30 million gallons per year capacity to 60 million gallons per year. This proposed policy provides a tax incentive to this same population of ethanol producers.

- Projected baseline ethanol for motor fuel demand in Michigan grows from 160 million gallons in 2005, to 500 million gallons in 2025.[4]
- Michigan's first baseline corn ethanol production scenario results from the five existing or under construction facilities totaling 250 Mgal/yr production. The second baseline scenario includes these facilities plus four projects that, as of June 2006, are in early permitting phases totaling 260 Mgal/yr of production.
- Production-scale cellulosic ethanol is an emerging technology. Potential feedstocks for cellulosic ethanol include both herbaceous and woody biomass.
- Cellulosic ethanol project will likely require additional state and federal support: US EPA Act 2005, Energy Renaissance Zone, 21st Century Job Fund.

MODEL PARAMETERS AND ASSUMPTIONS

Greenhouse-Gas Emission Reductions Model

- Analysis performed on a "well-to-pump" life-cycle basis.
- GHG-emission reduction occurs by displacing conventional gasoline GHG emissions from production cycle by GHG emissions from ethanol production cycle.
- Argonne National Lab-GREET Model used to generate vehicle-fuel specific GHG emission factors (grams per million British thermal units of fuel).
- In-state ethanol production used as 85% blend with gasoline and as oxygenate in reformulated gasoline.
- In-state corn production uses for human consumption and animal fee maintained.
- Corn yield range from 137 to 193 bushels per acre, and corn conversion range from 2.80 to 3.65 gallons per bushel.[5]
- Cellulosic yield from 4.22 t0 6.27 tons per acre, and cellulose conversion range from 95 to 116 gallons per ton.[6]

Economic Effects Model

- Economic modeling captures increases in capital spending for the construction of new ethanol facilities (both cellulosic and corn) from 2005-2010.
- Annual ethanol production is modeled as an increase in demand from the chemical sector. Per REMI, the chemical sector acts as an acceptable surrogate to the combined agricultural and ethanol production industries associated with renewable fuel production.
- Annual ethanol production is translated to a modeled reduction in petroleum demand.
- Modeled economic effects are primarily a result of shifting demand from a less regionally supported product class (petroleum production) to a more regionally supported product class (chemical production).

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[4]Estimated from Michigan specific fuel usage data from the US Federal Highway Administration 2004 Statistics and regional fuel usage predictions from the US Department of Energy Annual Energy Outlook,2006.

[5]National Corn Growing Association. *How Much Ethanol Can Come from Corn.* 2005.

[6]Wang, M. Q., et al. *Greenhouse Gas, Regulated Emissions and Energy in Transportation Model.* Argonne National Lab, 2003.

Carbon Sequestration Strategy
Policy Fact Sheet

POLICY

Cost-sharing incentives to encourage afforestation of marginal agricultural lands to offset carbon emissions.

- Michigan has an estimated 3,039,330 acres of marginal agricultural land;. Land would be afforested by means of a state government-initiated tree-planting program intended to offset carbon emissions. The tree-planting program would be an extension of the Forest Stewardship Program and the Forest Land Enhancement Program.
- Government and non-industrial private landowners (farmers) enter into a 40:60 cost-sharing agreement to set up and maintain afforestation projects. The agreement lasts for 10 years. During that period, the government (state or federal) own the rights to all carbon offsets generated by the project. After 10 years, the carbon rights belong to the landowner.
- State-funded and federally funded (Conservation Reserve Program (CRP) funds) scenarios were modeled. Greenhouse-Gas emission results were independent of the funding source.

RESULTS

Cumulative Greenhouse-Gas Emission Reductions

Scenario	*2015*	*2025*
MMTCE Reduced		
1% magland planted w/white spruce	0.28	1.03
10% magland planted w/white spruce	2.81	10.3

Average Annual Economic Effects

Scenario	*2015*	*2025*
Change in Gross State Product (millions of 2000 dollars)		
1% Magland, State Cost-Share	-9.80	-5.18
1% Magland, CRP Cost- Share	-8.76	-4.67
10% Magland, State Cost-Share	-98.1	-52.4
10% Magland, CRP Cost-Share	-87.6	-46.7
Change in Employment (job-years)		
1% Magland, State Cost-Share	-60	-32
1% Magland, CRP Cost- Share	-39	-21
10% Magland, State Cost-Share	-602	-323
10% Magland, CRP Cost-Share	-397	-212

These cumulative savings numbers represent the difference between the tree-planting program and the business as usual (BAU) scenario over the period 2007-2025.

IMPLICATIONS AND CONSIDERATIONS

- Economic effects of this policy are negative because of the costs to participating landowners and the government to plant the trees. These prices would be reduced if a price of carbon were factored into the economic model. However, the MCCP team was unable to include a price of carbon due to the uncertainty of future climate legislation.
- The Chicago Climate Exchange currently operates a carbon trading market and since 2003, the prices have ranged from $3.67-$18.33/ metric ton of carbon

equivalent. Considering the 10.3 MMTCE sequestered by planting 10% of marginal agricultural land with conifers, and the range of carbon prices from the Chicago Climate Exchange, this policy would generate $37.8 million to $189 million through the trading of carbon forestry offsets, and help offset the total costs of the tree-plating program ($204 million).

- An extended timeframe would better characterize the policy's full greenhouse-gas reduction potential. Sequestration models generally use a 50+ year timeframe to calculate carbon sequestered by growing trees. Economic benefits could also increase as mature trees are harvested and sold.

MODEL PARAMETERS AND ASSUMPTIONS

Greenhouse-Gas Emission Reduction Model

- Business as usual scenario assumes no voluntary planting or natural regeneration of trees on magland.
- Identified 3,039,330 acres of available magland acres (constant) using research sponsored by the Midwest Regional Carbon Sequestration Partnership.[7] Maglands defined as:
  - Severely eroded prime cropland.
  - Non-eroded marginal cropland.
  - Severely eroded marginal cropland.
  - Severely eroded pastureland.
  - Non-eroded marginal pastureland.
  - Severely eroded marginal pastureland.
  - Barren land.
- Carbon sequestration rates for densely planted conifers (>250 stems per acre) determined by the Chicago Climate Exchange.[8]
- Sequestered carbon includes live tree biomass. Carbon in soil, leaf litter, and understory are not included. (Note: Average soil, leaf litter, and understory carbon estimates for coniferous forests in Michigan will be added in another model run.)
- No harvesting or thinning of trees before 2025.
- Assumed minimum survival rate of 500 trees per acre.
- Staggered tree-plantings over a 10-year period.

Economic Effects Model

- Program costs and covered practices based on the Michigan Forest Land Enhancement Program.
- Profits from participation in carbon-exchange offset programs, like Chicago Climate Exchange Carbon Financial Instrument contracts, were not included.
- Increased the output of the forestry sector to account for increased spending on tree plantings.
- Changed government spending for the state to model the cost to the state of implementing the cost-share program. (Note: A separate model run will replace state funding with federal assistance from the Conservation Reserve Program. This will improve the change in Gross State Product and Employment results.)
- Changed the compensation to the farm sector to model the cost to farmers to implement the cost-share program.

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[7] Niu, Xianzeng and Duiker, Sjoerd W. *Carbon Sequestration Potential by Afforestation of Marginal Agricultural Land in the Midwestern.* US Forest Ecology and Management 223 (2006): 415-427.

[8] Carbon sequestration rates in live vegetation reported in "Regional Estimates of Timber Volume and Forest Carbon for Managed Timberland" by Richard Birdsey, in *Forests and Global Change*, Volume 2.

Building Codes Strategy
Policy Fact Sheet

POLICY

Mandate an increase in R-values required by the Residential Michigan Uniform Energy Code for all new homes.

- Modeled Policies
  - International Residential Code (2004).
  - Michigan at a Climate Crossroads Project-designed code (2006).
- All new single-family homes will be required to comply.
- Only addresses prescriptive approach for implementation. Does not include performance-based standards.
- Current Policy: Michigan Uniform Energy Code (1999) as business as usual case.

RESULTS

Cumulative Greenhouse-Gas Emission Reductions

Scenario	*2015*	*2025*
MMTCE Reduced		
International Residential Code (2004)	1.01	4.18
Michigan at a Climate Crossroads Proposal	1.35	5.25

Average Annual Economic Effects

Scenario	*2015*	*2025*
Change in Gross State Product (millions of 2000 dollars)		
International Residential Code (2004)	155	244
Michigan at a Climate Crossroads Proposal	327	539
Change in Employment (job-years)		
International Residential Code (2004)	2,460	3,460
Michigan at a Climate Crossroads Proposal	4,370	6,440

Presented results reflect net changes from a business as usual case starting January 1, 2007 through 2025.

IMPLICATIONS AND CONSIDERATIONS

- Renovations, which would be subject to codes, were not taken into account, indicating additional benefits are not fully captured in this study.
- Not all benefits were captured, as new homes have a longer service life than is modeled.
- With savings from insulation, houses could have smaller--less costly, more efficient-- furnaces for additional savings.
- Performance-based codes should be considered, but the MCCP team was unable to model them. Additionally, analysis of current housing stock could have even greater impacts.

MODEL PARAMETERS AND ASSUMPTIONS

Greenhouse-Gas Emission Reduction Model

- Assumed 41,128 new homes constructed per year based on the average US Census Bureau data from 2001-2005.
- Estimates modeled with Home Energy Saver software from Lawrence Berkeley Labs to determine energy savings for each home type.
- Homes sizes modeled: 1,200 sq. feet; 2,200 sq. feet; and 3,500 sq. feet.

- Climate regions were derived from the International Energy Efficiency Code climate delineation for each county (IEEC Regions 5, 6, and 7).
- The number of homes in each climate region and their sizes were weighted based on average county new home construction data from 2001-2005 (e.g. 61.3% of the new homes were in IEEC Region 5, primarily southern Michigan, and measuring 2,500 sq. feet).
- Modeled home size and climate combinations under each of the three energy codes, and compared potential emissions to emissions under the current code.

Economic Effects Model

- The analysis incorporated an estimated increase of 2% in housing price for each proposed code to determine the increased cost of higher efficiency homes. Assumed to be passed on 100% to the customer.
- The reduction in electricity and heating bills was included. Assumed the savings would be moved to other parts of consumer spending.
- Increase firm sales for the construction sector for the increase cost and sale price of homes.
- Reduced firm sales for the construction sector to model the reduction in capital expansion due to decreased electricity demand.
- Reduced the demand for electrical equipment manufacturing to model the reduction in capital equipment.
- Decreased the demand for coal products due to reduced electricity demand.
- Reduced firm sales for the utility sector to model reductions in electricity demand.

Code R-Values	Current	Proposed	Proposed
	MUEC 1999	IRC 2004	MCCP 2006
Walls			
Climate Zone 1	R-13	R-21	R-21
Climate Zone 2	R-15	R-21	R-26
Climate Zone 3	R19	R-21	R-26
Windows (U values)			
Climate Zone 1	U .4-.5	U .35	U .35
Climate Zone 2	U .4-.5	U .35	U .35
Climate Zone 3	U .4-.5	U .35	U .35
Roof/Ceiling			
Climate Zone 1	R-30	R-49	R-49
Climate Zone 2	R38	R-49	R-49
Climate Zone 3	R38	R-49	R-49
Floors			
Climate Zone 1	R-21	R-21	R-30
Climate Zone 2	R-30	R-21	R-30
Climate Zone 3	R-30	R-21	R-30
Basement Walls			
Climate Zone 1	R-5	R-11	R-11
Climate Zone 2	R-5	R-11	R-11
Climate Zone 3	R-5	R-19	R-19

Fuel-Switching Strategy
Policy Fact Sheet

POLICY

Mandate use of biodiesel (B20) in all diesel-powered urban public transit buses.

- In 2007, all urban transit authorities receiving state funding would be required to use Michigan-produced B20 in all diesel-powered public transit buses. Currently, only one transit authority (University of Michigan Transit Services) out of the 16 affected transit agencies uses biodiesel.
- Gasoline-powered buses, compressed natural gas-powered buses, and demand response vehicles (vehicles that do not follow a fixed route and transport passengers according to their requests; often called "Dial-a-Ride") are not included in the policy.

RESULTS

Cumulative Greenhouse-Gas Emission Reductions

Scenario	*2015*	*2025*
MMTCE Reduced		
Utilizing DOE/USDA Emission Factors[9]	0.06	0.13

Average Annual Economic Effects

	2015	*2025*
Change in Gross State Product (millions of 2000 dollars)	4.41	4.48
Change in Employment (job-years)	35.6	31.2

These cumulative savings numbers represent the difference between the B20 mandate and the business as usual (BAU) scenario over the period 2007-2025.

IMPLICATIONS AND CONSIDERATIONS

- Small cumulative greenhouse-gas emissions reductions are achieved, but there are strong positive effects on GSP and employment. A policy with a broader scope, focusing on a larger number of diesel vehicles, could further increase the greenhouse-gas reduction potential and economic benefits of a fuel-switching policy.
- The biodiesel processing plant in Gladstone, Michigan, with a production capacity of 5 million gallons per year, is capable of supplying all of the biodiesel required by the mandatory policy.
- One additional biodiesel plant in Bangor, with a production capacity of 10 million gallons per year, is currently under construction.
- Four additional biodiesel plants of varying production capacity are under serious consideration for development.

[9]US DOE and USDA. *Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus.* May 1998.

MODEL PARAMETERS AND ASSUMPTIONS

Greenhouse-Gas Emission Reduction Model

- Utilized the Federal Transit Administration's National Transit Database to calculate Michigan-specific business as usual (BAU) fuel scenarios:
    - BAU annual increase of 0.84 % for diesel fuel use.
    - BAU annual increase of 4.023 % B20 fuel use.
- Identified urban public transit agencies according to Michigan Department of Transportation (MDOT) classifications.[10]
- Same fuel economy of 3.65 miles per gallon of fuel for diesel and B20.[11]
- Transit routes and level of service remain constant.
- Well-to-wheel emission factors for heavy-duty vehicles determined by US DOE and USDA 1998 Lifecycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus.

Economic Effects Model

- Mandate creates positive economic effects and reduces foreign oil consumption. A policy with a broader scope, focusing on a larger number of diesel vehicles, could further increase the economic benefits of a fuel-switching policy.
- Michigan-grown soybeans are the main feedstock, based on RFS policy.
- Michigan-produced biodiesel is used to fulfill the policy.
- Increased firm sales for the construction sector to model building a new 5 million gallons per year stand-alone biodiesel refinery with acid esterification process capabilities.
- Decreased the demand for petroleum products to model the diesel fuel displaced by biodiesel.
- Increased demand for electrical equipment manufacturing to model the increase in capital equipment expansion due to a new biodiesel refinery.
- Increased industry sales for the chemical sector to model the new production of biodiesel.
- Modified intermediary inputs to the chemical sector to better represent agricultural inputs to the biodiesel facility. (Note: In general, it is difficult to use the REMI model for agriculture scenarios.)

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[10] Michigan Department of Transportation Public Transit Providers. http://www.michigan.gov/mdot/1,1607,7-151-9621_11056_11266-31837--,00.html.

[11] American Public Transportation Association. *Power Source Efficiency*. http://www.apta.com/research/stats/bus/powereff.cfm.

Combined Heat and Power Strategy
Policy Fact Sheet

POLICY

Provide Combined Heat and Power (CHP) tax credits to induce use of CHP technologies for on-site energy generation.

- Potential Incentives: Production Tax Credit, Investment Tax Credit, and Subsidy[12] State tax credits are based on cents per kWh.
    - Investment Tax Credit: Applies to capital, operations, and management costs.
    - Production Tax Credit: Based on kWh generated.
- Examples of qualifying CHP technologies include: Backpressure Steam Turbine, Gas Turbine, and Reciprocating Internal Combustion Engine.
- Total estimated MW generation capacity used to calculate emissions reductions is derived from the 21st Century Energy Plan, Alternative Technology Working Group efforts coordinated by the Michigan Public Service Commission. The21st Century Energy Plan conservatively estimates the state can feasibly generate approximately 180 MW of distributed generation from CHP.

RESULTS

Cumulative Greenhouse-Gas Emission Reductions

Scenario	*2015*	*2025*
MMTCE Reduced		
180 MW, 8,760 hr/yr full utilization	3.96	8.9
180 MW, 6,750 hr/yr majority utilization	2.71	6.09
180 MW, 4,380 hr/yr half utilization	1.98	4.45

Average Annual Economic Effects

Scenario	*2015*	*2025*
Change in Gross State Product (millions of 2000 dollars)		
$.05/ kWh	*-43.9*	*-13.6*
No Subsidy	*-49.3*	*-20.8*
Change in Employment (job-years)		
$.05/ kWh	*-511*	*-81.0*
No Subsidy	*-315*	*-21.4*

Note: Economic effects assumed operation for 6,570 hours per year.

IMPLICATIONS AND CONSIDERATIONS

- By 2025, Michigan can experience a reduction of 6.09 MMTCE.
- Individual CHP adopters will have different costs of implementing CHP systems. Investment costs will vary based on:
    - Current energy and/ or steam demands of adopter.
    - Current energy costs to adopter.
    - Ability to sell power to the grid (current barriers include: transmission and interconnection infrastructure and fees, electricity prices).
    - Changes in regulatory nature of the energy market.

[12] The MCCP modeled the effects of a state subsidy.

- Other considerations not captured by this study:
    - As adoption and utilization of CHP grows on all scales: projections in the state's energy capacity needs may be considerably reduced; technological innovations may reduce the capital investment, operations, and management costs of CHP systems; and emerging energy markets may better incorporate market demands for CHP-generated electricity.
    - Third-party investors may emerge in response to growing capacity to sell retail power to the grid.
    - Current Michigan standby and back-up electricity rates may make distributed generation cost prohibitive.

MODEL PARAMETERS AND ASSUMPTIONS

Greenhouse-Gas Emission Reduction Model

- Estimated GHG-emission reductions result from decreasing demand for utility-based electricity by replacing existing boilers and other facilities with CHP systems run on natural gas. Totals account for reductions of energy demand on the grid, reductions of energy demand from existing boilers and other facilities, and additions of natural gas demand for new CHP systems.
- Three distinct scenarios were used to calculate variations in savings based on full utilization (8,760 hr/yr); majority utilization (6,750 hr/yr); and half utilization (4,380 hr/yr) of future CHP systems.

Economic Model

- Commercial and industrial sectors are affected by this policy (both by costs and prices).
- Five major industries contribute to estimated MW potential:
    - Automotive/Transportation (43%).
    - Mining/Metal Forming (18%).
    - Pulp/Paper (15%).
    - Chemical/Pharmaceutical (10%).
    - Food Processing (9%).
- Model inputs include: Industry demand on utilities, industry electricity fuel costs, fuel imports to utilities from outside the state, and industry capital costs.

Appendix F. Renewable Portfolio Standard

Appendix F.1. Renewable Portfolio Standard Experiences in Other States

Qualifying Renewable Electricity Sources

State	Wind	Photo-voltaics	Solar Thermal	Biomass	Geo-thermal	Small Hydro-electric	Fuel Cells	Land Fill Gas	Tidal/ Ocean	Wave/ Thermal	Energy Efficiency
Arizona	✔	✔	✔	✔					✔		
California	✔	✔	✔	✔	✔		✔	✔	✔	✔	
Colorado	✔	✔		✔	✔	✔		✔	✔		
Connecticut	✔	✔	✔	✔			✔	✔	✔	✔	
Delaware	✔	✔	✔	✔	✔		✔	✔	✔	✔	
District of Columbia	✔	✔	✔	✔	✔		✔		✔	✔	
Hawaii	✔	✔	✔	✔	✔		✔	✔	✔	✔	✔
Illinois	✔	✔	✔	✔			✔		✔		
Iowa	✔	✔		✔			✔				
Maine	✔	✔	✔	✔			✔	✔	✔	✔	
Maryland	✔	✔	✔	✔	✔		✔	✔	✔	✔	
Massachusetts	✔	✔	✔	✔				✔	✔	✔	
Minnesota	✔			✔							
Montana	✔	✔	✔	✔	✔		✔	✔	✔		
Nevada	✔	✔	✔	✔	✔		✔		✔		✔
New Jersey	✔	✔		✔	✔		✔	✔	✔	✔	
New Mexico	✔	✔	✔	✔	✔		✔	✔	✔		
New York	✔	✔		✔			✔	✔	✔	✔	
Pennsylvania	✔	✔	✔	✔	✔		✔	✔	✔		✔
Rhode Island	✔	✔		✔	✔	✔		✔	✔	✔	
Texas	✔	✔	✔	✔	✔		✔		✔	✔	
Vermont	✔	✔	✔	✔			✔	✔	✔		
Wisconsin	✔	✔	✔	✔	✔		✔	✔	✔	✔	

Source: Database of State Incentives for Renewable Energy

Figure F.1-1. Qualifying Renewable Electricity Sources in States With Renewable Portfolio Standards

Source: Barry G. Rabe, “Race to the Top: The Expanding Role of U.S. State Renewable Portfolio Standards,” Pew Center on Global Climate Change, June 2006, 5. Reproduced with permission.

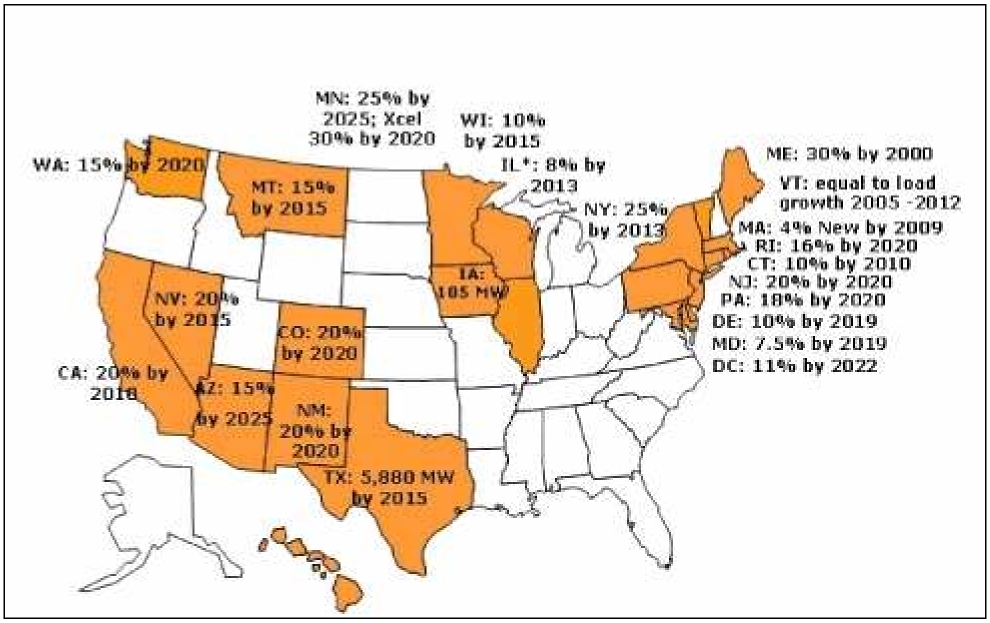


Figure F.1-2. States with Renewable Portfolio Standard (as of February 2007)

Adapted with permission from Barry G. Rabe, "Race to the Top: The Expanding Role of U.S. State Renewable Portfolio Standards," Pew Center on Global Climate Change, June 2006, 4, with updated map from Pew Center on Global Climate Change, "States with Renewable Portfolio Standards." Retrieved February 2007 from:
http://www.pewclimate.org/what_s_being_done/in_the_states/rps.cfm.

Appendix F.2. GHG Model Calculations for Renewable Portfolio Standard Analysis

Step 1: Obtain regulated utility sales data. The team obtained 2004 sales data from regulated utilities that was filed with the Michigan Public Service Commission (MPSC). This information provided each utility's total sales (MWh) during 2004.

Step 2: Obtain fuel mix data from regulated utilities. The team contacted each of the regulated utilities, and obtained records from their web sites regarding fuel mixes. In many cases, web site data was unavailable or insufficiently detailed, and in those cases, team members had phone conversations with utility personnel to obtain information in greater detail. Some fuel mix information was from early 2005; the team assumed that changes in fuel mix from late 2004 to early 2005 were inconsequential.[1] Variation existed across utility fuel mix reporting. Some utilities reported a "total renewable" percentage without specifying how it was distributed. Other utilities reported percentages of certain renewable fuels but did not report a "total renewable" percentage.

Step 3: Calculate portion of electric sales from each fuel. Figures calculated by multiplying the utility's total sales (from Step 1) by the percentage of its fuel mix obtained from that fuel (from Step 2).
Utility fuel mix data and electric sales data from 2004, used in calculations from Steps 1-3, can be seen in **Tables F.2-1 and F.2-2**.

[1] Some utility fuel mix data were not completely accurate, and calculating the sum of each fuel's percentage of generation yielded numbers less than, or greater than, 100%. For utilities where this was the case, several follow-up phone calls were made to each utility to address the discrepancies, and most of those calls were not returned.

Table F.2-1. Utility Fuel Mix Data

Fuel Mix	Total Net Generation (MWh)	Coal	Nuclear	Natural Gas	Oil	Hydro	Total Renewable
IOUs							
DTE Energy	40,378,836	79.40%	17.90%	1.00%	0.70%		0.90%
Consumers Energy	33,039,318	57.10%	16.80%	21.60%	0.50%	1.20%	
Wisconsin Electric Power (2005)	3,070,726	69.10%	26.60%	1.90%		1.40%	2.30%
AEP/Indiana Michigan Power	2,973,958	62.50%	37.10%			0.40%	
Edison Sault Electric	673,049	38.40%	13.80%	4.90%	0.40%	41.60%	
Upper Peninsula Power	761,218	63.50%	21.39%	2.91%	2.75%	8.95%	0.45%
Alpena Power	317,732	57.30%	18.00%	15.50%	0.50%	5.50%	3.20%
Wisconsin Public Service	304,133	81.60%	11.54%	4.65%	0.23%	1.62%	0.36%
No. States Power dba Xcel Energy	135,355	59.25%	13.50%	19.00%	0.50%		2.75%
Coops							
Great Lakes	1,185,365	70.76%	21.64%	5.91%	0.47%	0.69%	0.53%
Midwest Energy	484,145	77.90%	17.76%	2.60%	0.20%	0.25%	1.25%
Cherryland	312,993	70.76%	21.64%	5.91%	0.47%	0.69%	0.53%
Alger Delta (2003)	59,978	74.54%	16.11%	2.92%	1.78%	4.22%	0.42%
Cloverland	204,178	34.20%	11.60%	4.60%	0.30%	48.60%	
Ontonagon County REA	27,436						
Presque Isle	230,080	70.62%	22.51%	5.11%	0.46%	0.76%	0.54%
Thumb (99% from DTE)	137,061	79.40%	17.90%	1.00%	0.70%		0.90%
Tri-County	269,065	70.76%	21.64%	5.91%	0.47%	0.69%	0.53%

Table F.2-1. Utility Fuel Mix Data (cont'd)

Fuel Mix	Landfill Gas	Biofuel	Biomass	Solar	Wind	Wood	Sum %
IOUs							
DTE Energy		0.50%		0.40%			99.90%
Consumers Energy		0.05%			0.05%	2.90%	100.20%
Wisconsin Electric Power (2005)	0.50%	0.05%	0.08%		0.30%	0.07%	100.00%
AEP/Indiana Michigan Power							100.00%
Edison Sault Electric	0.20%				0.10%	0.60%	100.00%
Upper Peninsula Power			0.09%			0.27%	99.86%
Alpena Power			0.05%			2.50%	99.35%
Wisconsin Public Service			0.03%		0.12%	0.08%	99.87%
No. States Power dba Xcel Energy							95.00%
Coops							
Great Lakes	0.10%		0.02%			0.30%	99.89%
Midwest Energy	0.03%	1.00%	0.05%			0.15%	99.94%
Cherryland			0.02%			0.30%	99.79%
Alger Delta (2003)							99.57%
Cloverland	0.60%					0.40%	100.30%
Ontonagon County REA							
Presque Isle							100.00%
Thumb (99% from DTE)		0.50%		0.40%			99.90%
Tri-County	0.20%		0.02%			0.30%	99.99%

Table F.2-2. 2004 Utility Sales Data (MWh)

		Coal	Nuclear	Natural Gas	Oil	Hydro	Total Renewable
IOUs							
DTE Energy		32,060,795.8	7,227,811.6	403,788.4	282,651.9	0.0	363,409.5
Consumers Energy		18,865,450.6	5,550,605.4	7,136,492.7	165,196.6	396,471.8	0.0
Wisconsin Electric Power (2005)		2121871.666	816813.116	58343.794	0	42990.164	70626.698
AEP/Indiana Michigan Power		1,858,723.8	1,103,338.4	0.0	0.0	11,895.8	0.0
Edison Sault Electric		258,450.8	92,880.8	32,979.4	2,692.2	279,988.4	0.0
Upper Peninsula Power		483,373.4	162,824.5	22,151.4	20,933.5	68,129.0	3,425.5
Alpena Power		182,060.4	57,191.8	49,248.5	1,588.7	17,475.3	10,167.4
Wisconsin Public Service		248,172.5	35,096.9	14,142.2	699.5	4,927.0	1,094.9
No. States Power dba Xcel Energy		80,197.8	18,272.9	25,717.5	676.8	0.0	3,722.3
Coops							
Great Lakes		838,764.3	256,513.0	70,055.1	5,571.2	8,179.0	6,282.4
Midwest Energy		377,149.0	85,984.2	12,587.8	968.3	1,210.4	6,051.8
Cherryland		221,473.8	67,731.7	18,497.9	1,471.1	2,159.7	1,658.9
Alger Delta (2003)		44,707.6	9,662.5	1,751.4	1,067.6	2,531.1	251.9
Cloverland		69,828.9	23,684.6	9,392.2	612.5	99,230.5	0.0
Ontonagon County REA		17621.59408	6054.384428	762.364132	656.4063	2186.23766	189.44558
Presque Isle		162,482.5	51,791.0	11,757.1	1,058.4	1,748.6	1,242.4
Thumb (99% from DTE)		108,826.4	24,533.9	1,370.6	959.4	0.0	1,233.5
Tri-County		190,390.4	58,225.7	15,901.7	1,264.6	1,856.5	1,426.0

Table F.2-2. 2004 Utility Sales Data (MWh) (cont'd)

	Landfill Gas	Biofuel	Biomass	Solar	Wind	Wood	Sum %
IOUs							
DTE Energy	0.0	201,894.2	0.0	161,515.3	0.0	0.0	0.0
Consumers Energy	0.0	0.0	0.0	0.0	0.0	958,140.2	0.0
Wisconsin Electric Power (2005)	15,353.6	1,535.4	2,456.6	0.0	9,212.2	2,149.5	15,353.6
AEP/Indiana Michigan Power	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Edison Sault Electric	1,346.1	0.0	0.0	0.0	673.0	4,038.3	1,346.1
Upper Peninsula Power	0.0	0.0	685.1	0.0	0.0	2,055.3	0.0
Alpena Power	0.0	0.0	0.0	0.0	0.0	7,943.3	0.0
Wisconsin Public Service	0.0	0.0	91.2	0.0	365.0	243.3	0.0
No. States Power dba Xcel Energy	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coops							
Great Lakes	0.0	0.0	237.1	0.0	0.0	3,556.1	0.0
Midwest Energy	0.0	4,841.5	242.1	0.0	0.0	726.2	0.0
Cherryland	0.0	0.0	62.6	0.0	0.0	939.0	0.0
Alger Delta (2003)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cloverland	1,225.1	0.0	0.0	0.0	0.0	816.7	1,225.1
Ontonagon County REA	17.8	1.8	24.3	0.0	10.7	66.9	17.8
Presque Isle	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thumb (99% from DTE)	0.0	685.3	0.0	548.2	0.0	0.0	0.0
Tri-County	538.1	0.0	53.8	0.0	0.0	807.2	538.1

Step 4: Develop a business as usual (BAU) scenario. The team utilized projected growth in demand, projected rates of growth in specific renewable fuels, and assumed a constant level of generation from certain fuel sources to calculate MWh of sales generated by each fuel, for each utility, for each year in the 2005-2025 modeling period.

The team's calculation methodology included the following elements:

1. The team assumed that the amount of electricity from nuclear, oil, hydro, landfill gas, and wood stay constant over the modeling period.
2. The remaining available renewable fuels (biofuel, non-wood biomass, wind & solar) are projected to grow at 1.10% annually.
3. The remaining non-renewable fuels account for the portion of demand that is not met by existing fuels and new renewables, and that non-renewable component is apportioned among coal (88%) and natural gas (12%). (These percentages reflect the relative contributions to load growth in 2004 among coal and natural gas.)

To calculate specific utility sales of coal for year (n+1), the following equation was used: MWh of coal = (coal sales in year n)+(0.88*((total sales in year (n+1) – total sales in year n)-(total renewable sales in year (n+1) – total renewable sales in year n))).

To calculate specific utility sales of natural gas for year (n+1), the following equation was used:
MWh of natural gas = (natural gas sales in year n)+(0.12*((total sales in year (n+1) – total sales in year n) - (total renewable sales in year (n+1) – total renewable sales in year n))).

To calculate specific utility sales of wind (and other growing renewables--solar, biomass & biofuel) for year (n+1), the following equation was used, with a growth rate of 1.1%:
MWh of wind = (wind sales in year n)*(1+growth rate).

Step 5: Develop scenarios for MSEC RPS and MCCP RPS.

The fuel-specific annual sales data calculations were similar in the RPS scenarios as described above in the BAU scenario. The difference involved the calculation of the amount of sales from renewable sources that occur in each year, based on the ramp-up path of the RPS. The percentage of sales required from renewable sources in each year came from the ramp-up path, and the proportion of new renewables was divided between wind (87%), biomass (12%), and solar (1%). The remaining growth in demand not met by those renewables was apportioned between coal (88%) and natural gas (12%).

Step 6: Calculate GHG emissions reductions attributable to each RPS.
The GHG calculations were performed to assess the emissions reduction attributable to the RPS policy, so the calculations were based on the annual differences in electricity sales by fuel between BAU and each of the RPS scenarios. The calculations are explained below, and are followed by **Table F.2-3**, which shows fuel-specific conversion efficiencies, pollutant-specific emission factors, and conversion factors used in the calculations.

In order to calculate emissions reductions for CO_2, the team used the following calculation methodology.

The difference in fuel sales between an RPS scenario and BAU (MWh) was converted into a measure of energy content in the fuel (Mbtu). Transmission and distribution losses in the electric system were accounted for. Applying fuel-specific conversion efficiencies (the amount of electricity produced relative to the energy content of the fuel burned) was the next step. At this point, we have an amount of fuel burned in the power plant.

Applying an emissions factor (amount of pollutant per unit energy) allowed us to convert energy usage into an amount of each GHG produced. Subsequent conversions of pounds to tons, tons to metric tons, and metric tons to million metric tons were performed using standard unit conversions.

The final steps involved accounting for the differential impacts of each GHG on the climate, utilizing commonly accepted values of global warming potential (GWP). Applying the GWP value for CH_4 (21) and N_2O (310) converted all emissions to CO_2 equivalent, and multiplying by 12/44 converted CO_2 equivalent into carbon equivalent. Finally, summation of the emissions (in MMTCE) for each GHG yielded annual GHG emissions reductions attributable to each RPS.

Table F.2-3. Emissions Factors and Conversion Efficiencies Used in GHG Emissions Calculations

1 MWh=	3.412	Mbtu						
1 MWh=	0.003412	Bbtu						
Line Losses (T&D)	0.09							
	CH_4 Emissions Factor (Mton CH_4/Bbtu)				N_2O Emissions Factor (Mton N_2O/Bbtu)			
Coal	0.00100		CH_4 GWP		Coal	0.001403		N_20 GWP
Natural Gas	0.00095		21		Natural Gas	0.000095		310
Oil	0.00301				Oil	0.000601		
Wood	0.031625553				Wood	0.004220		
	Conversion Efficiency		CO_2 Emissions Factor (lbs C/Mbtu)					
Coal	0.3791		57.29					
Natural Gas	0.488		31.91					
Oil	0.362		57.56					

Appendix F.3. REMI Output Data

Note: For both the MSEC and MCCP RPS scenarios, two different variations were run by REMI. The first ("no change in local supply") assumed that no significant change would occur with respect to the level of renewable electric manufacturing activity in the state. The second ("high local supply") assumed that a greater proportion of manufacturing activity associated with renewable electric generation would occur in the state.

The vast majority of the output data were the same in both "no change in local supply" and "high local supply" cases. Those data are referred to as constants (for MSEC, **Table F.3-1,** and for MCCP, **Table F.3-4)**. The two variables that do show differences based on local supply characteristics are presented below the constant values (for MSEC, **Tables F.3-2 and F.3-3,** and for MCCP, **Tables F.3-5 and F.3-6**).

Table F.3-1. MSEC RPS – Constants

Variable	Sector	Unit	2007	2008	2009	2010	2011	2012	2013
Electricity Fuel Cost	Industrial	Percent	0.013	0.024	0.028	0.025	0.021	0.017	0.014
Electricity Fuel Cost	Commercial	Percent	0.015	0.028	0.033	0.030	0.026	0.022	0.019
Natural Gas Fuel Cost	Industrial	Percent	0	0	0	0.001	0.001	0.001	0.001
Natural Gas Fuel Cost	Commercial	Percent	0	0	0.001	0.001	0.001	0.002	0.002
Residual Fuel Cost	Industrial	Percent	0	0	0	0.001	0.001	0.001	0.001
Residual Fuel Cost	Commercial	Percent	0	0.001	0.001	0.002	0.002	0.002	0.002
Firm Sales	Utilities	2000 Fixed $ Million	95.92	176.6	210.1	195.6	168.7	142.2	120.0
Production Cost	Utilities	2000 Fixed $ Million	-3.379	93.23	220.1	190.9	152.6	135.7	97.55
Consumer Spending	Household Operation	2000 Fixed $ Million	25.76	76.86	123.7	111.0	92.25	79.79	62.17
Consumption Reallocation	All Consumption Sectors	2000 Fixed $ Million	-15.45	-46.12	-74.22	-66.60	-55.35	-47.88	-37.30
Industry Sales/Intl Exports	Broadcasting, exc Int;Telecomm	2000 Fixed $ Million	-10.30	-30.74	-49.48	-44.40	-36.90	-31.92	-24.87
Firm Sales	Construction	2000 Fixed $ Million	-4.591	697.3	170.4	170.1	158.9	164.3	168.3
Exogenous Final Demand	Petroleum, coal prod Mfg.	2000 Fixed $ Million	0.171	0.441	0.712	0.963	1.188	1.346	1.514

Table F.3-1. MSEC RPS – Constants (cont'd)

Variable	Sector	Unit	2014	2015	2016	2017	2018	2019	2020
Electricity Fuel Cost	Industrial	Percent	0.012	0.010	0.008	0.007	0.006	0.005	0.004
Electricity Fuel Cost	Commercial	Percent	0.016	0.014	0.012	0.011	0.010	0.009	0.008
Natural Gas Fuel Cost	Industrial	Percent	0.001	0.001	0.001	0.002	0.002	0.002	0.002
Natural Gas Fuel Cost	Commercial	Percent	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Residual Fuel Cost	Industrial	Percent	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Residual Fuel Cost	Commercial	Percent	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Firm Sales	Utilities	2000 Fixed $ Million	102.6	88.71	77.14	67.56	59.35	53.62	49.33
Production Cost	Utilities	2000 Fixed $ Million	81.13	119.2	135.5	64.01	-110.0	-295.7	-441.8
Consumer Spending	Household Operation	2000 Fixed $ Million	52.40	59.79	61.44	37.74	-15.91	-72.90	-118.0
Consumption Reallocation	All Consumption Sectors	2000 Fixed $ Million	-31.44	-35.88	-36.86	-22.65	9.547	43.74	70.78
Industry Sales/Intl Exports	Broadcasting, exc Int;Telecomm	2000 Fixed $ Million	-20.96	-23.92	-24.57	-15.10	6.365	29.16	47.19
Firm Sales	Construction	2000 Fixed $ Million	157.4	188.0	186.7	12.42	1.026	-29.23	-40.72
Exogenous Final Demand	Petroleum, coal prod Mfg.	2000 Fixed $ Million	1.661	1.776	1.872	1.948	2.025	2.104	2.177

Table F.3-1. MSEC RPS – Constants (cont'd)

Variable	Sector	Unit	2021	2022	2023	2024	2025
Electricity Fuel Cost	Industrial	Percent	0.004	0.005	0.005	0.005	0.005
Electricity Fuel Cost	Commercial	Percent	0.008	0.008	0.008	0.009	0.009
Natural Gas Fuel Cost	Industrial	Percent	0.002	0.002	0.002	0.002	0.002
Natural Gas Fuel Cost	Commercial	Percent	0.002	0.002	0.002	0.002	0.002
Residual Fuel Cost	Industrial	Percent	0.001	0.001	0.001	0.001	0.001
Residual Fuel Cost	Commercial	Percent	0.003	0.003	0.003	0.003	0.003
Firm Sales	Utilities	2000 Fixed $ Million	50.53	53.35	56.22	63.64	66.82
Production Cost	Utilities	2000 Fixed $ Million	-621.4	-828.6	-794.3	-549.6	-498.1
Consumer Spending	Household Operation	2000 Fixed $ Million	-172.0	-234.4	-222.3	-145.4	-127.9
Consumption Reallocation	All Consumption Sectors	2000 Fixed $ Million	103.2	140.7	133.4	87.24	76.72
Industry Sales/Intl Exports	Broadcasting, exc Int;Telecomm	2000 Fixed $ Million	68.79	93.77	88.93	58.16	51.15
Firm Sales	Construction	2000 Fixed $ Million	-54.98	-42.02	-42.40	-35.85	-25.92
Exogenous Final Demand	Petroleum, coal prod Mfg.	2000 Fixed $ Million	2.270	2.346	2.417	2.477	2.538

Table F.3-2. MSEC RPS – No Change in Local Supply

Variable	Sector	Unit	2007	2008	2009	2010	2011	2012	2013
Exogenous Final Demand	Machinery Mfg.	2000 Fixed $ Million	0	0	0	0	0	0	0
Exogenous Final Demand	Electrical Equip, appliance Mfg.	2000 Fixed $ Million	-0.550	311.2	74.49	72.96	63.64	61.81	60.83

Variable	Sector	Unit	2014	2015	2016	2017	2018	2019	2020
Exogenous Final Demand	Machinery Mfg.	2000 Fixed $ Million	0	0	0	0	0	0	0
Exogenous Final Demand	Electrical Equip, appliance Mfg.	2000 Fixed $ Million	56.40	69.35	64.92	-11.54	-19.27	-29.87	-25.74

Variable	Sector	Unit	2021	2022	2023	2024	2025
Exogenous Final Demand	Machinery Mfg.	2000 Fixed $ Million	0	0	0	0	0
Exogenous Final Demand	Electrical Equip, appliance Mfg.	2000 Fixed $ Million	-11.81	12.06	21.15	18.05	15.91

Table F.3-3. MSEC RPS – High Local Supply (2007-2013)

Variable	Sector	Unit	2007	2008	2009	2010	2011	2012	2013
Exogenous Final Demand	Machinery Mfg.	2000 Fixed $ Million	-0.550	311.24	74.49	72.96	63.64	61.81	60.83
Exogenous Final Demand	Electrical Equip, appliance Mfg.	2000 Fixed $ Million	0	0	0	0	0	0	0

Variable	Sector	Unit	2014	2015	2016	2017	2018	2019	2020
Exogenous Final Demand	Machinery Mfg.	2000 Fixed $ Million	56.40	69.35	64.92	-11.54	-19.27	-29.87	-25.74
Exogenous Final Demand	Electrical Equip, appliance Mfg.	2000 Fixed $ Million	0	0	0	0	0	0	0

Variable	Sector	Unit	2021	2022	2023	2024	2025
Exogenous Final Demand	Machinery Mfg.	2000 Fixed $ Million	-11.81	12.06	21.15	18.05	15.91
Exogenous Final Demand	Electrical Equip, appliance Mfg.	2000 Fixed $ Million	0	0	0	0	0

Table F.3-4. MCCP RPS – Constants

Variable	Sector	Unit	2007	2008	2009	2010	2011	2012	2013
Electricity Fuel Cost	Industrial	Percent	0.013	0.024	0.028	0.025	0.021	0.017	0.014
Electricity Fuel Cost	Commercial	Percent	0.015	0.028	0.033	0.030	0.026	0.022	0.019
Natural Gas Fuel Cost	Industrial	Percent	0	0	0	0.001	0.001	0.001	0.001
Natural Gas Fuel Cost	Commercial	Percent	0	0	0.001	0.001	0.001	0.002	0.002
Residual Fuel Cost	Industrial	Percent	0	0	0	0.001	0.001	0.001	0.001
Residual Fuel Cost	Commercial	Percent	0	0.001	0.001	0.002	0.002	0.002	0.002
Firm Sales	Utilities	2000 Fixed $ Million	95.92	176.6	210.1	195.6	168.7	142.2	120.0
Production Cost	Utilities	2000 Fixed $ Million	-3.379	93.23	220.1	190.9	152.6	135.7	97.55
Consumer Spending	Household Operation	2000 Fixed $ Million	25.76	76.86	123.7	111.0	92.25	79.79	62.17
Consumption Reallocation	All Consumption Sectors	2000 Fixed $ Million	-15.45	-46.12	-74.22	-66.60	-55.35	-47.88	-37.30
Industry Sales/Intl Exports	Broadcasting, exc Int;Telecomm	2000 Fixed $ Million	-10.30	-30.74	-49.48	-44.40	-36.90	-31.92	-24.87
Firm Sales	Construction	2000 Fixed $ Million	-4.591	697.3	170.4	170.1	158.9	164.3	168.3
Exogenous Final Demand	Petroleum, coal prod Mfg.	2000 Fixed $ Million	0.171	0.441	0.712	0.963	1.188	1.346	1.514

Table F.3-4. MCCP RPS – Constants (cont'd)

Variable	Sector	Unit	2014	2015	2016	2017	2018	2019	2020
Electricity Fuel Cost	Industrial	Percent	0.012	0.011	0.009	0.008	0.008	0.007	0.007
Electricity Fuel Cost	Commercial	Percent	0.017	0.015	0.014	0.013	0.012	0.012	0.012
Natural Gas Fuel Cost	Industrial	Percent	0.001	0.001	0.001	0.002	0.002	0.002	0.002
Natural Gas Fuel Cost	Commercial	Percent	0.002	0.002	0.002	0.002	0.002	0.003	0.003
Residual Fuel Cost	Industrial	Percent	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Residual Fuel Cost	Commercial	Percent	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Firm Sales	Utilities	2000 Fixed $ Million	106.3	94.70	86.27	80.53	76.69	75.62	75.00
Production Cost	Utilities	2000 Fixed $ Million	134.0	235.0	294.9	261.5	207.0	99.05	-14.26
Consumer Spending	Household Operation	2000 Fixed $ Million	69.23	95.78	110.9	99.57	82.64	50.88	17.47
Consumption Reallocation	All Consumption Sectors	2000 Fixed $ Million	-41.54	-57.47	-66.56	-59.74	-49.58	-30.53	-10.48
Industry Sales/Intl Exports	Broadcasting, exc Int;Telecomm	2000 Fixed $ Million	-27.69	-38.31	-44.37	-39.83	-33.06	-20.35	-6.988
Firm Sales	Construction	2000 Fixed $ Million	320.6	362.9	373.8	376.2	386.6	368.5	378.3
Exogenous Final Demand	Petroleum, coal prod Mfg.	2000 Fixed $ Million	1.667	1.790	1.897	1.988	2.084	2.190	2.293

Table F.3-4. MCCP RPS – Constants (cont'd)

Variable	Sector	Unit	2021	2022	2023	2024	2025
Electricity Fuel Cost	Industrial	Percent	0.007	0.008	0.008	0.008	0.009
Electricity Fuel Cost	Commercial	Percent	0.012	0.012	0.012	0.013	0.014
Natural Gas Fuel Cost	Industrial	Percent	0.002	0.002	0.002	0.002	0.002
Natural Gas Fuel Cost	Commercial	Percent	0.003	0.003	0.003	0.003	0.003
Residual Fuel Cost	Industrial	Percent	0.001	0.002	0.002	0.002	0.002
Residual Fuel Cost	Commercial	Percent	0.003	0.003	0.003	0.003	0.003
Firm Sales	Utilities	2000 Fixed $ Million	77.49	82.95	88.49	96.67	105.7
Production Cost	Utilities	2000 Fixed $ Million	-155.3	-325.1	-589.3	-78.48	-67.90
Consumer Spending	Household Operation	2000 Fixed $ Million	-23.22	-71.93	-149.2	3.353	9.399
Consumption Reallocation	All Consumption Sectors	2000 Fixed $ Million	13.93	43.16	89.51	-2.012	-5.639
Industry Sales/Intl Exports	Broadcasting, exc Int;Telecomm	2000 Fixed $ Million	9.289	28.77	59.67	-1.341	-3.760
Firm Sales	Construction	2000 Fixed $ Million	377.2	416.0	411.1	447.9	479.9
Exogenous Final Demand	Petroleum, coal prod Mfg.	2000 Fixed $ Million	2.421	2.537	2.649	2.752	2.864

Table F.3-5. MCCP RPS – No Change in Local Supply

Variable	Sector	Unit	2007	2008	2009	2010	2011	2012	2013
Exogenous Final Demand	Machinery Mfg.	2000 Fixed $ Million	0	0	0	0	0	0	0
Exogenous Final Demand	Electrical Equip, appliance Mfg.	2000 Fixed $ Million	-0.550	311.2	74.49	72.96	63.64	61.80	129.1

Variable	Sector	Unit	2014	2015	2016	2017	2018	2019	2020
Exogenous Final Demand	Machinery Mfg.	2000 Fixed $ Million	0	0	0	0	0	0	0
Exogenous Final Demand	Electrical Equip, appliance Mfg.	2000 Fixed $ Million	127.6	143.9	142.9	143.1	141.6	128.9	139.9

Variable	Sector	Unit	2021	2022	2023	2024	2025
Exogenous Final Demand	Machinery Mfg.	2000 Fixed $ Million	0	0	0	0	0
Exogenous Final Demand	Electrical Equip, appliance Mfg.	2000 Fixed $ Million	154.4	189.0	200.5	214.6	224.8

Table F.3-6. MCCP RPS – High Local Supply (2007-2013)

Variable	Sector	Unit	2007	2008	2009	2010	2011	2012	2013
Exogenous Final Demand	Machinery Mfg.	2000 Fixed $ Million	-0.550	311.2	74.49	72.96	63.64	61.80	129.1
Exogenous Final Demand	Electrical Equip, appliance Mfg.	2000 Fixed $ Million	0	0	0	0	0	0	0

Variable	Sector	Unit	2014	2015	2016	2017	2018	2019	2020
Exogenous Final Demand	Machinery Mfg.	2000 Fixed $ Million	127.6	143.9	142.9	143.1	141.6	128.9	139.9
Exogenous Final Demand	Electrical Equip, appliance Mfg.	2000 Fixed $ Million	0	0	0	0	0	0	0

Variable	Sector	Unit	2021	2022	2023	2024	2025
Exogenous Final Demand	Machinery Mfg.	2000 Fixed $ Million	154.4	189.0	200.5	214.6	224.8
Exogenous Final Demand	Electrical Equip, appliance Mfg.	2000 Fixed $ Million	0	0	0	0	0

Appendix G. Appliance Efficiency Standards

Appendix G.1. Copy of SB 1333[i]

June 27, 2006, Introduced by Senators BRATER, PRUSI, CLARK-COLEMAN, BASHAM, JACOBS and WHITMER and referred to the Committee on Technology and Energy.

A bill to establish minimum efficiency standards for certain products sold or installed in the state; to prescribe the powers and duties of certain state agencies and officials; and to provide for penalties.

THE PEOPLE OF THE STATE OF MICHIGAN ENACT:

Sec. 1. The legislature finds all of the following:

(a) That efficiency standards for certain products sold or installed in the state assure consumers and businesses that the products meet minimum efficiency performance levels thus saving money on utility bills.

(b) That efficiency standards save energy and reduce pollution and other environmental impacts associated with the production, distribution, and use of electricity, natural gas, and oil.

(c) That efficiency standards can make electricity systems more reliable by reducing the strain on the electricity grid during peak demand periods. Improved energy efficiency can reduce or delay the need for new power plants, power transmission lines, and power distribution system upgrades.

(d) Energy efficiency standards contribute to the economy of this state by helping to better balance energy supply and demand, thus reducing pressure for higher natural gas and electricity prices. By saving consumers and businesses money on energy bills, efficiency standards help the state and local economy, since energy bill savings can be spent on local goods and services.

Sec. 2. As used in this act:

(a) "Ballast" means a device used with an electric discharge lamp to obtain necessary circuit conditions, such as voltage, current, and waveform, for starting and operating the lamp.

(b) "Boiler" means a self-contained low-pressure appliance for supplying steam or hot water primarily designed for space heating. Commercial boiler means a boiler with a heat input rate of 300,000 btu per hour or more that is shipped complete with heating equipment, mechanical draft equipment, and automatic controls. Commercial boiler includes a factory-built boiler manufactured as a unit or system, disassembled for shipment, and reassembled at the site of installation. Residential boiler means a self-contained appliance for supplying steam or hot water, which uses natural gas, propane, or home heating oil, and which has a heat input rate of less than 300,000 btu per hour.

(c) "Bottle-type water dispenser" means a water dispenser that uses a bottle or reservoir as the source of potable water.

(d) "Commission" means the Michigan public service commission.

(e) "Commercial hot food holding cabinet" means an appliance that is a heated, fully-enclosed compartment with 1 or more solid doors, and that is designed to maintain the temperature of hot food that has been cooked in a separate appliance. Commercial hot food holding cabinet does not include heated glass merchandising cabinets, drawer warmers, or cook-and-hold appliances.

(f) "Compact audio product", also known as a mini, mid, micro, or shelf audio system, means an integrated audio system encased in a single housing that includes an amplifier and radio tuner, attached or separable speakers, and can reproduce audio from magnetic tape, CD, DVD, or flash memory. Compact audio product does not include products that can be independently powered by internal batteries or that have a powered external satellite antenna or that can provide a video output signal.

(g) "Compensation" means money or any other valuable thing, regardless of form, received or to be received by a person for services rendered.

(h) "Digital versatile disc" and "DVD" mean a laser-encoded plastic medium capable of storing a large amount of digital audio, video, and computer data.

(i) "Digital versatile disc player" and "digital versatile disc recorder" mean commercially available electronic products encased in a single housing that includes an integral power supply and for which the sole purpose is the decoding or production or recording of digitized video signal on a DVD. DVD recorder does not include models that have an electronic programming guide function that provides an interactive, onscreen menu of television listings, and that downloads program information from the vertical blanking interval of a regular television signal.

(j) "Electricity ratio" is the ratio of furnace electricity use to total furnace energy use. Electricity ratio = $(3.412*E_{AE}/(1000*E_F + 3.412*E_{AE})$ where E_{AE} (average annual auxiliary electrical consumption) and E_F (average annual fuel energy consumption) are defined in appendix n to subpart B of part 430 of title 10 of the code of federal regulations and E_F is expressed in millions of btus per year.

(k) "High-intensity discharge lamp" means a lamp in which light is produced by the passage of an electric current through a vapor or gas and in which the light-producing arc is stabilized by bulb wall temperature and the arc tube has a bulb wall loading in excess of 3 watts per square centimeter.

(*l*) "Liquid-immersed distribution transformer" means a transformer that has an input voltage of 34,500 volts or less, has an output voltage of 600 volts or less, uses oil or other liquid as a coolant, and is rated for operation at a frequency of 60 hertz.

(m) "Medium voltage dry-type distribution transformer" means a transformer that has an input voltage of more than 600 volts but less than or equal to 34,500 volts, is air-cooled, does not use oil as a coolant, and is rated for operation at a frequency of 60 hertz.

(n) "Metal halide lamp" means a high-intensity discharge lamp in which the major portion of the light is produced by radiation of metal halides and their products of dissociation, possibly in combination with metallic vapors.

(o) "Metal halide lamp fixture" means a light fixture designed to be operated with a metal halide lamp and a ballast for a metal halide lamp.

(p) "Pool heater" means an appliance designed for heating nonpotable water contained at atmospheric pressure, including heating water in swimming pools, spas, hot tubs, and similar applications.

(q) "Portable electric spa" means a factory-built electric spa or hot tub, supplied with equipment for heating and circulating water.

(r) "Probe-start metal halide ballast" means a ballast used to operate metal halide lamps, which does not contain an igniter and which instead starts lamps by using a third starting electrode probe in the arc tube.

(s) "Residential furnace" means a self-contained space heater designed to supply heated air through ducts of more than 10 inches in length and which utilizes only single-phase electric current, or single-phase electric current or DC current in conjunction with natural gas, propane, or home heating oil, and all of the following apply:

(*i*) Is designed to be the principal heating source for the living space of 1 or more residences.

(*ii*) Is not contained within the same cabinet as a central air conditioner whose rated cooling capacity is above 65,000 btu per hour.

(*iii*) Has a heat input rate of less than 225,000 btu per hour.

(t) "Residential pool pump" means a pump used to circulate and filter residential swimming pool water in order to maintain clarity and sanitation.

(u) "Single-voltage external AC to DC power supply" means a device that is all of the following:

(*i*) Designed to convert line voltage AC input into lower voltage DC output.

(*ii*) Able to convert to only 1 DC output voltage at a time.

(*iii*) Sold with, or intended to be used with, a separate end-use product that constitutes the primary power load.

(*iv*) Contained within a separate physical enclosure from the end-use product.

(*v*) Connected to the end-use product via a removable or hard-wired male/female electrical connection, cable, cord, or other wiring.

(*vi*) Does not have batteries or battery packs, including those that are removable, that physically attach directly to the power supply unit.

(*vii*) Does not have a battery chemistry or type selector switch and indicator light, or does not have a battery chemistry or type selector switch and a state of charge meter.

(*viii*) Has a nameplate output power less than or equal to 250 watts.

(v) "State-regulated incandescent reflector lamp" means a lamp, not colored or designed for rough or vibration service applications, with an inner reflective coating on the outer bulb to direct the light, an E26 medium screw base, a rated voltage or voltage range that lies at least partially within 115 to 130 volts, and that falls into either of the following categories: a blown PAR (BPAR), bulged reflector (BR), or elliptical reflector (ER) bulb shape with a diameter equal to or greater than 2.25 inches; or a reflector (R), parabolic aluminized reflector (PAR), or similar bulb shape with a diameter of 2.25 to 2.75 inches, inclusive.

(w) "Transformer" means a device consisting of 2 or more coils of insulated wire and that is designed to transfer alternating current by electromagnetic induction from 1 coil to another to change the original voltage or current value. This term does not include devices with multiple voltage taps, with the highest voltage tap equaling at least 20% more than the lowest voltage tap or devices, such as those commonly known as drive transformers, rectifier transformers, auto-high transformers, uninterruptible power system transformers, impedance transformers, regulating transformers, sealed and non-ventilating transformers, machine tool transformers, welding transformers, grounding transformers, or testing transformers, that are designed to be used in a special purpose application and are unlikely to be used in general purpose applications.

(x) "Walk-in refrigerator" and "walk-in freezer" mean a space refrigerated to temperatures, respectively, at or above and below 32 degrees Fahrenheit that can be walked into.

(y) "Water dispenser" means a factory-made assembly that mechanically cools and heats potable water and that dispenses the cooled or heated water by integral or remote means.

Sec. 3. (1) This act shall apply to the following types of new products sold, offered for sale, or installed in the state after the effective date of this act:

(a) Bottle-type water dispensers.

(b) Commercial boilers.

(c) Commercial hot food holding cabinets.

(d) Compact audio products.

(e) Digital versatile disc players and digital versatile disc recorders.

(f) Liquid-immersed distribution transformers.

(g) Medium voltage dry-type distribution transformers.

(h) Metal halide lamp fixtures.

(i) Pool heaters.

(j) Residential furnaces and residential boilers.

(k) Residential pool pumps.

(*l*) Portable electric spas.

(m) Single-voltage external AC to DC power supplies.

(n) State-regulated incandescent reflector lamps.

(o) Walk-in refrigerators and walk-in freezers.

(p) Any other products as may be designated by the commission under section 7.

(2) This act does not apply to any of the following:

(a) New products manufactured in the state and sold outside the state.

(b) New products manufactured outside the state and sold at wholesale inside the state for final retail sale and installation outside the state.

(c) Products installed in mobile manufactured homes at the time of construction.

(d) Products designed expressly for installation and use in recreational vehicles.

Sec. 4. (1) No later than 1 year after the effective date of this act, the commission shall adopt regulations establishing minimum efficiency standards for the types of new products subject to this act.

(2) The regulations required under subsection (1) shall provide for all of the following minimum efficiency standards:

(a) Bottle-type water dispensers designed for dispensing both hot and cold water shall not have standby energy consumption greater than 1.2 kilowatt-hours per day, as measured in accordance with the test criteria contained in version 1 of the federal environmental protection agency's "Energy Star Program Requirements for Bottled Water Coolers", except units with an integral, automatic timer shall not be tested using section D, "Timer Usage", of the test criteria.

(b) The thermal efficiency of commercial boilers, as determined in accordance with hydronics institute testing standard BTS 2000, "Method to Determine Efficiency of Commercial Space Heating Boilers", shall not be less than the following:

(*i*) 80% for gas-fired commercial boilers.

(*ii*) 82% for oil-fired commercial boilers.

(c) Commercial hot food holding cabinets shall have a maximum idle energy rate of 40 watts per cubic foot of interior volume, as determined by the "idle energy rate-dry test" in ASTM F2140-01, "Standard Test Method for Performance of Hot Food Holding Cabinets" published by ASTM international. Interior volume shall be measured in accordance with the method shown in the federal environmental protection agency's "Energy Star Program Requirements for Commercial Hot Food Holding Cabinets" as in effect on August 15, 2003.

(d) Compact audio products shall not use more than 2 watts in standby-passive mode for those without a permanently illuminated clock display and 4 watts in standby-passive mode for those with a permanently illuminated clock display, as measured in accordance with international electrotechnical commission test method 62087:2002(E), "Methods of measurement for the power consumption of audio, video, and related equipment".

(e) Digital versatile disc players and digital versatile disc recorders shall not use more than 3 watts in standby-passive mode, as measured in accordance with international electrotechnical commission test method 62087:2002(E), "Methods of measurement for the power consumption of audio, video, and related equipment".

(f) Medium voltage dry-type distribution transformers shall meet minimum efficiency levels 3/10 of a percentage point higher than the class 1 efficiency levels for medium voltage distribution transformers specified in Table 4-2 of the "Guide for Determining Energy Efficiency for Distribution Transformers" published by the national electrical manufacturers association, NEMA Standard TP-1-2002.

(g) Liquid-immersed distribution transformers shall meet minimum efficiency levels 2/10 of a percentage point higher than the class 1 efficiency levels specified in Table 4-1 of the "Guide for Determining Energy Efficiency for Distribution Transformers" published by the national electrical manufacturers association, NEMA Standard TP-1-2002.

(h) Metal halide lamp fixtures designed to be operated with lamps rated greater than or equal to 150 watts but less than or equal to 500 watts shall not contain a probe-start metal halide ballast.

(i) Pool heaters shall be equipped with an intermittent ignition device and the thermal efficiency of pool heaters shall be not less than 80%, as measured in accordance with the federal test method for measuring the energy consumption of pool heaters contained in appendix p to subpart b of part 430, title 10, CFR.

(j) Portable electric spas shall not have a standby power greater than $5(V^{2/3})$ watts where V = the total volume in gallons.

(k) Residential furnaces and residential boilers shall comply with the following annual fuel utilization efficiency and electricity ratio values:

Product Type	Minimum AFUE	Maximum electricity ratio
Natural gas- and propane-fired furnaces	90%	2.0%
Oil-fired furnaces ≥94,000 btu/hour in capacity	83%	2.0%
Oil-fired furnaces <94,000 btu/hour in capacity	83%	2.3%
Natural gas-, oil-, and propane-fired hot water residential boilers	84%	Not applicable
Natural gas-, oil-, and		

propane-fired steam residential boilers 82% Not applicable

The commissioner may adopt rules to exempt compliance with the foregoing residential furnace or residential boiler standards at any building, site, or location where complying with the standards would be in conflict with any local zoning ordinance, building, or plumbing code, or other rule regarding installation and venting of residential furnaces or residential boilers.

(*l*) Residential pool pump motors may not be split-phase or capacitor start-induction run type motors. Pool pump motors with a capacity of 1 horsepower or more shall have the capability of operating at 2 or more speeds with a low speed having a rotation rate that is not more than 1/2 of the motor's maximum rotation rate. Pool pump motor controls shall have the capability of operating the pool pump at at least 2 speeds. The default circulation speed shall be the lowest speed, with a high speed override capability being for a temporary period not to exceed 1 normal cycle.

(m) Single-voltage external AC to DC power supplies shall meet the energy efficiency requirements in the following table:

Nameplate Output Power	Minimum Efficiency in Active Mode
0 to <1 watt	0.49 * Nameplate Output
≥1 watt and ≤49 watts	0.09*Ln(Nameplate Output Power) + 0.49
>49 watts	0.84
	Maximum Energy Consumption in No-Load Mode
0 to <10 watts	0.5 watts
≥10 watts and ≤250 watts	0.75 watts

Where Ln (Nameplate Output) = Natural Logarithm of the nameplate output expressed in watts

This standard applies to single voltage AC to DC power supplies that are sold individually and to those that are sold as a component of or in conjunction with another product. For purposes of this subparagraph, the efficiency of single-voltage external AC to DC power supplies shall be measured in accordance with the test methodology specified by the federal environmental protection agency's energy star program, "Test Method for Calculating the Energy Efficiency of Single-Voltage External AC-DC and AC-AC Power Supplies (August 11, 2004)".

(n) State-regulated incandescent reflector lamps shall meet the minimum average lamp efficacy requirements for federally regulated incandescent reflector lamps contained in 42 USC 6295(i)(1)(A). The following types of incandescent reflector lamps are exempt from these requirements:

(*i*) Lamps rated at 50 watts or less of the following types: BR30, ER30, BR40, and ER40.

(*ii*) Lamps rated at 65 watts of the following types: BR30, BR40, and ER40.

(*iii*) R20 lamps of 45 watts or less.

(o) Walk-in refrigerators and walk-in freezers with the applicable motor types shown in the table below shall include the required components shown:

<u>Motor Type Required Components</u>

All Interior lights; light sources with
an efficacy of 45 lumens per watt
or more, including ballast losses
(if any). This efficacy standard does
not apply to LED light sources until
January 1, 2010
All Automatic door closers that firmly
close all reach-in doors
All Automatic door closers that firmly
close all walk-in doors no wider than
3.9 feet and no higher than 6.9 feet
that have been closed to within 1
inch of full closure
All Wall, ceiling, and door insulation at
least R-28 for refrigerators and at
least R-34 for freezers
All Floor insulation at least R-28 for
freezers (no requirement for
refrigerators)
Condenser fan Electronically commutated motors,
motors   permanent split capacitor-type
of under 1 motors, or polyphase motors of 1/2

horsepower horsepower or more
Single-phase Electronically commutated motors
evaporator fan
motors of under
1 horsepower
and less than
460 volts

(p) Walk-in refrigerators and walk-in freezers with transparent reach-in doors shall meet the following requirements:

(*i*) Transparent reach-in doors shall be of triple pane glass with either heat-reflective treated glass or gas fill.

(*ii*) If the appliance has an anti-sweat heater without anti-sweat controls, then the appliance shall have a total door rail, glass, and frame heater power draw of no more than 40 watts if it is a freezer or 17 watts if it is a refrigerator per foot of door frame width.

(*iii*) If the appliance has an anti-sweat heater with anti-sweat heat controls, and the total door rail, glass, and frame heater power draw is more than 40 watts if it is a freezer or 17 watts if it is a refrigerator per foot of door frame width, then the anti-sweat heat controls shall reduce the energy use of the anti-sweat heater in an amount corresponding to the relative humidity in the air outside the door or to the condensation on the inner glass pane.

Sec. 5. (1) Except as provided under subsection (2), on or after January 1, 2008, no new bottle-type water dispenser, commercial hot food holding cabinet, compact audio product, digital versatile disc player or digital versatile disc recorder, liquid-immersed distribution transformer, medium voltage dry-type distribution transformer, metal halide lamp fixture, residential pool pump, portable electric spa, state-regulated incandescent reflector lamp, single-voltage external AC to DC power supply, or walk-in refrigerator or walk-in freezer may be sold or offered for sale in the state unless the efficiency of the new product meets or exceeds the efficiency standards set forth in the regulations adopted under section 4.

(2) Residential pool pumps that do not meet the efficiency standards contained in section 4(2)(*l*) may be sold in this state until January 1, 2010.

(3) No later than 6 months after the effective date of this act, the commission, in consultation with the attorney general, shall determine if implementation of state standards for commercial boilers, pool heaters, and residential furnaces and residential boilers requires a waiver from federal preemption. If the commission determines that a waiver from federal preemption is not needed, then on or after January 1, 2008, or the date which is 1 year after the date of the determination, if later, no new commercial boiler, pool heater, or residential furnace or boiler may be sold or offered for sale in this state unless the efficiency of the new product meets or exceeds the efficiency standards set forth in section 4. If the commission determines that a waiver from federal preemption is required, then the commission shall apply for the waiver within 1 year of the determination and upon approval of the waiver application, the applicable state standards shall go into effect at the earliest date permitted by federal law.

(4) One year after the date upon which the sale or offering for sale of certain products becomes subject to the requirements of this section, no products may be installed for compensation in the state unless the efficiency of the new product meets or exceeds the efficiency standards set forth in section 4.

Sec. 6. The commission may adopt, revise, modify, or amend the regulations required under this act to establish increased efficiency standards for the products listed in section 3. The commission may also establish standards for products not specifically listed in section 3. In considering new or amended standards, the commission shall set efficiency standards upon a determination that increased efficiency standards would serve to promote energy conservation in the state and would be cost-effective for consumers who purchase and use new products, provided that no new or increased efficiency standards shall become effective within 1 year following the adoption of any amended regulations establishing the increased efficiency standards. The commission may apply for a waiver of federal preemption in accordance with federal procedures for state efficiency standards for any product regulated by the federal government.

Sec. 7. (1) The manufacturers of products covered by this act shall test samples of their products in accordance with the test procedures adopted under this act. The commission shall adopt by rule test procedures for determining the energy efficiency of the products covered by section 3 if such procedures are not provided for in section 4. The commission shall adopt federal department of energy approved test methods or, in the absence of such test methods, other appropriate nationally recognized test methods. The commission may adopt updated test methods when new versions of test procedures become available.

(2) Manufacturers of new products covered by section 3, except for single voltage external AC to DC power supplies, walk-in refrigerators, and walk-in freezers, shall certify to the commission that the products are in compliance with this act. The certifications shall be based on test results. The commission shall promulgate rules governing the certification of the products and shall coordinate with the certification programs of other states and federal agencies with similar standards.

(3) Manufacturers of new products covered by section 3 shall identify each product offered for sale or installation in the state as in compliance with the provisions of this act by means of a mark, label, or tag on the product and packaging at the time of sale or installation. The commission shall promulgate rules governing the identification of the products and packaging, which shall be coordinated to the greatest practical extent with the labeling programs of other states and federal agencies with equivalent efficiency standards. The commission shall allow the use of existing marks, labels, or tags which connote compliance with the efficiency requirements of this act.

(4) The commission may test products covered by section 3. If products so tested are found not to be in compliance with the minimum efficiency standards established under section 4, the commission shall charge the manufacturer of the product for the cost of product purchase and testing, and make information available to the public on products found not to be in compliance with the standards.

(5) With prior notice and at reasonable and convenient hours, the commission may cause periodic inspections to be made of distributors or retailers of new products covered by section 3 in order to determine compliance with this act.

(6) The commission shall investigate complaints received concerning violations of this act and shall report the results of the investigations to the attorney general. The attorney general may institute proceedings to enforce this act. Any manufacturer, distributor, or retailer, or any person who installs a product covered by this act for compensation, who violates this act shall be issued a warning by the commission for any first violation.

Repeat violations shall be subject to a civil penalty of not more than $250.00. Each violation shall constitute a separate offense, and each day that such violation continues shall constitute a separate offense. Penalties assessed under this subsection are in addition to costs assessed under subsection (4).

(7) The commission may promulgate further rules as necessary to insure the proper implementation and enforcement of this act.

Appendix G.2. ACEEE Report Appendix: Leading the Way

This report appendix can be found at: http://standardsasap.org/a051_mi.pdf

Referenced June 2006

Appendix G.3. Model Results: 2015

GHG	Source	Appliance	Sector	Percent contribution to total FF source	MWh	MBTU	BBTU	Emission Factor (lbsC/MBTU)	Combustion Efficiency	Emissions (short tons)	Emissions (MMTCE)
CO_2	Coal (Utility)	*Bottle type water dispensers*	Commercial	0.88	32,775	324,246	324	57.29	1	9,288	0.0084
		Commercial Hot Food Holding Cabinets	Commercial	0.88	29,317	290,030	290	57.29	1	8,308	0.0075
		Compact Audio Products	Residential	0.88	302,472	2,992,359	2,992	57.29	1	85,716	0.0778
		DVD Players and recorders	Residential	0.88	43,804	433,355	433	57.29	1	12,413	0.0113
		Liquid-immersed distribution transformers	Utility	0.88	656,358	6,493,357	6,493	57.29	1	186,002	0.1687
		Medium voltage dry-type distribution transformers	Utility	0.88	40,293	398,616	399	57.29	1	11,418	0.0104
		metal halide lamp fixtures	Commercial	0.88	703,411	6,958,855	6,959	57.29	1	199,336	0.1808
		portable electric spas (hot tubs)	Commercial	0.88	2,858	28,276	28	57.29	1	810	0.0007
		Residential furnaces and residential boilers	Residential	0.88	284,416	2,813,729	2,814	57.29	1	80,599	0.0731
		singe-voltage external AC to DC power supplies	Commercial	0.88	700,555	6,930,593	6,931	57.29	1	198,527	0.1801
		State-regulated incandescent reflector	Commercial	0.88	1,338,451	13,241,313	13,241	57.29	1	379,297	0.3441
		Walk-in refrigerators and freezers	Commercial	0.88	409,480	4,050,988	4,051	57.29	1	116,041	0.1053
	Natural Gas (Utility)	*Bottle type water dispensers*	Commercial	0.12	4,469	34,339	34	31.91	1	548	0.0005
		Commercial Hot Food Holding Cabinets	Commercial	0.12	3,998	30,716	31	31.91	1	490	0.0004
		Compact Audio Products	Residential	0.12	41,246	316,907	317	31.91	1	5,056	0.0046
		DVD Players and recorders	Residential	0.12	5,973	45,895	46	31.91	1	732	0.0007
		Liquid-immersed distribution transformers	Utility	0.12	89,503	687,681	688	31.91	1	10,972	0.0100
		Medium voltage dry-type distribution transformers	Utility	0.12	5,494	42,216	42	31.91	1	674	0.0006
		metal halide lamp fixtures	Commercial	0.12	95,920	736,980	737	31.91	1	11,759	0.0107
		portable electric spas (hot tubs)	Commercial	0.12	390	2,995	3	31.91	1	48	0.0000
		Residential furnaces and residential boilers	Residential	0.12	38,784	297,989	298	31.91	1	4,754	0.0043
		singe-voltage external AC to DC power supplies	Commercial	0.12	95,530	733,987	734	31.91	1	11,711	0.0106
		State-regulated incandescent reflector	Commercial	0.12	182,516	1,402,326	1,402	31.91	1	22,374	0.0203
		Walk-in refrigerators and freezers	Commercial	0.12	55,838	429,021	429	31.91	1	6,845	0.0062
					Million Standard Cubic Feet	**Heat Content (thousand BTU/Cubic Feet)**					
	Natural Gas (Non Utility)	*Commercial Boilers*	Commercial	N/A	171	1.03102	176	31.91	1	2,807	0.003
		pool heaters	Commercial and Residential	N/A	558	1.03102	575	31.91	1	9,176	0.008
		Residential furnaces and residential boilers	Residential	N/A	33,442	1.03102	34,479	31.91	1	550,117	0.499
		Total CO_2 Savings (Short Tons, MMTCE)								**1,925,819**	**1.75**

GHG	Source	Appliance	Sector	Percent contribution to total FF source	MWh	MBTU	BBTU	Emission Factor (Mton/BBtu)	Emissions (Mton)	GWP	Emissions (MMTCE)
CH4	Coal (Utility)	*Bottle type water dispensers*	Commercial	0.88	32,775	111,829	112	0.001	0.11	21	6.42E-07
		Commercial Hot Food Holding Cabinets	Commercial	0.88	29,317	100,028	100	0.001	0.10	21	5.742E-07
		Compact Audio Products	Residential	0.88	302,472	1,032,035	1,032	0.001	1.03	21	5.924E-06
		DVD Players and recorders	Residential	0.88	43,804	149,460	149	0.001	0.15	21	8.58E-07
		Liquid-immersed distribution transformers	Utility	0.88	656,358	2,239,494	2,239	0.001	2.24	21	1.286E-05
		Medium voltage dry-type distribution transformers	Utility	0.88	40,293	137,479	137	0.001	0.14	21	7.892E-07
		metal halide lamp fixtures	Commercial	0.88	703,411	2,400,039	2,400	0.001	2.41	21	1.378E-05
		portable electric spas (hot tubs)	Commercial	0.88	2,858	9,752	10	0.001	0.01	21	5.598E-08
		Residential furnaces and residential boilers	Residential	0.88	284,416	970,427	970	0.001	0.97	21	5.571E-06
		singe-voltage external AC to DC power supplies	Commercial	0.88	700,555	2,390,292	2,390	0.001	2.40	21	1.372E-05
		State-regulated incandescent reflector	Commercial	0.88	1,338,451	4,566,796	4,567	0.001	4.58	21	2.622E-05
		Walk-in refrigerators and freezers	Commercial	0.88	409,480	1,397,145	1,397	0.001	1.40	21	8.02E-06
	Natural Gas (Utility)	*Bottle type water dispensers*	Commercial	0.12	4,469	15,249	15	0.00095	0.014	21	8.293E-08
		Commercial Hot Food Holding Cabinets	Commercial	0.12	3,998	13,640	14	0.00095	0.013	21	7.418E-08
		Compact Audio Products	Residential	0.12	41,246	140,732	141	0.00095	0.134	21	7.653E-07
		DVD Players and recorders	Residential	0.12	5,973	20,381	20	0.00095	0.019	21	1.108E-07
		Liquid-immersed distribution transformers	Utility	0.12	89,503	305,386	305	0.00095	0.290	21	1.661E-06
		Medium voltage dry-type distribution transformers	Utility	0.12	5,494	18,747	19	0.00095	0.018	21	1.02E-07
		metal halide lamp fixtures	Commercial	0.12	95,920	327,278	327	0.00095	0.311	21	1.78E-06
		portable electric spas (hot tubs)	Commercial	0.12	390	1,330	1	0.00095	0.001	21	7.232E-09
		Residential furnaces and residential boilers	Residential	0.12	38,784	132,331	132	0.00095	0.126	21	7.197E-07
		singe-voltage external AC to DC power supplies	Commercial	0.12	95,530	325,949	326	0.00095	0.310	21	1.773E-06
		State-regulated incandescent reflector	Commercial	0.12	182,516	622,745	623	0.00095	0.591	21	3.387E-06
		Walk-in refrigerators and freezers	Commercial	0.12	55,838	190,520	191	0.00095	0.181	21	1.036E-06
					Million Standard Cubic Feet	**Heat Content (thousand BTU/Cubic Feet)**					
	Natural Gas (Non Utility)	*Commercial Boilers*	Commercial	N/A	171	1.03102	176	0.00475	0.835	21	4.784E-06
		pool heaters	Commercial and Residential	N/A	558	1.03102	575	0.00475	2.731	21	1.564E-05
		Residential furnaces and residential boilers	Residential	N/A	33,442	1.03102	34,479	0.00475	163.699	21	0.0009375
		Total CH4 Savings (M Tons, MMTCE)							**184.81291**		**0.00106**

GHG	Source	Appliance	Sector	Percent contribution to total FF source	MWh	MBTU	BBTU	Emission Factor (Mton/BBtu)	Emissions (Mton)	GWP	Emissions (MMTCE)
N2O	Coal (Utility)	*Bottle type water dispensers*	Commercial	0.88	32,775	111,829	112	0.0014	0.157	310	1.327E-05
		Commercial Hot Food Holding Cabinets	Commercial	0.88	29,317	100,028	100	0.0014	0.140	310	1.187E-05
		Compact Audio Products	Residential	0.88	302,472	1,032,035	1,032	0.0014	1.448	310	0.0001224
		DVD Players and recorders	Residential	0.88	43,804	149,460	149	0.0014	0.210	310	1.773E-05
		Liquid-immersed distribution transformers	Utility	0.88	656,358	2,239,494	2,239	0.0014	3.143	310	0.0003
		Medium voltage dry-type distribution transformers	Utility	0.88	40,293	137,479	137	0.0014	0.193	310	1.631E-05
		metal halide lamp fixtures	Commercial	0.88	703,411	2,400,039	2,400	0.0014	3.368	310	0.0002847
		portable electric spas (hot tubs)	Commercial	0.88	2,858	9,752	10	0.0014	0.014	310	1.157E-06
		Residential furnaces and residential boilers	Residential	0.88	284,416	970,427	970	0.0014	1.362	310	0.0001
		singe-voltage external AC to DC power supplies	Commercial	0.88	700,555	2,390,292	2,390	0.0014	3.354	310	0.0003
		State-regulated incandescent reflector	Commercial	0.88	1,338,451	4,566,796	4,567	0.0014	6.408	310	0.0005
		Walk-in refrigerators and freezers	Commercial	0.88	409,480	1,397,145	1,397	0.0014	1.961	310	0.0002
	Natural Gas (Utility)	*Bottle type water dispensers*	Commercial	0.12	4,469	15,249	15	0.0001	0.001	310	1.224E-07
		Commercial Hot Food Holding Cabinets	Commercial	0.12	3,998	13,640	14	0.0001	0.001	310	1.095E-07
		Compact Audio Products	Residential	0.12	41,246	140,732	141	0.0001	0.013	310	1.13E-06
		DVD Players and recorders	Residential	0.12	5,973	20,381	20	0.0001	0.002	310	1.636E-07
		Liquid-immersed distribution transformers	Utility	0.12	89,503	305,386	305	0.0001	0.029	310	2.452E-06
		Medium voltage dry-type distribution transformers	Utility	0.12	5,494	18,747	19	0.0001	0.002	310	1.505E-07
		metal halide lamp fixtures	Commercial	0.12	95,920	327,278	327	0.0001	0.031	310	2.627E-06
		portable electric spas (hot tubs)	Commercial	0.12	390	1,330	1	0.0001	0.000	310	1.068E-08
		Residential furnaces and residential boilers	Residential	0.12	38,784	132,331	132	0.0001	0.013	310	1.062E-06
		singe-voltage external AC to DC power supplies	Commercial	0.12	95,530	325,949	326	0.0001	0.031	310	2.617E-06
		State-regulated incandescent reflector lamps	Commercial	0.12	182,516	622,745	623	0.0001	0.059	310	4.999E-06
		Walk-in refrigerators and freezers	Commercial	0.12	55,838	190,520	191	0.0001	0.018	310	1.529E-06
					Million Standard Cubic Feet	**Heat Content (thousand BTU/Cubic Feet)**					
	Natural Gas (Non Utility)	*Commercial Boilers*	Commercial	N/A	171	1.03102	176	0.0001	0.017	310	1.412E-06
		pool heaters	Commercial and Residential	N/A	558	1.03102	575	0.0001	0.055	310	4.617E-06
		Residential furnaces and residential boilers	Residential	N/A	33,442	1.03102	34,479	0.0001	3.274	310	0.0003
		Total N2O Savings (M Tons, MMTCE))							**25.30**		**0.0021**
		Total GHG reductions from savings (MMTCE)									**1.75**

Appendix G.4. Model Results: 2025

GHG	Source	Appliance	Sector	Percent contribution to total FF source	MWh	MBTU	BBTU	Emission Factor (lbsC/MBTU)	Combustion Efficiency	Emissions (short tons)	Emissions (MMTCE)
CO_2	Coal (Utility)	*Bottle type water dispensers*	Commercial	0.88	114,713	1,134,861	1,135	57.29	1	32,508	0.029
		Commercial Hot Food Holding Cabinets	Commercial	0.88	146,583	1,450,149	1,450	57.29	1	41,540	0.038
		Compact Audio Products	Residential	0.88	852,421	8,433,011	8,433	57.29	1	241,564	0.219
		DVD Players and	Residential	0.88	123,448	1,221,273	1,221	57.29	1	34,983	0.032
		Liquid-immersed distribution transformers	Utility	0.88	3,365,138	33,291,339	33,291	57.29	1	953,630	0.865
		Medium voltage dry-type distribution transformers	Utility	0.88	206,580	2,043,699	2,044	57.29	1	58,542	0.053
		metal halide lamp	Commercial	0.88	3,606,379	35,677,939	35,678	57.29	1	1,021,995	0.927
		portable electric spas (hot tubs)	Commercial	0.88	49,542	490,118	490	57.29	1	14,039	0.013
		Residential furnaces and residential boilers	Residential	0.88	1,458,195	14,425,942	14,426	57.29	1	413,231	0.375
		singe-voltage external AC to DC power supplies	Commercial	0.88	2,257,343	22,331,912	22,332	57.29	1	639,698	0.580
		State-regulated incandescent reflector lamps	Commercial	0.88	3,130,680	30,971,846	30,972	57.29	1	887,189	0.805
		Walk-in refrigerators and freezers	Commercial	0.88	1,871,908	18,518,804	18,519	57.29	1	530,471	0.481
	Natural Gas (Utility)	*Bottle type water dispensers*	Commercial	0.12	15,643	120,188	120	31.91	1	1,918	0.0017
		Commercial Hot Food Holding Cabinets	Commercial	0.12	19,989	153,579	154	31.91	1	2,450	0.0022
		Compact Audio Products	Residential	0.12	116,239	893,101	893	31.91	1	14,249	0.0129
		DVD Players and	Residential	0.12	16,834	129,339	129	31.91	1	2,064	0.0019
		Liquid-immersed distribution transformers	Utility	0.12	458,882	3,525,731	3,526	31.91	1	56,253	0.0510
		Medium voltage dry-type distribution transformers	Utility	0.12	28,170	216,439	216	31.91	1	3,453	0.0031
		metal halide lamp	Commercial	0.12	491,779	3,778,485	3,778	31.91	1	60,286	0.0547
		portable electric spas (hot tubs)	Commercial	0.12	6,756	51,906	52	31.91	1	828	0.0008
		Residential furnaces and residential boilers	Residential	0.12	198,845	1,527,785	1,528	31.91	1	24,376	0.0221
		singe-voltage external AC to DC power supplies	Commercial	0.12	307,819	2,365,069	2,365	31.91	1	37,735	0.0342
		State-regulated incandescent reflector lamps	Commercial	0.12	426,911	3,280,085	3,280	31.91	1	52,334	0.0475
		Walk-in refrigerators and freezers	Commercial	0.12	255,260	1,961,241	1,961	31.91	1	31,292	0.0284
					Million Standard Cubic Feet	**Heat Content (thousand BTU/Cubic Feet)**					
	Natural Gas (Non-Utility)	*Commercial Boilers*	Commercial	N/A	3,242	1.03102	3,343	31.91	1	53,330	0.0484
		pool heaters	Commercial and Residential	N/A	2,789	1.03102	2,876	31.91	1	45,881	0.0416
		Residential furnaces and residential boilers	Residential	N/A	171,456	1.03102	176,775	31.91	1	2,820,439	2.5587
		Total CO2 Savings (Short Tons,								**8076277**	**7.32675**

GHG	Source	Appliance	Sector	Percent contribution to total FF source	MWh	MBTU	BBTU	Emission Factor (Mton/BBtu)	Emissions (Mton)	GWP	Emissions (MMTCE)
CH4	Coal (Utility)	*Bottle type water dispensers*	Commercial	0.88	114,713	1,134,861	1,135	0.001	1.14	21	6.515E-06
		Commercial Hot Food Holding Cabinets	Commercial	0.88	146,583	1,450,149	1,450	0.001	1.45	21	8.325E-06
		Compact Audio Products	Residential	0.88	852,421	8,433,011	8,433	0.001	8.45	21	4.841E-05
		DVD Players and	Residential	0.88	123,448	1,221,273	1,221	0.001	1.22	21	7.011E-06
		Liquid-immersed distribution transformers	Utility	0.88	3,365,138	33,291,339	33,291	0.001	33.37	21	0.0002
		Medium voltage dry-type distribution transformers	Utility	0.88	206,580	2,043,699	2,044	0.001	2.05	21	1.173E-05
		metal halide lamp	Commercial	0.88	3,606,379	35,677,939	35,678	0.001	35.76	21	0.0002
		portable electric spas (hot tubs)	Commercial	0.88	49,542	490,118	490	0.001	0.49	21	2.814E-06
		Residential furnaces and residential boilers	Residential	0.88	1,458,195	14,425,942	14,426	0.001	14.46	21	8.281E-05
		singe-voltage external AC to DC power supplies	Commercial	0.88	2,257,343	22,331,912	22,332	0.001	22.38	21	0.0001
		State-regulated incandescent reflector lamps	Commercial	0.88	3,130,680	30,971,846	30,972	0.001	31.04	21	0.0002
		Walk-in refrigerators and freezers	Commercial	0.88	1,871,908	18,518,804	18,519	0.001	18.56	21	0.0001
	Natural Gas (Utility)	*Bottle type water dispensers*	Commercial	0.12	15,643	120,188	120	0.00095	0.114	21	6.536E-07
		Commercial Hot Food Holding Cabinets	Commercial	0.12	19,989	153,579	154	0.00095	0.146	21	8.352E-07
		Compact Audio Products	Residential	0.12	116,239	893,101	893	0.00095	0.848	21	4.857E-06
		DVD Players and	Residential	0.12	16,834	129,339	129	0.00095	0.123	21	7.034E-07
		Liquid-immersed distribution transformers	Utility	0.12	458,882	3,525,731	3,526	0.00095	3.348	21	1.917E-05
		Medium voltage dry-type distribution transformers	Utility	0.12	28,170	216,439	216	0.00095	0.206	21	1.177E-06
		metal halide lamp	Commercial	0.12	491,779	3,778,485	3,778	0.00095	3.588	21	2.055E-05
		portable electric spas (hot tubs)	Commercial	0.12	6,756	51,906	52	0.00095	0.049	21	2.823E-07
		Residential furnaces and residential boilers	Residential	0.12	198,845	1,527,785	1,528	0.00095	1.451	21	8.309E-06
		singe-voltage external AC to DC power supplies	Commercial	0.12	307,819	2,365,069	2,365	0.00095	2.246	21	1.286E-05
		State-regulated incandescent reflector lamps	Commercial	0.12	426,911	3,280,085	3,280	0.00095	3.115	21	1.784E-05
		Walk-in refrigerators and freezers	Commercial	0.12	255,260	1,961,241	1,961	0.00095	1.862	21	1.067E-05
					Million Standard Cubic Feet	**Heat Content (thousand BTU/Cubic Feet)**					
	Natural Gas (Non-Utility)	*Commercial Boilers*	Commercial	N/A	3,242	1.03102	3342.54	0.00475	15.87	21	9.089E-05
		pool heaters	Commercial and Residential	N/A	2,789	1.03102	2875.66	0.00475	13.65	21	7.819E-05
		Residential furnaces and residential boilers	Residential	N/A	171,456	1.03102	176775	0.00475	839.28	21	0.005
		Total CH4 Savings (M Tons, MMTCE)							**1,056**		**0.006**

GHG	Source	Appliance	Sector	Percent contribution to total FF source	MWh	MBTU	BBTU	Emission Factor (Mton/BBtu)	Emissions (Mton)	GWP	Emissions (MMTCE)
N2O	Coal (Utility)	*Bottle type water dispensers*	Commercial	0.88	114,713	1,134,861	1,135	0.001403224	1.59	310	0.0001
		Commercial Hot Food Holding Cabinets	Commercial	0.88	146,583	1,450,149	1,450	0.001403224	2.03	310	0.0002
		Compact Audio Products	Residential	0.88	852,421	8,433,011	8,433	0.001403224	11.83	310	0.0010
		DVD Players and	Residential	0.88	123,448	1,221,273	1,221	0.001403224	1.71	310	0.0001
		Liquid-immersed distribution transformers	Utility	0.88	3,365,138	33,291,339	33,291	0.001403224	46.72	310	0.0039
		Medium voltage dry-type distribution transformers	Utility	0.88	206,580	2,043,699	2,044	0.001403224	2.87	310	0.0002
		metal halide lamp	Commercial	0.88	3,606,379	35,677,939	35,678	0.001403224	50.06	310	0.0042
		portable electric spas (hot tubs)	Commercial	0.88	49,542	490,118	490	0.001403224	0.69	310	0.0001
		Residential furnaces and residential boilers	Residential	0.88	1,458,195	14,425,942	14,426	0.001403224	20.24	310	0.0017
		singe-voltage external AC to DC power supplies	Commercial	0.88	2,257,343	22,331,912	22,332	0.001403224	31.34	310	0.0026
		State-regulated incandescent reflector lamps	Commercial	0.88	3,130,680	30,971,846	30,972	0.001403224	43.46	310	0.0037
		Walk-in refrigerators and freezers	Commercial	0.88	1,871,908	18,518,804	18,519	0.001403224	25.99	310	0.0022
	Natural Gas (Utility)	*Bottle type water dispensers*	Commercial	0.12	15,643	120,188	120	9.4955E-05	0.011	310	9.649E-07
		Commercial Hot Food Holding Cabinets	Commercial	0.12	19,989	153,579	154	9.4955E-05	0.015	310	1.233E-06
		Compact Audio Products	Residential	0.12	116,239	893,101	893	9.4955E-05	0.085	310	7.17E-06
		DVD Players and	Residential	0.12	16,834	129,339	129	9.4955E-05	0.012	310	1.038E-06
		Liquid-immersed distribution transformers	Utility	0.12	458,882	3,525,731	3,526	9.4955E-05	0.335	310	2.83E-05
		Medium voltage dry-type distribution transformers	Utility	0.12	28,170	216,439	216	9.4955E-05	0.021	310	1.738E-06
		metal halide lamp	Commercial	0.12	491,779	3,778,485	3,778	9.4955E-05	0.359	310	3.033E-05
		portable electric spas (hot tubs)	Commercial	0.12	6,756	51,906	52	9.4955E-05	0.005	310	4.167E-07
		Residential furnaces and residential boilers	Residential	0.12	198,845	1,527,785	1,528	9.4955E-05	0.145	310	1.227E-05
		singe-voltage external AC to DC power supplies	Commercial	0.12	307,819	2,365,069	2,365	9.4955E-05	0.225	310	1.899E-05
		State-regulated incandescent reflector lamps	Commercial	0.12	426,911	3,280,085	3,280	9.4955E-05	0.311	310	2.633E-05
		Walk-in refrigerators and freezers	Commercial	0.12	255,260	1,961,241	1,961	9.4955E-05	0.186	310	1.574E-05
					Million Standard Cubic Feet	**Heat Content (thousand BTU/Cubic Feet)**					
	Natural Gas (Non-Utility)	*Commercial Boilers*	Commercial	N/A	3,242	1.03102	3,343	9.4955E-05	0.317	310	2.683E-05
		pool heaters	Commercial and Residential	N/A	2,789	1.03102	2,876	9.4955E-05	0.273	310	2.309E-05
		Residential furnaces and residential boilers	Residential	N/A	171,456	1.03102	176,775	9.4955E-05	16.786	310	0.001
		Total N2O Savings (M Tons, MMTCE))							**258**		**0.022**
		Total GHG reductions from savings (MMTCE)									**7.355**

Appendix G.5. Annual GHG Figures

Products	Annual Savings from one year's sales (GWh, BTU)	Annual Savings from one year's sales (MWh, MCFE)	Annual Savings Per Unit (kWh or BTU (or /kVA))	Affected Annual State Sales of each unit (Units, BTU's)	Avg life of equipment (yrs)
Bottle type water dispensers	1	1,164	266	4,376	8
Commercial Boilers	**20,475,622,123**	**20,074,139**	**51,363,889**	**399**	**30**
Commercial Hot Food Holding Cabinets	1	1,058	1,815	583	15
Compact Audio Products	12	12,499	53	236,324	5
DVD Players and recorders	2	1,810	11	168,822	5
Liquid-immersed distribution transformers	24	23,678	6	3,933,741	30
Medium voltage dry-type distribution transformers	1	1,454	6	252,290	30
metal halide lamp fixtures	25	25,376	307	82,764	20
pool heaters	**18,063,004,188**	**17,708,828**	**5,800,000**	**3,114**	**15**
Portable Electric Spas (hot tubs)	0	433	250	1,732	10
Residential furnaces: Fans	103	102,600	79,412	129	20
Residential Furnaces and Boilers: Thermal Efficiency	**1,082,880,495,251**	**1,061,647,544**	**11,136,941**	**97,233**	**20**
singe-voltage external AC to DC power supplies	25	25,273	4	6,110,824	7
State-regulated incandescent reflector lamps	217	216,662	61	3,551,837	1
Walk-in refrigerators and freezers	15	14,772	8,220	1,797	12
Total	427.00	427000, **1089.81**			

Products	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2015 Cumulative
Bottle type water dispensers	-1,746	-582	582	1,746	2,910	4,074	5,238	6,401	7,565	9,311	37,245
Commercial Boilers	**-30**	**-10**	**10**	**30**	**50**	**70**	**90**	**110**	**130**	**151**	**632**
Commercial Hot Food Holding Cabinets	-1,586	-529	529	1,586	2,644	3,702	4,759	5,817	6,874	7,932	33,314
Compact Audio Products	-18,748	-6,249	6,249	18,748	31,247	43,746	62,494	62,494	62,494	62,494	343,718
DVD Players and recorders	-2,715	-905	905	2,715	4,525	6,335	9,050	9,050	9,050	9,050	49,777
Liquid-immersed distribution transformers	-35,517	-11,839	11,839	35,517	59,195	82,874	106,552	130,230	153,908	177,586	745,862
Medium voltage dry-type distribution transformers	-2,180	-727	727	2,180	3,634	5,087	6,541	7,995	9,448	10,902	45,787
metal halide lamp fixtures	-38,063	-12,688	12,688	38,063	63,439	88,815	114,190	139,566	164,941	190,317	799,331
pool heaters	**-27**	**-9**	**9**	**27**	**44**	**62**	**80**	**97**	**115**	**133**	**558**
Portable Electric Spas (hot tubs)	-650	-217	217	650	1,083	1,516	1,949	2,382	2,815	3,248	13,641
Residential furnaces: Fans	-15,390	-5,130	5,130	15,390	25,651	35,911	46,171	56,432	66,692	76,952	323,200
Residential Furnaces and Boilers: Thermal Efficiency	**-1,592**	**-531**	**531**	**1,592**	**2,654**	**3,716**	**4,777**	**5,839**	**6,901**	**7,962**	**33,442**
singe-voltage external AC to DC power supplies	-37,909	-12,636	12,636	37,909	63,181	88,454	113,726	138,999	176,908	176,908	796,085
State-regulated incandescent reflector lamps	-324,993	-108,331	203,662	203,662	203,662	203,662	203,662	203,662	203,662	203,662	1,520,968
Walk-in refrigerators and freezers	-22,158	-7,386	7,386	22,158	36,930	51,702	66,474	81,246	96,018	110,790	465,318
Total											

Products	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2025 Cumulative
Bottle type water dispensers	9,311	9,311	9,311	9,311	9,311	9,311	9,311	9,311	9,311	9,311	130,356
Commercial Boilers	171	191	211	231	251	271	291	311	331	351	3,242
Commercial Hot Food Holding Cabinets	8,990	10,047	11,105	12,162	13,220	14,278	15,864	15,864	15,864	15,864	166,572
Compact Audio Products	62,494	62,494	62,494	62,494	62,494	62,494	62,494	62,494	62,494	62,494	968,660
DVD Players and recorders	9,050	9,050	9,050	9,050	9,050	9,050	9,050	9,050	9,050	9,050	140,282
Liquid-immersed distribution transformers	201,264	224,942	248,621	272,299	295,977	319,655	343,333	367,011	390,689	414,368	3,824,020
Medium voltage dry-type distribution transformers	12,355	13,809	15,262	16,716	18,170	19,623	21,077	22,530	23,984	25,437	234,750
metal halide lamp fixtures	215,693	241,068	266,444	291,819	317,195	342,570	367,946	393,322	418,697	444,073	4,098,158
pool heaters	151	168	186	204	221	239	266	266	266	266	2,789
Portable Electric Spas (hot tubs)	3,681	4,331	4,331	4,331	4,331	4,331	4,331	4,331	4,331	4,331	56,298
Residential furnaces: Fans	87,213	97,473	107,733	117,994	128,254	138,514	148,775	159,035	169,295	179,555	1,657,040
Residential Furnaces and Boilers: Thermal Efficiency	9,024	10,086	11,147	12,209	13,271	14,332	15,394	16,456	17,517	18,579	171,456
singe-voltage external AC to DC power supplies	176,908	176,908	176,908	176,908	176,908	176,908	176,908	176,908	176,908	176,908	2,565,162
State-regulated incandescent reflector lamps	203,662	203,662	203,662	203,662	203,662	203,662	203,662	203,662	203,662	203,662	3,557,591
Walk-in refrigerators and freezers	125,562	140,334	155,106	177,264	177,264	177,264	177,264	177,264	177,264	177,264	2,127,168
Total											

Appendix G.6. REMI Model Results

Policy	Output Variable	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Appliance Efficiency Standards	Employment (Thousand)	0	0	0.02441	0.04541	0.0566	0.6387	0.2236	0.2339	0.2476	0.2666	0.3652
	Gross State Product (Billion Fixed 2000$)	0	0	-0.00104	0.00012	0.0007	0.0446	0.0162	0.0169	0.018	0.0202	0.0286

Policy	Output Variable	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Appliance Efficiency Standards	Employment (Thousand)	-0.0059	0.0669	0.3008	0.6768	0.7988	0.8809	0.6592	0.916	0.9556	0.9541
	Gross State Product (Billion Fixed 2000$)	-0.0017	0.0028	0.02228	0.05682	0.071	0.0817	0.0642	0.0894	0.0968	0.0999

Policy	Output Variable	2005-2015 Avg	2005-2015 Cumulative	2005-2025 Avg	2005-2025 Cumulative
Appliance Efficiency Standards	Employment (Thousand)	0.233562222	2.10206	0.437120579	8.305291
	Gross State Product (Billion Fixed 2000$)	0.016031833	0.1442865	0.0382945	0.7275955

Appendix H. Alternative Fuels and Alternative Vehicles

Appendix H.1. Sample Alternative Fuel and Alternative Vehicle Policy Strategies

In a preliminary phase of research the MCCP catalogued applicable state and federal policies for the renewable fuels and alternative vehicle technology sector. What follows is brief summary of that research.

Federal and State Policies and Programs

Michigan is not the only state pursuing programs and policies to reduce GHG emissions within the transportation sector. At the federal and state level, several GHG emission reduction strategies exist that cut across the transportation sector What follows is a brief presentation of the policies/programs that are inline with the two transportation related strategies prioritized by the MCCP stakeholders.

Federal Policies/Programs

Energy Policy Act of 1992 (EPAct)

EPAct was passed to reduce the nation's reliance on foreign petroleum and improve air quality. Several parts of EPAct were designed to encourage use of AFs. Titles III and V employ regulatory approaches for encouraging the fundamental changes necessary to building a self-sustaining alternative fuel market. Through EPAct, the federal government was able to mandate procurement standards and requirements for AVTs within states and centrally fueled fleets in metropolitan areas. EPAct requires certain fleets to purchase a percentage of light-duty AVTs, which are "capable" of running on alternative fuels, each year. Some types of vehicles are excluded.[2]

Clean Cities Program

The mission of the Clean Cities Program is to advance the nation's economic, environmental, and energy security by supporting local decisions to adopt practices that contribute to the reduction of petroleum consumption. Clean Cities carries out this mission through a network of more than 80 volunteer coalitions, which develop public/private partnerships to promote alternative fuels and vehicles, fuel blends, fuel economy, hybrid vehicles, and idle reduction.[3]

Federal Tax Incentives for Purchasing HEVs

The federal government provides a federal income tax credit for qualifying hybrids placed into service after December 31, 2005. Table H.1-1 contains a partial list of

[2] U.S. Department of Energy – Energy Efficiency and Renewable Energy . Accessed April 2006. <http://www1.eere.energy.gov/vehiclesandfuels/epact/about/index.html>.
[3] U.S. Department of Energy – Energy Efficiency and Renewable Energy . Accessed April 2006. <http://www.eere.energy.gov/cleancities/>.

qualifying hybrids and the full credit amount for each. The credit amount will begin to phase out once a manufacturer has sold over 60,000 eligible vehicles.[4]

Table H.1-1. Federal Income Tax Credit for HEV

Vehicle Make & Model	Credit Amount
Ford Motor Company	
2006 Ford Escape Hybrid (2X4)	$2,600*
2006 Ford Escape Hybrid (4X4)	$1,950*
2006 Mercury Mariner Hybrid (4X4)	$1,950*
Honda	
2006 Insight (auto trans. only)	$1,450*
2005-06 Accord Hybrid	$650*
2005 Civic Hybrid	$1,700*
2006 Civic Hybrid	$2,100*
* Based on manufacturer's estimate; certification awaiting approval from IRS.	

State Level Policies/Programs

AVT State Fleet Standards or Procurement Policies

States have instituted a requirement for government or public agencies to maintain a certain percentage of their annual fleet purchases as AVTs. A less restrictive optionis also used in allowing state fleets to preference AVTs in their procurement contracts. Examples of these types of policies are below followed by a list of state's that use this method.

> Washington D.C. "For covered fleets, certain percentages of new vehicle purchases must be clean fuel vehicles. Beginning in model year (MY) 2000 and every MY thereafter, 70% of newly purchased vehicles 8,500 pounds (lbs.) gross vehicle weight rating (GVWR) and under, and 50% of vehicles between 8,500 lbs. and 26,000 lbs. GVWR, must be clean fuel vehicles. (Reference D.C. Code Division VIII, Title 50, Subtitle III, Chapter 7, 50-703)."

> Illinois "In awarding contracts that require procurement of vehicles, state agencies are permitted to give preference to an otherwise qualified bidder who will fulfill the contract through the use of vehicles powered by ethanol produced from Illinois corn or biodiesel fuels produced from Illinois soybeans. (Reference 30 Illinois Compiled Statutes 500/45-60)."

[4] U.S. Department of Energy – Energy Efficiency and Renewable Energy . Accessed April 2006. <http://www.fueleconomy.gov/feg/tax_hybrid_new.shtml>.

Other States: AK, KS, KY, NM, NV, NY, OR, PA, SC, WI.

Mechanisms for AF Supply

State's have instituted policies and programs to assure the AF supply is available. Policies include tasks force (MN), a mandate to provide the AF (AL), deregulation of AF refueling industry (MD), and making publicly available a database of all the AVTs in the state (IL).

Production Credit for AF

State's will provide a per gallon credit for the production of either Ethanol or Biodiesel. Allotted production credits range from $0.05 to $0.20 per gallon. States that have instituted AF production credits include: MD, ME, MN, MO, MS, OK and UT.

Grants and Funding for AF Processing and Refueling

State's will establish funding mechanisms, either through grants or low interest rate loans, that will be directed towards the development or construct of an AF processing facility or refueling station. Below is an example of Illinois' program language, other states with similar programs follows.

> "Through the Opportunity Returns initiative and a grant from the Illinois Clean Energy Community Foundation, $500,000 in funding is now available for the Illinois E85 Clean Energy Infrastructure Development Program, to establish new E85 facilities at retail gasoline outlets in Illinois. The program, administered by the Illinois Department of Commerce and Economic Opportunity (DCEO), will provide up to 50% of the total cost for converting an existing facility (maximum grant of $2,000 per site) to E85 operation, or for the construction of a new refueling facility (maximum grant of up to $40,000 per facility)."

Other States: DE, NM, PA, UT, NY, IL, OH, PA, NJ, CA, OR, OK, RI, NE, CO

Hydrogen Infrastructure Demonstration Programs

New Mexico and California have both instituted policies that require the funding and development of Hydrogen refueling infrastructure. These are intended to facilitate the development and distribution of the fuel cell AVT.

Tax and Rebate Programs

- Tax credit, rebate, or exemption of titling fee for the incremental cost of converting to or purchasing an AVT. OR, NC, CA, NJ, OK, MT, WV, ME, NY, KS, LA, CO.
- Tax credit for a percentage of the cost to construct a biodiesel or ethanol processing facility. NC, MT.
- Reduction of the per gallon state fuel tax for qualifying AFs. NM, NJ, NV, PA, TX, CA, NE, KY, IA, CO, KS, IS, OK, ME, MT.
- Exemption from the state titling fee for qualifying AVTs. MN, DC.
- Tax credit for a percentage of the cost to construct, modify or purchase equipment for an AF refueling station. CT, NY, OK, RI, NC, ME, CO, KS.

- Tax credit for the cost of R&D for AVT and AF. HA.
- Supplier tax credit per gallon of AF sold. WY, MT.
- Tax credit or tax deduction for the purchase of an AVT, analogous to the federal program. OR, WI.
- Sales tax exemption for the sale of AF. CT, IL, KS.

Energy Credit Banking Program – North Carolina

The State Energy Office administers an energy credit banking program which enables the state to generate funds from the sale of Energy Policy Act of 1992 (EPAct) credits. The moneys generated by the sale of EPAct credits are deposited into the Alternative Fuel Revolving Fund, which enables state agencies to offset the costs of alternative fuel, related refueling infrastructure, and AFVs. Funds are distributed to state departments, institutions and agencies in proportion to the number of EPAct credits generated by each.

Renewable Fuel Standards - Washington Example

Biodiesel Standard: By Nov. 30 2008, at least 2% of all diesel sold in WA must be biodiesel. When there is sufficient crushing capacity and feedstock production in WA to supply 3% of all diesel from biodiesel, the standard bumps up to 5%. If biodiesel reaches 10% of total diesel, and more than half of that is from instate feedstocks, the Governor can submit an executive request legislation to repeal the standard.

Ethanol standard: By Dec. 1 2008, at least 2% of all gasoline sold in WA must be ethanol. The Agriculture Director may ramp up the standard as high as 10%, when s/he determines that "sufficient raw materials are available within Washington to support economical production of ethanol at higher levels", and when the Ecology Director determines that higher levels will not jeopardize Clean Air Act attainment. If ethanol reaches 20% of total gasoline, and more than half of that is from instate feedstocks, the Governor can submit an executive request legislation to repeal the standard.

State fleets: 2% biodiesel immediately for lubricity; 20% biodiesel, including vessels (ferries) by 2009.

Other provisions: An advisory committee, testing and certifications standards, non-disclosure language, etc.

Final bill report at
http://www.leg.wa.gov/pub/billinfo/2005-06/Pdf/Bill%20Reports/Senate%20Final/6508-S.FBR.pdf.

Final language at:
http://www.leg.wa.gov/pub/billinfo/2005-06/Pdf/Bills/Senate%20Passed%20Legislature/6508-S.PL.pdf.

Other states have versions of a RFS along the lines of Washington's requirement. Many are requirements for the state's fleets or are limited to Biodiesel 2% (B2) only. States with these types of policies include: IL, KS, MD, MN, MO, MT, NC, NE, NM, OH.

Kentucky – Tax Incentive for the Manufacturing of HEV

House Bill 272 –As part of KY's recent tax modernization plan, HB272 provides income tax credit for the manufacture of products that are better for human health or the environment. The incentives are for businesses that make at least a $5 million investment. The state will pay 100 percent of training costs for workers and 25 percent of equipment costs. Toyota, Inc. will be taking advantage of this incentive for its transition of the Toyota Camry plant in Georgetown, KY to manufacture HEV Camry's.

Final language at:
http://www.lrc.ky.gov/record/05rs/HB272.htm.

Michigan Programs and Policies

Existing Alternative Fuel Stations

Michigan already has the beginnings of an AF infrastructure for a number of alternative fuels. Table H.1-2 provides an accounting of the number of refueling stations in the state for various alternative fuels.

Table H.1-2. Summary of Michigan's Existing AF Infrastructure[5,6]

Fuel	Number of Refueling Stations
CNG	15
LPG	94
E85	4
Biodiesel	13
Hydrogen	4 (with 3 planned)

Existing Programs

Michigan has also begun to take initiatives to provide access and promote AVTs and AFs. Michigan's Department of Labor and Economic Growth (DLEG) maintains a transportation group within its Energy Office. This group works to promote the use of AVTs and AFs. Its efforts include involvement in the following programs:

- Ethanol Coalition of Michigan - The ECOM is a coalition uniting commodity organizations, fuel suppliers, universities, businesses, government agencies and individuals working to promote the production and use of ethanol in Michigan. Among other organizations, the coalition includes the State Energy Office, the Corn Marketing Program of Michigan (CMPM), the MI Dept. of Agriculture, and the Dept. of Environmental Quality. ECOM meets quarterly to advance goals including: increasing public awareness on the benefits of ethanol; encouraging positive ethanol marketing practices; and presenting ethanol educational programs to schools, civic groups and other interested parties.

  Ethanol continues to be an area of great interest as an alternative to gasoline. Figure 1 below shows the growth in the fuel ethanol market over the past twenty-five years. Additionally, Table H.1-3 provides a summary of the ethanol biorefineries in the State of Michigan and compares the state's total and planned capacity to that of the whole nation.

[5] NextEnery, Inc. Hydrogen Infrastructure. Accessed April 2006. <*http://www.nextenergy.org/industryservices/hydrogeninstallations.asp*>.
[6] National Renewable Energy Lab. U.S. Office of Energy Efficiency and Renewable Energy . Accessed April 2006. <*http://afdcmap.nrel.gov/locator/LocatePane.asp*>.

Figure H.1-1. Ethanol Market 1980-2005[7]

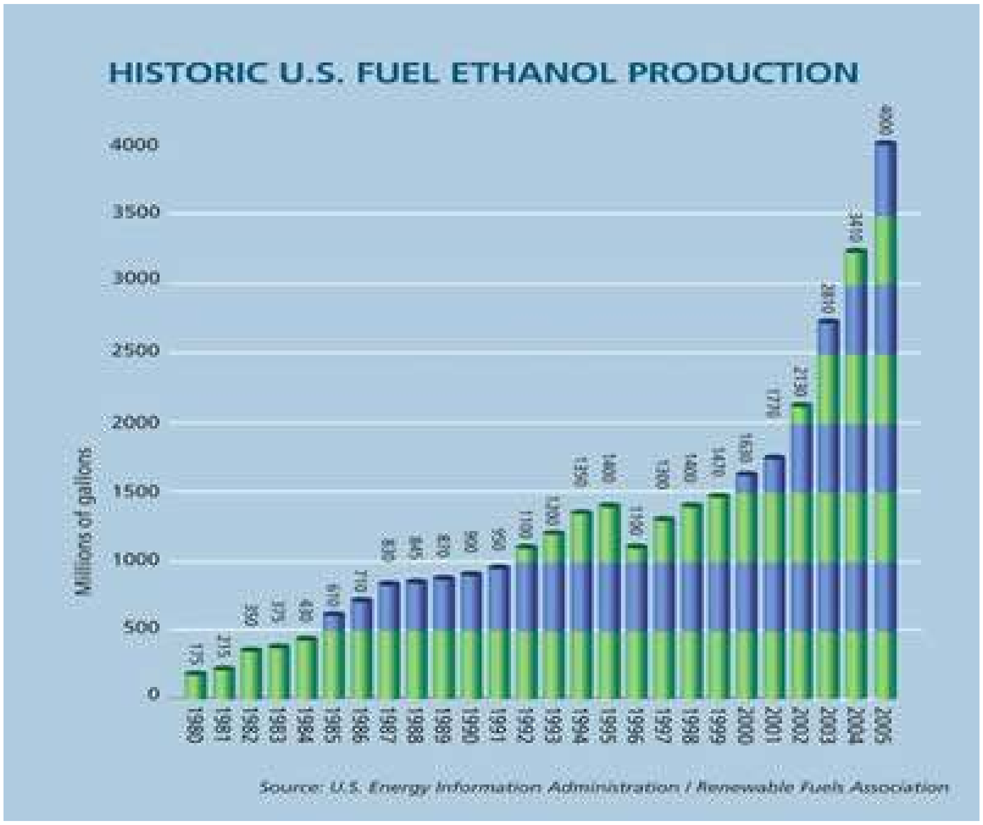


Table H.1-3. Michigan Fuel Ethanol Capacity[8]

Facility Name Location	Existing (MMgal/yr)	Planned (MMgal/yr)	Feed Stock
Michigan Ethanol, LLC – Cairo, MI	50	--	Corn
Midwest Grain Processors – Rigo, MI	--	57	Corn
The Anderson's Albion Ethanol – Albion, MI	--	55	Corn
US BioEnergy Corp – Lake Odessa, MI	--	45	Corn
State-wide Total	50	157	
National Total	4,441.4	2,041	
Michigan % of National	1.1%	7.7%	

- State of Michigan AFV Fleet - The State of Michigan, along with other states, is required under the Energy Policy Act (EPACT) of 1992 to acquire alternative fuel vehicles (AFVs) as an increasing percentage of new fleet vehicle purchases each year. AFVs run on electricity, ethanol (E-85), methanol (M-85), natural gas, or

[7] Renewable Fuels Association. Accessed April 2006. <http://www.ethanolrfa.org/resource/facts/economy/>.
[8] Renewable Fuels Association. Accessed March 2006 <http://www.ethanolrfa.org/industry/locations/>.

propane. Most of the AFVs purchased are E-85 flexible fuel vehicles (FFVs), since they are offered at the same price as their gasoline counterparts. FFVs are designed to run on various blends of gasoline and ethanol from 100% gasoline to 85% ethanol (E-85). Automakers are manufacturing new models of FFVs each year. The State of Michigan now owns or leases more than 1,350 FFVs and 50 CNG vehicles.[9]

- Clean Cities Program - Clean Cities is a locally-based government and industry partnership, coordinated by the U.S. Department of Energy (DOE) to expand the use of alternatives to gasoline and diesel fuel. It combines local decision making with voluntary action by partners in a grass roots approach designed to build a sustainable alternative fuels market. Michigan has three areas designated as Clean Cities:
  - Ann Arbor Area (Washtenaw County).
  - Detroit Area (Livingston, Macomb, Monroe, Oakland, St. Clair, and Wayne Counties).
  - Greater Lansing Area (Clinton, Eaton, and Ingham Counties).

The Detroit Area Clean Cities Coalition is monitored by the NextEnergy non-profit corporation, which has a mission to support the commercialization of energy technologies that positively contribute to economic competitiveness, energy security and the environment. As it pertains to the transportation sector, NextEnergy has initiated the NextEnergy Alternative Fuel Infrastructure program. This program was partially funded by the U.S. Department of Energy to test and demonstrate emerging alternative fuel production and storage systems, including hydrogen, natural gas, bio/synthetic-fuel development platforms for vehicular and on-site power. To date initiatives have included[10]:

- Multi-use hydrogen fueling system (vehicles, stationary power).
- Renewable and synthetic fuel collaborative research program.
- On-site hydrogen generation test bed.

It has recently been announced that NextEnergy will be teaming up with Wayne State University to operate the National Biofuel Energy Lab. This lab is made possible through a $2 million U.S. Department of Energy grant and has a goal to develop and strengthen B20 (20% bio-diesel blend) specifications and standards and facilitate widespread warrant of B20 use by vehicle and engine OEMs and component suppliers.[11]

In addition to the programs within the DLEG-Energy Office, the state government has two other programs that create mechanisms to provide grants, loans and tax incentives for the development and commercialization of AVTs and AFs. These programs are described below.

The 21st Century Jobs Fund

The 21st Century Jobs Fund is intended to jump start the Michigan economy and diversify and grow the state's economy in the future by encouraging the development

[9] Michigan Department of Labor and Economic Growth – Energy Office. Transportation Group. Accessed April 2006. http://www.michigan.gov/cis/0,1607,7-154-25676_25694-50096--,00.html.
[10] NextEnergy. Accessed April 2006. <http://www.nextenergy.org/aboutus/>.
[11] Wayne State University – College of Engineering. Accessed April 2006. <http://www.eng.wayne.edu/news.php?id=297>.

and commercialization of competitive-edge technologies. The Fund intends to invest in basic research at our universities and non-profit research institutions, applied research, university technology transfer, and the commercialization of products, processes, and services. The four competitive-edge technologies are:

- Life sciences.
- Alternative energy.
- Advanced automotive, manufacturing and materials.
- Homeland security and defense.

The 21st Century Jobs Fund allots $2 Billion over the next ten years to these initiatives, $100 million of which is available in 2006. Funds will be dispersed as grants to higher education institutions and non-profit organizations and loan or other investment instruments to for-profit entities.

The NextEnergy Authority

The Michigan NextEnergy Authority (MNEA) (this is a separate effort from NextEnergy, Inc. the non-profit discussed above) was created to promote the development of alternative energy technologies and to provide tax incentives for business activities and property related to the research, development, and manufacturing of those technologies. The MNEA is a seven-member board, comprised of the State Treasurer, the directors of the state departments of Management and Budget and Transportation, and four private-sector members appointed by the Governor. The MNEA is responsible for certifying taxpayers and property as eligible for tax credits against the Michigan Single Business Tax (SBT) or exemptions from the General Property Tax.

The MNEA has provided key definitions within in the state as they relate to AVTs and AFs that maybe considered for the tax credits and exemptions within its authority. The definitions summarized below maybe a point of leverage in future policies promoting the development and adoption of AVTs and AFs.[12]

> **Alternative energy vehicle** means a motor vehicle manufactured by an original equipment manufacturer that fully warrants and certifies that the motor vehicle meets federal motor vehicle safety standards for its class of vehicles as defined by the Michigan vehicle code, 1949 PA 300, MCL 257.1 to 257.923, and certifies that the motor vehicle meets local emissions standards, that is propelled by an alternative energy system. Alternative energy vehicle includes the following:
> (i) An alternative fueled vehicle. As used in this subparagraph, "alternative fueled vehicle" means a motor vehicle that can only be powered by a clean fuel energy system and can only be fueled by a clean fuel.
>
> > **Clean fuel** means 1 or more of the following:
> > (i) Methane; (ii) Natural gas; (iii) Methanol neat or methanol blends containing at least 85% methanol; (iv) Denatured ethanol neat or ethanol blends containing at least 85% ethanol; (v) Compressed natural gas; (vi) Liquefied natural gas. (vii) Liquefied petroleum gas; (viii) Hydrogen.
> > **Clean fuel energy system** means a device that is designed and used solely for the purpose of generating power from a clean fuel. Clean fuel energy system does not include a conventional gasoline or diesel fuel engine or a retrofitted conventional diesel or gasoline engine.

[12] Michigan NextEnergy Authority. Certification Guidebook. June 2003.

(ii) A fuel cell vehicle - means a motor vehicle powered solely by a fuel cell energy system.
(iii) An electric vehicle - means a motor vehicle powered solely by a battery cell energy system.
(iv) A hybrid vehicle - means a motor vehicle that can only be powered by 2 or more alternative energy systems.
(v) A solar vehicle - means a motor vehicle powered solely by a photovoltaic energy system.
(vi) A hybrid electric vehicle - means a motor vehicle powered by an integrated propulsion system consisting of an electric motor and combustion engine. Hybrid electric vehicle does not include a retrofitted conventional diesel or gasoline engine. A hybrid electric vehicle obtains the power necessary to propel the motor vehicle from a combustion engine and 1 of the following:
(a) A battery cell energy system; (b) A fuel cell energy system; (c) A photovoltaic energy system.

Proposed Legislation

Beyond the programs described above, there have been several bills proposed promoting the transition to AVTs and AFs. A brief summary of these proposals is provided below.

Expansions of the MNEA and MI Renaissance Zone Act:

Senate Bill 0583 would amend the Michigan Next Energy Authority Act to include items related to the research anddevelopment, along with the manufacturing of an alternative energy system and alternative energy vehicles. Expands the definitions of "alternative energy system" to include anaerobic digester energy system, thermoelectric energy system and biomass energy system. Also expands the definition of "alternative energy vehicle" to include Hydraulic Hybrid Vehicle.

http://www.legislature.mi.gov/(4ct2io45vpkt0hrapn3pstrn)/mileg.aspx?page=BillStatus&objectname=2005-SB-0583.

Senate Bill 0584 would amend the Michigan Renaissance Zone Act to require designated alternative energy zones promote and increase the testing, as well as the research, development, and manufacturing, of alternative energy technology, and expand these activities to alternative energy systems and alternative energy vehicles (as defined in the MNEA Act).

http://www.legislature.mi.gov/(4ct2io45vpkt0hrapn3pstrn)/mileg.aspx?page=BillStatus&objectname=2005-SB-0584.

Bills Proposed supporting AFs:

Senate Bill 1074 would amend the Motor Fuel Tax Act to impose a 12-cents-per-gallon tax on gasoline that is at least 85% ethanol (E85) and diesel that contains at least 5% biodiesel (B5) (as compared to 19 cents and 15 cents, respectively) for up to 10 years. It would require the determination of the difference between the amount of revenue collected under the bill and the amount that would have been collected under existing tax provisions and then appropriate the difference to the Michigan Transportation Fund. The tax would no longer be effective should the Director certify that the total cumulative rate differential was greater than $2.5 million.

http://www.legislature.mi.gov/(4ct2io45vpkt0hrapn3pstrn)/mileg.aspx?page=BillStatus&objectname=2006-SB-1074&queryid=12940135.

Senate Bill 1075 would amend the Management and Budget Act to require the Director of the Department of Management and Budget, by October 1, 2006, to install the necessary fueling infrastructure, or contract with a supplier to supply alternative fuels, at all State motor transport facilities so that all State-owned vehicles capable of using alternative fuels were able to use them. "Alternative fuel" would mean E85 fuel and biodiesel fuel blends.

http://www.legislature.mi.gov/(4ct2io45vpkt0hrapn3pstrn)/mileg.aspx?page=BillStatus&objectname=2006-SB-1075&queryid=12940135.

Senate Bill 1076 would amend the Michigan Strategic Fund Act to require the Fund to create and administer a matching grant program to provide incentives to service station owners and operators to convert existing fuel delivery systems, and to create new fuel delivery systems, designed to provide E85 fuel and biodiesel blends. The grant program would have to provide grants of up to 50% of the costs to convert an existing fuel delivery system, not to exceed $2,000 per facility; and up to 50% of the new construction costs to create a fuel delivery system, not to exceed $20,000 per facility.

http://www.legislature.mi.gov/(4ct2io45vpkt0hrapn3pstrn)/mileg.aspx?page=BillStatus&objectname=2006-SB-1076&queryid=12940135.,

Senate Bill 1077 would create the "Fuels of the Future Commission Act" to establish the Fuels of the Future Commission within the Michigan Department of Agriculture (MDA). The proposed Act would be repealed on January 1, 2010. The Commission would have to investigate and recommend strategies that the Governor and the Legislature could implement to promote the use of alternative fuels and encourage the use of vehicles that used alternative fuels. The Commission also would have to identify mechanisms that promoted alternative fuel research. Additionally, the Commission would have to identify mechanisms that promoted effective communication and coordination of efforts between the State and local governments, private industry, and institutes of higher education concerning the investigation of, research into, and promotion of alternative fuels. The Commission could review any State regulation that could hinder the use, research, and development of alternative fuels and vehicles that were able to use them, and recommend changes to the Governor. Within one year after the bill's effective date, the Commission would have to issue to the Legislature and the Governor a written report on its investigation and recommendations. Follow-up reports would have to be issued at leased annually.

http://www.legislature.mi.gov/(4ct2io45vpkt0hrapn3pstrn)/mileg.aspx?page=BillStatus&objectname=2006-SB-1077&queryid=12940135.

Senate Bill 1078 (S-3) would amend the Michigan Renaissance Zone Act to allow the State Administrative Board, upon the recommendation of the Michigan Strategic Fund board, to designate up to 10 additional renaissance zones for renewable energy facilities in one or more cities, villages, or townships that consented to the creation of a renaissance zone within their boundaries. The bill would define "renewable energy facility" as a system that creates energy from a process using residue from corn, soybeans, wood, paper products industries, and food production and processing; trees and grasses grown specifically to be used as energy crops; and gaseous fuels produced from solid biomass, animal waste, or landfills.
http://www.legislature.mi.gov/(wxycuu45xviodm45vjddjl3z)/mileg.aspx?page=BillStatus&objectname=2006-SB-1078&queryid=12940646.

Senate Bill 1079 would amend the Motor Fuels Quality Act to extend to diesel and specified alternative fuels regulations concerning the quality, storage, manufacture, delivery, and sale of gasoline; require distributors and retail dealers of diesel and alternative fuels to obtain a license for each retail outlet; and require firms selling hydrogen in Michigan to register with and be approved by the Department of Agriculture.

http://www.legislature.mi.gov/(4ct2io45vpkt0hrapn3pstrn)/mileg.aspx?page=BillStatus&objectname=2006-SB-1079&queryid=12940135.

Appendix H.2. Ethanol PTC GHG Model

The MCCP Ethanol PTC GHG Model was developed using Microsoft Excel to calculate the net GHG benefit from displacing conventional petroleum based gasoline with either corn derived or cellulosic derived ethanol. Figure A-1 and A-2 present the calculation steps of both the corn based and cellulosic based ethanol models. The green boxes represent the input sections of the models and the yellow boxes represent the calculation stages of the models.

Tables H.2-1 and H.2-2 provide the detailed input files for the GREET model, which generated the WTP GHG emission factors for the fuel types used in this model. Table H.2-3 provides the GREET output, WTP GHG emission factors, for the conventional fuel displaced, as well as the corn and cellulosic derived ethanol.

As indicated in Figures H.2-1 and H.2-2, the MCCP Ethanol PTC GHG models assess the effects to both the amounts and acres of biomass needed to produce the modeled amount of ethanol. These effects are not used directly to calculate the GHG impact of the ethanol capacity, however, MCCP recognizes the importance of understanding the agricultural impacts of in-state ethanol production.[13]

[13] GREET captures all of the biomass production GHG emissions in generating WTP GHG emission factors on per fuel energy basis. Actual acres and tons of biomass produced are not necessary inputs to the GREET model.

Figure H.2-1. Well-to-Pump Greenhouse Gas Emissions Model of Cellulosic Ethanol Production in the State of Michigan

(Model Years 2005-2025)

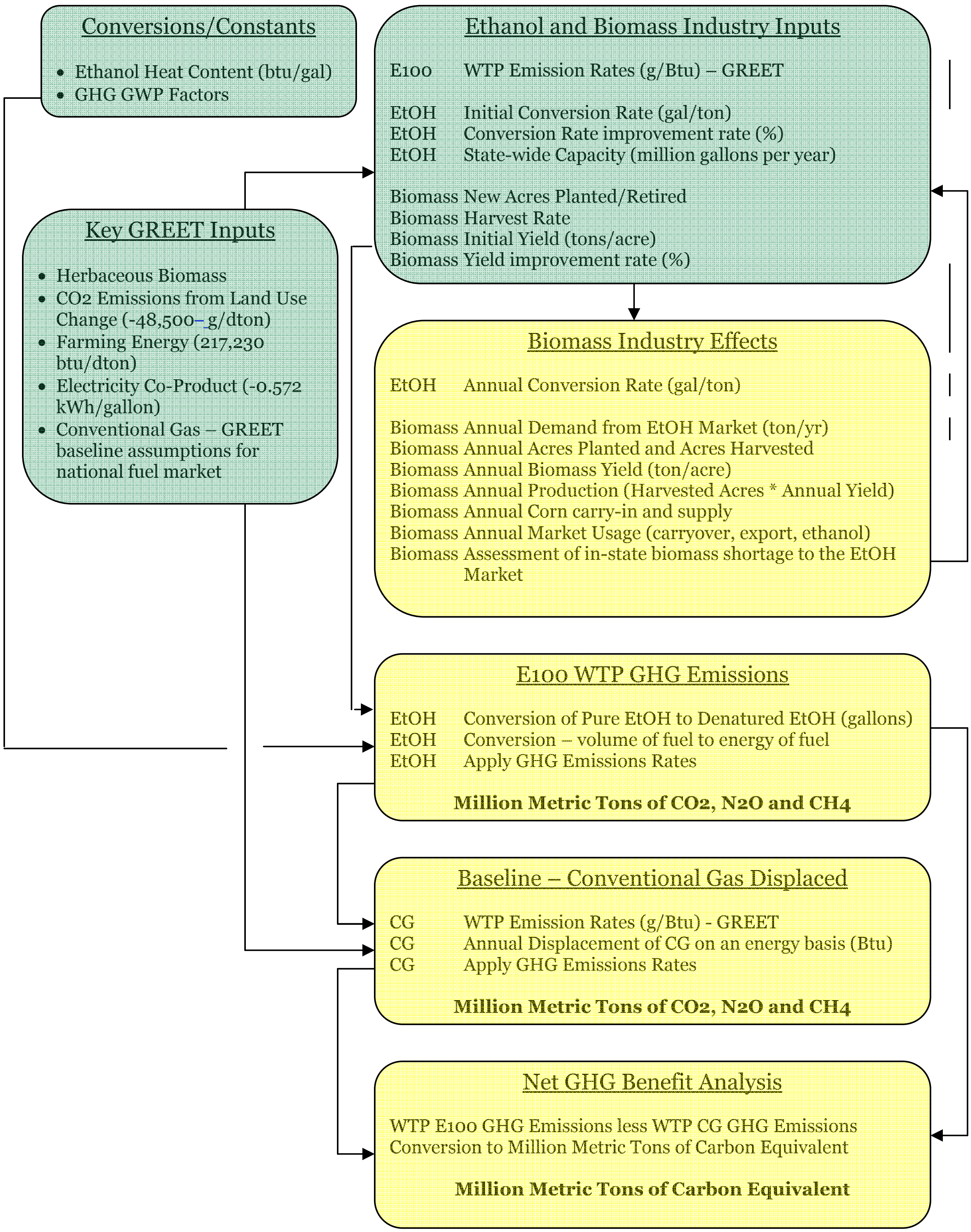


Figure H.2-2. Well-to-Pump Greenhouse Gas Emissions Model of Corn Ethanol Production in the State of Michigan

(Model Years 2005-2025)

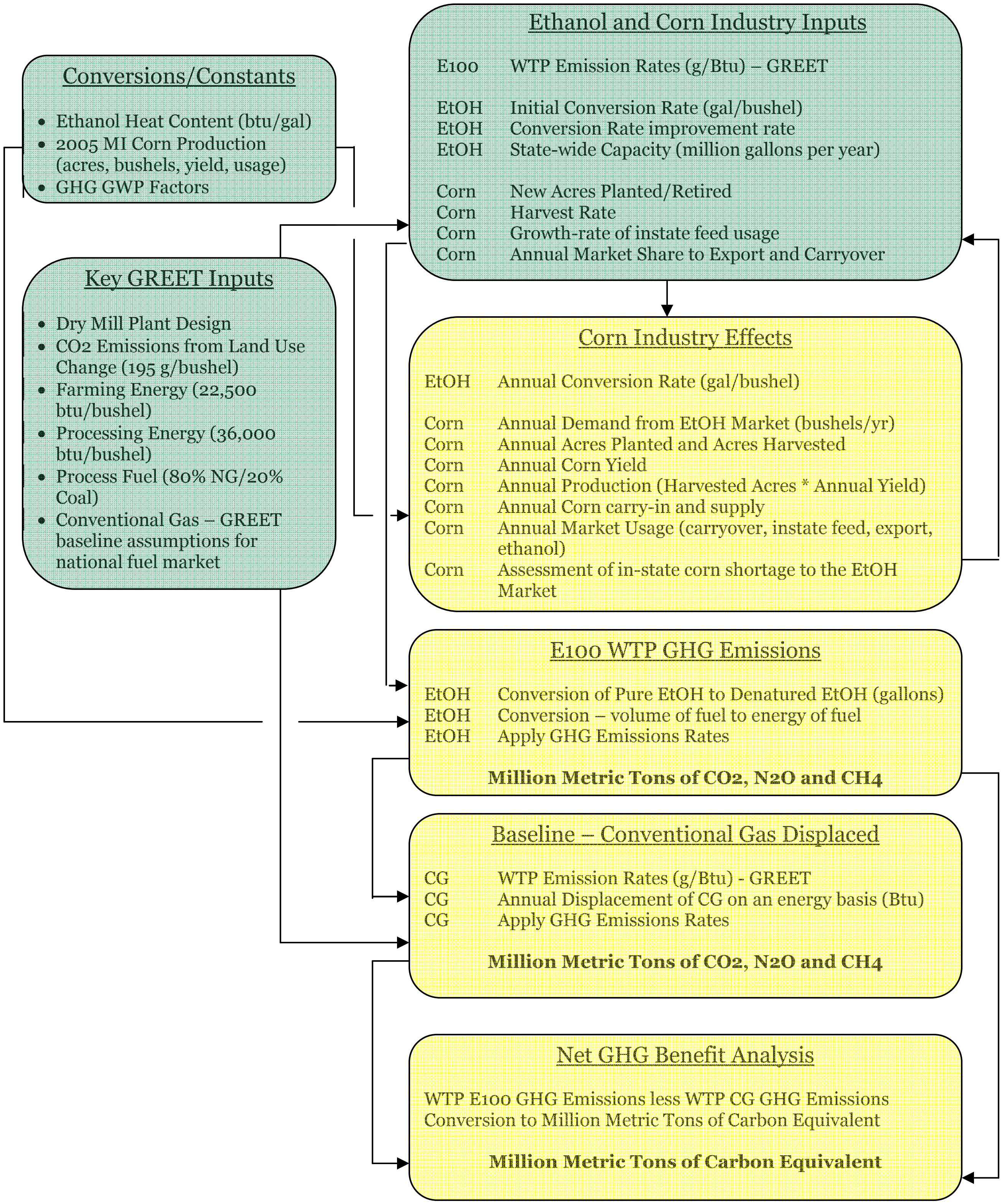


Table H.2-1. GREET Input File for Corn Ethanol GHG Model

Conventional Gasoline	
Vehicle Technology	
Spark Ignition Engine	
Pathway Options	
Conventional Gasoline O2 Content (%):	0
Conventional Gasoline Sulfur Level (ppm):	25.5
Conventional Gasoline Oxygenate:	No Oxygenate
Ethanol	
Vehicle Technology	
Flexible-Fuel Vehicle Spark Ignition Engine	
Low-Level Blend Spark Ignition Engine	
Low-Level Blend Compression Ignition,Direct-Injection engine	
Fuel-Cell Vehicle	
Pathway Options	
Corn Ethanol, Share of Ethanol Plant Type, Dry Milling Plant (%):	100
Corn Ethanol, Share of Ethanol Plant Type, Wet Milling Plant (%):	0
Share of Process Fuels in Dry Mill Ethanol Plant: Natural Gas (%):	80
Share of Process Fuels in Dry Mill Ethanol Plant: Coal (%):	20
Ethanol Co-Production Credit Calculation Method:	Displacement
Electricity	
Pathway Options	
NG turbine combined cycle share of total NG power plant capacity (%):	44
Simple-cycle NG turbine share of total NG power plant capacity (%):	36
Advanced coal technology share of total coal power plant capacity (%):	0
Advanced biomass technology share of total biomass power plant capacity (%):	0
LWR Plant Technology Shares for Electricity Production: Gas Diffusion (%):	25
LWR Plant Technology Shares for Electricity Production: Centrifuge (%):	75
HTGR Plant Technology Shares for Electricity Production: Gas Diffusion (%):	25
HTGR Plant Technology Shares for Electricity Production: Centrifuge (%):	75
Woody Biomass Plant Technology Shares for Electricity Production (%):	100
Herbaceous Biomass Plant Technology Shares for Electricity Production (%):	0
Type of Electricity Displaced by Cogeneration of Electricity in NG-Based Fuel Production Plants:	Natural Gas Combined Cycle
Type of Electricity Displaced by Electricity cogenerated in Biomass-Based Fuel Production Plants	Average Electricity Generation Mix
Type of Electricity Displaced by Cogeneration of Electricity in Biomass-Based Fuel Production Plants:	Average Electricity Generation Mix

Table H.2-1. GREET Input File for Corn Ethanol GHG Model (cont'd)

Marginal Generation Mix	
Residual Oil (%):	2.7
Natural Gas (%):	18.9
Coal (%):	50.7
Nuclear Power (%):	18.7
Biomass Electricity (%):	1.3
Others (%):	7.7
Average Generation Mix	
Residual Oil (%):	2.7
Natural Gas (%):	18.9
Coal (%):	50.7
Nuclear Power (%):	18.7
Biomass Electricity (%):	1.3
Others (%):	7.7
Petroleum	
Items	Assumptions
Crude Recovery Efficiency	98.0%
CG Refining Efficiency	86.00%

Ethanol	
Items	Assumptions
CO2 Emissions from Landuse Change by Corn Farming (g/bushel)	195
Corn Farming Energy Use (Btu/bushel)	22,500
Ethanol Production Energy Use:Dry Mill (Btu/gallon)	36,000

Electricity	
Items	Assumptions
Residual Oil Utility Boiler Efficiency	34.8%
NG Utility Boiler Efficiency	34.8%
NG Simple Cycle Turbine Efficiency	33.1%
NG Combined Cycle Turbine Efficiency	53.0%
Coal Utility Boiler Efficiency	34.1%
Electricity Transmission and Distribution Loss	8.0%
Energy intensity in HTGR reactors (MWh/g of U-235)	8.704
Energy intensity in LWR reactors (MWh/g of U-235)	6.926
Electricity Use of Uranium Enrichment (kWh/SWU): Gaseous Diffusion Plants for LWR electricity generation	2,400
Electricity Use of Uranium Enrichment (kWh/SWU): Centrifuge Plants for LWR electricity generation	50.0
Electricity Use of Uranium Enrichment (kWh/SWU): Gaseous Diffusion Plants for HTGR electricity generation	2,400
Electricity Use of Uranium Enrichment (kWh/SWU): Centrifuge Plants for HTGR electricity generation	50

Table H.2-2. GREET Input File for Cellulosic Ethanol GHG Model

Conventional Gasoline	
Vehicle Technology	
Spark Ignition Engine	
Pathway Options	
Conventional Gasoline O2 Content (%):	0
Conventional Gasoline Sulfur Level (ppm):	25.5
Conventional Gasoline Oxygenate:	No Oxygenate
Ethanol	
Vehicle Technology	
Flexible-Fuel Vehicle Spark Ignition Engine	
Low-Level Blend Spark Ignition Engine	
Low-Level Blend Compression Ignition,Direct-Injection engine	
Fuel-Cell Vehicle	
Pathway Options	
Electricity	
Pathway Options	
NG turbine combined cycle share of total NG power plant capacity (%):	44
Simple-cycle NG turbine share of total NG power plant capacity (%):	36
Advanced coal technology share of total coal power plant capacity (%):	0
Advanced biomass technology share of total biomass power plant capacity (%):	0
LWR Plant Technology Shares for Electricity Production: Gas Diffusion (%):	25
LWR Plant Technology Shares for Electricity Production: Centrifuge (%):	75
HTGR Plant Technology Shares for Electricity Production: Gas Diffusion (%):	25
HTGR Plant Technology Shares for Electricity Production: Centrifuge (%):	75
Woody Biomass Plant Technology Shares for Electricity Production (%):	100
Herbaceous Biomass Plant Technology Shares for Electricity Production (%):	0
Type of Electricity Displaced by Cogeneration of Electricity in NG-Based Fuel Production Plants:	Natural Gas Combined Cycle
Type of Electricity Displaced by Electricity cogenerated in Biomass-Based Fuel Production Plants	Average Electricity Generation Mix
Type of Electricity Displaced by Cogeneration of Electricity in Biomass-Based Fuel Production Plants:	Average Electricity Generation Mix
Marginal Generation Mix	
Residual Oil (%):	2.7
Natural Gas (%):	18.9
Coal (%):	50.7
Nuclear Power (%):	18.7
Biomass Electricity (%):	1.3
Others (%):	7.7
Average Generation Mix	
Residual Oil (%):	2.7
Natural Gas (%):	18.9
Coal (%):	50.7
Nuclear Power (%):	18.7
Biomass Electricity (%):	1.3
Others (%):	7.7

Table H.2-2. GREET Input File for Cellulosic Ethanol GHG Model (cont'd)

Petroleum	
Items	**Assumptions**
Crude Recovery Efficiency	98.0%
CG Refining Efficiency	86.00%

Ethanol	
Items	**Assumptions**
CO2 Emissions Due to Land Use Change by HBiomass Farming (g/dry ton)	-48,500
Herbaceous Biomass Farming Energy Use (Btu/dry ton)	217,230
EtOH Yield from Herbaceous Biomass Fermentation Plant (gallons/dry ton)	95
Electricity Co-Product in Herbaceous Biomass Fermentation Plant (kWh/gallon)	-0.572

Electricity	
Items	**Assumptions**
Residual Oil Utility Boiler Efficiency	34.8%
NG Utility Boiler Efficiency	34.8%
NG Simple Cycle Turbine Efficiency	33.1%
NG Combined Cycle Turbine Efficiency	53.0%
Coal Utility Boiler Efficiency	34.1%
Electricity Transmission and Distribution Loss	8.0%
Energy intensity in HTGR reactors (MWh/g of U-235)	8.704
Energy intensity in LWR reactors (MWh/g of U-235)	6.926
Electricity Use of Uranium Enrichment (kWh/SWU): Gaseous Diffusion Plants for LWR electricity generation	2,400
Electricity Use of Uranium Enrichment (kWh/SWU): Centrifuge Plants for LWR electricity generation	50.0
Electricity Use of Uranium Enrichment (kWh/SWU): Gaseous Diffusion Plants for HTGR electricity generation	2,400
Electricity Use of Uranium Enrichment (kWh/SWU): Centrifuge Plants for HTGR electricity generation	50

Table H.2-3. PTC WTP GHG Emission Factor Summary

Model Parameter	Units	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Conventional Gas Production	-	-	-	-	-	-	-	-	-	-	-
CG - WTP CO2 Emission Factor (GREET)	g/MBtu	17,773	17,775	17,773	17,772	17,772	17,771	17,765	17,760	17,754	17,748
CG - WTP CH4 Emission Factor (GREET)	g/MBtu	106.58	106.60	106.61	106.62	106.62	106.63	106.64	106.65	106.66	106.67
CG - WTP N2O Emission Factor (GREET)	g/MBtu	0.295	0.296	0.293	0.293	0.292	0.292	0.292	0.292	0.293	0.293
Corn Ethanol Production	-	-	-	-	-	-	-	-	-	-	-
E100 - WTP CO2 Emission Factor (GREET)	g/MBtu	-18,107	- 18,563	-19,027	-19,501	- 19,985	-20,479	-20,490	-20,501	-20,514	-20,527
E100 - WTP CH4 Emission Factor (GREET)	g/MBtu	113.50	113.09	112.67	112.24	111.79	111.33	111.45	111.56	111.68	111.79
E100 - WTP N2O Emission Factor (GREET)	g/MBtu	54.244	53.909	53.592	53.295	53.017	52.758	52.628	52.498	52.368	52.238
Cellulosic Ethanol Production											
E100 - WTP CO2 Emission Factor (GREET)	g/MBtu	-76,559	- 76,523	-76,487	-76,451	- 76,414	-76,376	-76,388	-76,399	-76,410	-76,420
E100 - WTP CH4 Emission Factor (GREET)	g/MBtu	8.21	8.10	8.00	7.91	7.82	7.73	7.57	7.42	7.26	7.11
E100 - WTP N2O Emission Factor (GREET)	g/MBtu	47.862	47.336	46.822	46.319	45.827	45.346	44.872	44.409	43.955	43.510

Table H.2-3. PTC WTP GHG Emission Factor Summary (cont'd)

Model Parameter	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Conventional Gas Production	-	-	-	-	-	-	-	-	-	-	-
CG - WTP CO2 Emission Factor (GREET)	17,742	17,840	17,938	18,035	18,133	18,231	18,231	18,231	18,231	18,231	18,231
CG - WTP CH4 Emission Factor (GREET)	106.68	106.80	106.93	107.05	107.18	107.30	107.30	107.30	107.30	107.30	107.30
CG - WTP N2O Emission Factor (GREET)	0.293	0.295	0.297	0.299	0.301	0.303	0.303	0.303	0.303	0.303	0.303
Corn Ethanol Production	-	-	-	-	-	-	-	-	-	-	-
E100 - WTP CO2 Emission Factor (GREET)	-20,541	-20,546	-20,553	-20,560	-20,568	-20,577	-19,385	-19,385	-19,385	-19,385	-19,385
E100 - WTP CH4 Emission Factor (GREET)	111.90	111.94	111.97	112.01	112.04	112.07	113	113	113	113	113
E100 - WTP N2O Emission Factor (GREET)	52.109	51.980	51.851	51.722	51.593	51.464	52	52	52	52	52
Cellulosic Ethanol Production											
E100 - WTP CO2 Emission Factor (GREET)	-76,429	-76,442	-76,454	-76,465	-76,476	-76,486	-63,199	-63,199	-63,199	-63,199	-63,199
E100 - WTP CH4 Emission Factor (GREET)	6.96	6.84	6.72	6.60	6.49	6.37	28.95	28.95	28.95	28.95	28.95
E100 - WTP N2O Emission Factor (GREET)	43.075	42.647	42.228	41.817	41.415	41.019	10.63	10.63	10.63	10.63	10.63

Appendix H.3. Ethanol PTC Economic Modeling

The economic modeling of the Ethanol PTC captured the economic costs associated with additional production of in-state ethanol. Tables H.3-1 through H.3-4 presents the key economic implications to increased ethanol production in the state. These implications include capital costs to plant construction and consumer level fuel price. Note that the Energy 2020-REMI models capture the associated economy-wide benefits from these modeled costs.

Table H.3-5 presents the modeled effect on the selected REMI policy variables. The data presented in Table H.3-5 represents an increase or decrease to the baseline value of that REMI variable. Baseline values are established by REMI. Variable descriptions are included in Appendix D.

Table H.3-1. Baseline Information for Cellulosic Ethanol Production

Reference facility is 69.3 Million gallon/yr (NREL 2002 Aden, et al). All dollars in US$ 2000.

	Estimated Cost for Reference Facility (Million $)	Proportion of Total	Cost Per Production ($/gal)
Cost of Equipment	$ 74.80	38%	$ 1.079
Cost of Installation (Labor)	$ 38.90	20%	$ 0.561
Other Capital Cost	$ 83.70	42%	$ 1.208
Total	$ 197.40	100%	$ 2.848

Table H.3-2. Baseline Information for Corn Ethanol Production

Corn – typically reported capital cost: $1.40/gallon (DMP) – (Urnanchuk, 2006). Applying Cellulosic Ratios to $1.40 Total Capital):

	Proportion of Total	Cost Per Production ($/gal)
Cost of Equipment	38%	$ 0.530
Cost of Installation (Labor)	20%	$ 0.276
Other Capital Cost	42%	$ 0.594
Total	100%	$ 1.40

Table H-3.3. Estimated Regional Wholesale Ethanol Price

Note: 2005 Data pulled from EIA Data, 2006 Data from Chicago Exchange, 2007 - 2025 projected using the EIA Growth Rate on the 2006 Data Point.

Ethanol Wholesale Price	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
	184.20	289.00	292.04	295.12	298.23	301.37	304.55	307.76	311.00	314.28	317.59
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
	320.93	324.31	327.73	331.18	334.67	338.20	341.76	345.36	349.00	352.68	

Table H.3-4. Estimated Regional Motor Fuel Price

Note: 2005 Data pulled from EIA Data, 2006 Data from Chicago Exchange, 2007 - 2025 projected using the EIA Growth Rate on the 2006 Data Point.

Motor Gasoline	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
	231.00	301.00	304.54	308.12	311.75	315.41	319.12	322.87	326.67	330.51	334.40
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
	338.33	342.31	346.34	350.41	354.53	358.70	362.92	367.19	371.51	375.88	
Ethanol (E85)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
	210.00	293.00	296.46	299.96	303.50	307.08	310.70	314.37	318.08	321.83	325.63
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
	329.47	333.36	337.29	341.27	345.30	349.37	353.50	357.67	361.89	366.16	

Table H.3-5. Ethanol PTC Modeled REMI Variables – 2000 Fixed $ Million

Variable	Sector	2005	2006	2007	2008	2009	2010	2011	2012
Firm Sales	Construction	54.34397	76.08156	86.95035	186.2751	142.8	0	0	0
Firm Sales	Electrical Equip, Appliance Mfg.	33.15603	46.41844	53.04965	113.6491	87.12428	0	0	0
Industry Sales/Int Exports	Chemical Mfg.	0	0	0	0	0	0	0	0
Exogenous Final Demand	Petroleum, Coal Prod Mfg.	-69.7328	-116.221	-185.954	-278.931	-372.557	-581.012	-579.717	-578.465
Consumer Spending	Gasoline and Oil	16.51723	27.52871	44.04594	66.06891	87.44281	137.7379	139.0333	140.2847
Consumption Reallocation	All Consumption Sectors	-16.5172	-27.5287	-44.0459	-66.0689	-87.4428	-137.738	-139.033	-140.285
Firm Sales	Chemical Mfg.	104.9	174.8	279.7	419.6	559.5	849.3	849.3	849.3
Government Spending	State	0	0	0	-1.875	-1.875	-1.875	-1.875	-1.875

Variable	Sector	2013	2014	2015	2016	2017	2018	2019	2020
Firm Sales	Construction	0	0	0	0	0	0	0	0
Firm Sales	Electrical Equip, Appliance Mfg.	0	0	0	0	0	0	0	0
Industry Sales/Int Exports	Chemical Mfg.	0	0	0	0	0	0	0	0
Exogenous Final Demand	Petroleum, Coal Prod Mfg.	-577.257	-576.092	-574.969	-573.888	-572.847	-571.846	-570.885	-569.961
Consumer Spending	Gasoline and Oil	141.4928	142.6579	143.7808	144.8622	145.9029	146.9037	147.8655	148.7892
Consumption Reallocation	All Consumption Sectors	-141.493	-142.658	-143.781	-144.862	-145.903	-146.904	-147.865	-148.789
Firm Sales	Chemical Mfg.	849.3	849.3	849.3	849.3	849.3	849.3	849.3	849.3
Government Spending	State	-1.875	-1.875	-1.875	-1.875	-1.875	0	0	0

Table H.3-5. Ethanol PTC Modeled REMI Variables – 2000 Fixed $ Million (cont'd)

Variable	Sector	2021	2022	2023	2024	2025
Firm Sales	Construction	0	0	0	0	0
Firm Sales	Electrical Equip, Appliance Mfg.	0	0	0	0	0
Industry Sales/Int Exports	Chemical Mfg.	0	0	0	0	0
Exogenous Final Demand	Petroleum, Coal Prod Mfg.	-569.472	-568.994	-568.526	-568.07	-567.623
Consumer Spending	Gasoline and Oil	149.2782	149.7562	150.2236	150.6804	151.1268
Consumption Reallocation	All Consumption Sectors	-149.278	-149.756	-150.224	-150.68	-151.127
Firm Sales	Chemical Mfg.	849.3	849.3	849.3	849.3	849.3
Government Spending	State	0	0	0	0	0

Table H.3-6. Ethanol PTC Modeled REMI Outputs

	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	
Employment (Thousand)	1.448	1.977	3.265	3.46	3.426	3.343	3.277	3.204	3.132	
Gross State Product (Billion Fixed 2000$)	0.1564	0.2304	0.3824	0.4464	0.5354	0.542	0.5428	0.5431	0.5434	
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Employment (Thousand)	3.065	3.007	2.957	2.956	2.916	2.883	2.85	2.825	2.798	2.774
Gross State Product (Billion Fixed 2000$)	0.5444	0.5457	0.5476	0.5523	0.555	0.5579	0.5605	0.5637	0.5669	0.5704

Appendix H.4. RFS GHG Model

The MCCP Ethanol RFS GHG Model was developed using Microsoft Excel to calculate the net GHG benefit from establishing fixed alternative fuel usage levels in the Michigan transportation sector. Figure H.4-1 provides the calculation methodology for the RFS model and presents the following primary steps for model execution:

- Determine the baseline fuel usage in the state for the modeling period (2005-2025), presented in Table H.4-1.
- Input the renewable fuel levels consistent with the planned RFS policy.
- Calculate the fuel usage profile in the state under the RFS for the modeling period (2005-2025), presented in Table H.4-2.
- Determine the amount of conventional gasoline displaced by the higher levels of renewable fuel usage under the RFS.
- Establish the types of vehicles using the additional renewable fuels as well as the types of vehicles that would have used the displaced conventional gasoline based on estimated market shares for each vehicle type, presented in Table H.4-3.
- Determine the vehicle miles traveled by the vehicles using the additional renewable fuels and the displaced conventional gasoline.
- Apply the WTW GHG emission factor (grams/VMT) to the calculated vehicle mile traveled profile associated with additional renewable fuels and displaced conventional fuel. WTW emission factors were derived using the GREET model. GREET model inputs are included in Table H.4-4 through Table H.4-6. Table H.4-7 presents the GREET emission factors used in this model.
- Calculate the net benefit of displacing conventional fuel at the RFS level with renewable fuel alternatives.

The remainder of this appendix provides the critical pieces of input data used in developing the MCCP RFS GHG Model.

Figure H.4-1. Well-to-Wheel Greenhouse Gas Emissions Model of a Proposed Renewable Fuel Standard for the State of Michigan

(Model Years 2005-2025)

Conversions/Constants

- Motor Fuel Heat Content Summary (btu/gal)
- GHG GWP Factors

Key GREET Inputs

- One of Two Scenarios: All Corn EtOH or Increase Cellulosic Market Share
- EtOH, Biodiesel, Petdiesel, RFG and CG use GREET baseline assumptions for national fuel market
- CG/RFG Market Share Mix from GHG Model calculation of displaced

Baseline Michigan Motor Fuel Usage

Input	2005 Fuel Usage (gallons) – Gasoline, E85, PetDiesel, Biodiesel Projected Fuel Usage Growth Rates (2005 – 20025) Projected Conventional Gas/Reformulated Gas Market Share (2005 – 2025)
Calculation	Baseline Annual Total Motor Fuel Usage in the State (gallons) Baseline Annual Fuel Usage (gallons) – CG, RFG, E85, Petdiesel, Biodiesel Baseline Annual State Renewable Contribution (%)

Proposed RFS

Input	Proposed RFS – Percent of In-state Fuel Usage Supplied by a Renewable Source Growth Rates of Each Fuel Required to Meet the RFS (RFG, E85, Biodiesel) Estimated Distribution of EtOH used to Meet the RFS used in E85 and RFG(E10) fuels
Calculation	RFS Annual Additional E85 (gallons) Required to maintain the Baseline Motor Fuel Energy Content RFS Annual Total Motor Fuel Usage in the State (gallons) RFS Annual Fuel Usage (gallons) – CG, RFG, E85, Petdiesel, Biodiesel RFS Annual State Renewable Contribution (%)

Net Effect on Fuel Usage in the State Under the RFS

Calculation	Annual Gallons of Conventional Gas (CG) and Reformulated Gas (RFG) displaced by the RFS Annual Gallons of additional E85 over the baseline under the RFS Annual Gallons of Petdiesel displaced by the RFS Annual Gallons of additional Biodiesel over the baseline under the RFS

Assessment of Vehicle Miles Traveled by Vehicle Type on Displaced and New Renewable Fuels

Input	Baseline Michigan Market Share of LD Flex Fuel Cars and Trucks and LD Diesel Cars and Trucks Fuel Economy (mi/gal gas equiv) for LD Conventional, LD Flex Fuel and LD Diesel Cars and Trucks
Calculation	Distribution of CG, RFG and Petdiesel displaced (gallons) by vehicle type (LDC-G-ICE, LDT-G-ICE, LDC-D-ICE, LDT-D-ICE) Distribution of E85 and Biodiesel above the baseline (gallons) by vehicle type (LDC-E-FFV, LDT-E-FFV, LDC-D-ICE, LDT-D-ICE) Annual Miles Traveled by Vehicle Type on displaced CG, RFG and Petdiesel Annual Miles Traveled by Vehicle Type on additional E85 and Biodiesel

Net GHG Benefit Analysis

Input	CO2, N2O and CH4 Emission Factors by Vehicle Type (g pollutant/mile) - GREET
Calculation	CO2, N2O and CH4 Emissions from VMT on Displaced CG, RFG and Petdiesel CO2, N2O and CH4 Emissions from VMT on Additional E85 and Biodiesel Net GHG Emissions (Additional Alternative Fuel less Displaced Conventional Fuel) Conversion to Million Metric Tons of Carbon Equivalent

Million Metric Tons of Carbon Equivalent

Table H.4-1. Baseline Michigan Fuel Usage 2005-2025 (thousand gallons)

	2005	2006	2007	2008	2009	2010	2011
Reformulated Gas (RFG/E10)	1,680,292	1,815,368	2,269,992	2,629,935	2,989,497	3,390,408	3,783,143
Conventional Gas (CG)	3,369,295	3,266,485	2,844,335	2,517,072	2,190,400	1,822,588	1,463,164
E85 Blended Motor Fuel	149	157	165	174	183	193	203
Biodiesel[1]	3,000	3,158	3,325	3,501	3,686	3,880	4,085
Petdiesel	989,731	1,002,141	1,014,701	1,027,413	1,040,280	1,053,302	1,066,481
Total Motor Fuel	6,042,467	6,087,310	6,132,518	6,178,096	6,224,046	6,270,371	6,317,076
Percent Renewable	2.70%	2.89%	3.58%	4.11%	4.64%	5.21%	5.77%

	2012	2013	2014	2015	2016	2017	2018
Reformulated Gas (RFG/E10)	4,128,891	4,333,548	4,410,173	4,485,581	4,569,661	4,648,105	4,768,551
Conventional Gas (CG)	1,150,941	980,022	937,350	896,112	846,422	802,586	716,971
E85 Blended Motor Fuel	214	225	237	249	262	276	291
Biodiesel[1]	4,301	4,528	4,767	5,019	5,284	5,563	5,857
Petdiesel	1,079,819	1,093,316	1,106,976	1,120,799	1,134,787	1,148,941	1,163,263
Total Motor Fuel	6,364,164	6,411,639	6,459,503	6,507,761	6,556,416	6,605,472	6,654,932
Percent Renewable	6.25%	6.51%	6.58%	6.64%	6.72%	6.79%	6.92%

	2019	2020	2021	2022	2023	2024	2025
Reformulated Gas (RFG/E10)	4,861,652	4,951,223	5,044,417	5,140,120	5,180,033	5,201,437	5,246,805
Conventional Gas (CG)	658,922	604,627	546,936	486,961	483,005	497,788	488,838
E85 Blended Motor Fuel	306	322	339	357	376	396	417
Biodiesel[1]	6,166	6,492	6,835	7,196	7,576	7,976	8,397
Petdiesel	1,177,755	1,192,418	1,207,253	1,222,262	1,237,447	1,252,809	1,268,350
Total Motor Fuel	6,704,801	6,755,082	6,805,780	6,856,897	6,908,437	6,960,406	7,012,807
Percent Renewable	7.00%						

1. Biodiesel is the portion of state diesel usage that is derived from renewable feedstock. It is sold throughout the state as B100, B20, and B2 blends.

Table H.4-2. Michigan Fuel Usage 2005-2025 under the RFS (thousand gallons)

	2005	2006	2007	2008	2009	2010	2011
Reformulated Gas (RFG/E10)	1,680,292	1,815,368	2,269,992	2,608,606	2,928,819	3,218,191	3,565,767
Conventional Gas (CG)	3,369,295	3,266,485	2,844,335	2,496,658	2,145,942	1,730,009	1,379,092
E85 Blended Motor Fuel	149	157	165	56,001	140,495	352,765	400,677
Biodiesel[1]	3,000	3,158	3,325	15,445	35,010	79,359	85,547
Petdiesel	989,731	1,002,141	1,014,701	1,015,469	1,008,955	977,823	985,019
Total Motor Fuel	6,042,467	6,087,310	6,132,518	6,192,179	6,259,222	6,358,148	6,416,103
Percent Renewable	2.65%	2.84%	3.53%	4.93%	6.68%	10.17%	11.25%

	2012	2013	2014	2015	2016	2017	2018
Reformulated Gas (RFG/E10)	3,860,523	4,014,923	4,043,369	4,063,553	4,083,305	4,088,482	4,119,083
Conventional Gas (CG)	1,076,133	907,965	859,388	811,801	756,336	705,956	619,320
E85 Blended Motor Fuel	455,240	517,687	589,162	670,519	763,081	868,460	988,163
Biodiesel[1]	92,218	99,409	107,162	115,520	124,530	134,244	144,717
Petdiesel	991,902	998,436	1,004,582	1,010,298	1,015,541	1,020,260	1,024,403
Total Motor Fuel	6,476,015	6,538,420	6,603,663	6,671,691	6,742,793	6,817,403	6,895,686
Percent Renewable	12.30%	13.23%	14.06%	14.97%	15.99%	17.11%	18.39%

	2019	2020	2021	2022	2023	2024	2025
Reformulated Gas (RFG/E10)	4,112,604	4,088,254	4,111,419	4,131,257	4,101,128	4,051,780	4,016,148
Conventional Gas (CG)	557,400	499,244	445,776	391,384	382,404	387,764	374,180
E85 Blended Motor Fuel	1,124,559	1,279,825	1,366,310	1,458,635	1,557,707	1,663,694	1,776,666
Biodiesel[1]	156,007	168,180	174,525	181,111	187,947	195,041	202,405
Petdiesel	1,027,914	1,030,730	1,039,563	1,048,347	1,057,076	1,065,744	1,074,342
Total Motor Fuel	6,978,484	7,066,232	7,137,593	7,210,734	7,286,263	7,364,023	7,443,741
Percent Renewable	19.77%	21.29%	22.10%	22.94%	23.76%	24.61%	25.52%

1. Biodiesel is the portion of state diesel usage that is derived from renewable feedstock. It is sold throughout the state as B100, B20, and B2 blends.

Table H.4-3. LDV Market Share Data Used in the RFS GHG Model

Vehicle Type	Light-Duty Car Stock	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LDC-G-ICE	Gasoline ICE Vehicles	4,402.5	4,423.8	4,445.2	4,466.7	4,488.4	4,510.1	4,510.7	4,511.3	4,511.9	4,512.5
LDT-G-ICE	Gasoline ICE Vehicles	2,941.2	3,027.2	3,115.8	3,206.9	3,300.6	3,397.1	3,479.7	3,564.2	3,650.8	3,739.5
LDC-E-FF	Ethanol-Flex Fuel ICE	117.3	132.4	149.4	168.5	190.1	214.5	227.5	241.2	255.8	271.3
LDT-E-FF	Ethanol-Flex Fuel ICE	112.8	131.5	153.2	178.5	208.0	242.4	264.6	288.8	315.3	344.1
LDC-D-ICE	TDI Diesel ICE	39.6	40.0	40.5	41.0	41.6	42.1	43.2	44.3	45.4	46.6
LDT-D-ICE	TDI Diesel ICE	83.6	89.5	95.8	102.5	109.8	117.5	124.9	132.8	141.1	150.0
Market Share Breakdown by Fuel Type											
LDC-G-ICE	Gasoline ICE Vehicles	59.95%	59.37%	58.79%	58.21%	57.62%	57.04%	56.45%	55.86%	55.27%	54.68%
LDT-G-ICE	Gasoline ICE Vehicles	40.05%	40.63%	41.21%	41.79%	42.38%	42.96%	43.55%	44.14%	44.73%	45.32%
LDC-E-FF	Ethanol-Flex Fuel ICE	50.98%	50.17%	49.37%	48.56%	47.75%	46.95%	46.23%	45.51%	44.80%	44.08%
LDT-E-FF	Ethanol-Flex Fuel ICE	49.02%	49.83%	50.63%	51.44%	52.25%	53.05%	53.77%	54.49%	55.20%	55.92%
LDC-D-ICE	TDI Diesel ICE	32.12%	30.92%	29.74%	28.59%	27.46%	26.36%	25.68%	25.01%	24.35%	23.71%
LDT-D-ICE	TDI Diesel ICE	67.88%	69.08%	70.26%	71.41%	72.54%	73.64%	74.32%	74.99%	75.65%	76.29%

Vehicle Type	Light-Duty Car Stock	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
LDC-G-ICE	Gasoline ICE Vehicles	4,513.1	4,506.1	4,499.1	4,492.0	4,485.0	4,478.0	4,474.8	4,471.5	4,468.2	4,464.9	4,461.6
LDT-G-ICE	Gasoline ICE Vehicles	3,830.3	3,895.3	3,961.3	4,028.5	4,096.8	4,166.2	4,219.1	4,272.6	4,326.7	4,381.6	4,437.2
LDC-E-FF	Ethanol-Flex Fuel ICE	287.7	295.8	304.2	312.8	321.6	330.7	335.4	340.1	344.9	349.8	354.7
LDT-E-FF	Ethanol-Flex Fuel ICE	375.7	394.1	413.4	433.7	454.9	477.2	491.0	505.3	519.9	535.0	550.5
LDC-D-ICE	TDI Diesel ICE	47.8	49.7	51.6	53.6	55.6	57.8	61.1	64.5	68.2	72.0	76.1
LDT-D-ICE	TDI Diesel ICE	159.5	169.1	179.2	189.9	201.3	213.4	227.6	242.6	258.7	275.9	294.1
Market Share Breakdown by Fuel Type												
LDC-G-ICE	Gasoline ICE Vehicles	54.09%	53.64%	53.18%	52.72%	52.26%	51.80%	51.47%	51.14%	50.80%	50.47%	50.14%
LDT-G-ICE	Gasoline ICE Vehicles	45.91%	46.36%	46.82%	47.28%	47.74%	48.20%	48.53%	48.86%	49.20%	49.53%	49.86%
LDC-E-FF	Ethanol-Flex Fuel ICE	43.37%	42.88%	42.39%	41.90%	41.42%	40.93%	40.58%	40.23%	39.88%	39.53%	39.18%
LDT-E-FF	Ethanol-Flex Fuel ICE	56.63%	57.12%	57.61%	58.10%	58.58%	59.07%	59.42%	59.77%	60.12%	60.47%	60.82%
LDC-D-ICE	TDI Diesel ICE	23.07%	22.71%	22.35%	22.00%	21.65%	21.31%	21.16%	21.00%	20.85%	20.70%	20.55%
LDT-D-ICE	TDI Diesel ICE	76.93%	77.29%	77.65%	78.00%	78.35%	78.69%	78.84%	79.00%	79.15%	79.30%	79.45%

Table H.4-4. GREET Input File for Motor Fuels - RFS GHG Model

Federal Reformulated Gasoline	
Vehicle Technology	
Spark Ignition Engine	
Pathway Options	
FRFG O2 Content (%):	2.3
FRFG Sulfur Level (ppm):	25.5
Conventional Gasoline Oxygenate:	Ethanol
FRFG Ethanol Feedstock: Corn (%):	100
FRFG Ethanol Feedstock: Woody Biomass (%):	0
FRFG Ethanol Feedstock: Herbaceous Biomass (%):	0
Conventional Gasoline	
Vehicle Technology	
Spark Ignition Engine	
Pathway Options	
Conventional Gasoline O2 Content (%):	0
Conventional Gasoline Sulfur Level (ppm):	25.5
Conventional Gasoline Oxygenate:	No Oxygenate
Low Sulfur Diesel	
Vehicle Technology	
Compression-Ignition, Direct Injection	
Grid Independent Hybrid Electric Vehicle Compression Ignition, Direct Injection Engine	
Pathway Options	
Low-Sulfur Diesel: Sulfur Level (ppm):	11
Low-Sulfur Diesel Location for Use:	United States
Conventional Diesel	
Vehicle Technology	
Compression-Ignition, Direct Injection	
Grid Independent Compression-Ignition, Direct Injection	
Pathway Options	
Conventional Diesel: Sulfur Level (ppm):	200
Conventional Diesel Location for Use:	United States
Ethanol	
Vehicle Technology	
Flexible-Fuel Vehicle Spark Ignition Engine	
Pathway Options	
Corn Ethanol, Share of Ethanol Plant Type, Dry Milling Plant (%):	80
Corn Ethanol, Share of Ethanol Plant Type, Wet Milling Plant (%):	20
Share of Process Fuels in Dry Mill Ethanol Plant: Natural Gas (%):	80
Share of Process Fuels in Dry Mill Ethanol Plant: Coal (%):	20
Share of Process Fuels in Dry Mill Ethanol Plant: Natural Gas (%):	60
WMP Share of Process Fuels in Dry Mill Ethanol Plant: Coal (%):	40
Ethanol Co-Production Credit Calculation Method:	Displacement

Table H.4-4. GREET Input File for Motor Fuels - RFS GHG Model (cont'd)

Electricity	
Pathway Options	
NG turbine combined cycle share of total NG power plant capacity (%):	44
Simple-cycle NG turbine share of total NG power plant capacity (%):	36
Advanced coal technology share of total coal power plant capacity (%):	0
Advanced biomass technology share of total biomass power plant capacity (%):	0
LWR Plant Technology Shares for Electricity Production: Gas Diffusion (%):	25
LWR Plant Technology Shares for Electricity Production: Centrifuge (%):	75
HTGR Plant Technology Shares for Electricity Production: Gas Diffusion (%):	25
HTGR Plant Technology Shares for Electricity Production: Centrifuge (%):	75
Woody Biomass Plant Technology Shares for Electricity Production (%):	100
Herbaceous Biomass Plant Technology Shares for Electricity Production (%):	0
Type of Electricity Displaced by Cogeneration of Electricity in NG-Based Fuel Production Plants:	Natural Gas Combined Cycle
Type of Electricity Displaced by Electricity cogenerated in Biomass-Based Fuel Production Plants	Average Electricity Generation Mix
Type of Electricity Displaced by Cogeneration of Electricity in Biomass-Based Fuel Production Plants:	Average Electricity Generation Mix
Biodiesel	
Vehicle Technology	
Compression-Ignition, Direct Injection	
Grid Independent, Hybrid Electric Vehicle, Compression-Ignition, Direct Injection	
Pathway Options	
Soybean Farming Soy Diesel (%):	62.1
Soybean Farming, Co-Products (%):	37.9
Soy Oil Extraction, Soy Diesel (%):	62.1
Soy Oil Extraction, Co-Products (%):	37.9
Soy Oil Transesterification, Soy Diesel (%):	79.6
Soy Oil Transesterification, Co-Products (%):	20.4
Marginal Generation Mix	
Residual Oil (%):	2.7
Natural Gas (%):	18.9
Coal (%):	50.7
Nuclear Power (%):	18.7
Biomass Electricity (%):	1.3
Others (%):	7.7
Average Generation Mix	
Residual Oil (%):	2.7
Natural Gas (%):	18.9
Coal (%):	50.7
Nuclear Power (%):	18.7
Biomass Electricity (%):	1.3
Others (%):	7.7

Table H.4-4. GREET Input File for Motor Fuels - RFS GHG Model (cont'd)

Petroleum	
Items	**Assumptions**
Crude Recovery Efficiency	98.0%
CG Refining Efficiency	86.0%
RFG Refining Efficiency	85.5%
CD Refining Efficiency	89.0%
LSD Refining Efficiency	87.00%

Ethanol	
Items	**Assumptions**
CO2 Emissions from Landuse Change by Corn Farming (g/bushel)	195
Corn Farming Energy Use (Btu/bushel)	22,500
Ethanol Production Energy Use:Dry Mill (Btu/gallon)	36,000
Ethanol Production Energy Use:Wet Mill (Btu/gallon)	45,950
CO2 Emissions Due to Land Use Change by HBiomass Farming (g/dry ton)	-48,500
Herbaceous Biomass Farming Energy Use (Btu/dry ton)	217,230
EtOH Yield from Herbaceous Biomass Fermentation Plant (gallons/dry ton)	95
Electricity Co-Product in Herbaceous Biomass Fermentation Plant (kWh/gallon)	-0.572

Electricity	
Items	**Assumptions**
Residual Oil Utility Boiler Efficiency	34.8%
NG Utility Boiler Efficiency	34.8%
NG Simple Cycle Turbine Efficiency	33.1%
NG Combined Cycle Turbine Efficiency	53.0%
Coal Utility Boiler Efficiency	34.1%
Electricity Transmission and Distribution Loss	8.0%
Energy intensity in HTGR reactors (MWh/g of U-235)	8.704
Energy intensity in LWR reactors (MWh/g of U-235)	6.926
Electricity Use of Uranium Enrichment (kWh/SWU): Gaseous Diffusion Plants for LWR electricity generation	2,400
Electricity Use of Uranium Enrichment (kWh/SWU): Centrifuge Plants for LWR electricity generation	50.0
Electricity Use of Uranium Enrichment (kWh/SWU): Gaseous Diffusion Plants for HTGR electricity generation	2,400
Electricity Use of Uranium Enrichment (kWh/SWU): Centrifuge Plants for HTGR electricity generation	50

Table H.4-5. GREET Input File for LDC Vehicles - RFS GHG Model

Baseline Vehicles (Model Year 2005)		
Items	SI Vehicle: CG and RFG	CIDI Vehicle: CD and LSD
Gasoline Equivalent MPG	24.8	33.73
Exhuast VOC	0.122	0.088
Evaporative VOC	0.058	0
CO	3.745	0.539
NOx	0.141	0.141
Exhuast PM10	0.0081	0.009
Brake and Tire Wear PM10	0.0205	0.0205
CH4	0.0146	0.0026
N2O	0.012	0.012

MPG and Emission Ratios: AFV/GV (Model Year 2005)					
Items	CIDI Vehicle: CD and LSD	SI Vehicle: EtOH FFV	CIDI Vehicle: BD	GI HEV: CD and LSD	GI HEV: BD
Gasoline Equivalent MPG	1.360	1.050	1.360	1.740	1.740
Exhuast VOC		100.0%	100.0%	78.0%	78.0%
Evaporative VOC		85.0%	0.0%	0.0%	0.0%
CO		100.0%	100.0%	100.0%	100.0%
NOx		100.0%	100.0%	87.0%	87.0%
Exhuast PM10		100.0%	100.0%	100.0%	100.0%
Brake and Tire Wear PM10		100.0%	100.0%	100.0%	100.0%
CH4		100.0%	100.0%	100.0%	100.0%
N2O		100.00%	100.00%	100.00%	100.00%

Table H.4-6. GREET Input File for LDT Vehicles - RFS GHG Model

Baseline Vehicles (Model Year 2005)		
Items	SI Vehicle: CG and RFG	CIDI Vehicle: CD and LSD
Gasoline Equivalent MPG	19.4	26.38
Exhuast VOC	0.144	0.13
Evaporative VOC	0.069	0
CO	3.916	0.412
NOx	0.229	0.291
Exhuast PM10	0.012	0.014
Brake and Tire Wear PM10	0.021	0.021
CH4	0.016	0.003
N2O	0.012	0.012

MPG and Emission Ratios: AFV/GV (Model Year 2005)					
Items	CIDI Vehicle: CD and LSD	SI Vehicle: EtOH FFV	CIDI Vehicle: BD	GI HEV: CD and LSD	GI HEV: BD
Gasoline Equivalent MPG	1.360	1.050	1.360	1.740	1.740
Exhuast VOC		100.0%	100.0%	78.0%	78.0%
Evaporative VOC		85.0%	0.0%	0.0%	0.0%
CO		100.0%	100.0%	100.0%	100.0%
NOx		100.0%	100.0%	87.0%	87.0%
Exhuast PM10		100.0%	100.0%	100.0%	100.0%
Brake and Tire Wear PM10		100.0%	100.0%	100.0%	100.0%
CH4		100.0%	100.0%	100.0%	100.0%
N2O		100.00%	100.00%	100.00%	100.00%

Table H.4-7. GREET WTW GHG Emission Factors

		2005	2006	2007	2008	2009	2010	2011	2012
Light Duty Vehicle - CO2 Emission Rates (g/mi)									
LDC-G-ICE	Gasoline Vehicle: CG and RFG	463.5	455.3	447.1	439.2	431.8	425.1	423.9	422.6
LDC-E-FF	EtOH FFV: E85, Corn	318.5	313.0	307.4	302.0	296.7	291.6	290.3	289.1
LDC-D-ICE	Conventional and LS Diesel	371.1	361.5	351.9	342.6	333.6	324.8	317.4	310.4
LDC-D-ICE	CIDI Vehicle: BD20	333.0	324.0	315.0	306.4	298.0	289.8	283.2	276.8
Light Duty Truck - CO2 Emission Rates (g/mi)									
LDT-G-ICE	Gasoline Vehicle: CG and RFG	598.2	586.4	574.7	563.5	553.0	543.5	536.5	529.8
LDT-E-FF	EtOH FFV: E85, Corn	411.1	403.1	395.2	387.5	380.0	372.8	367.5	362.4
LDT-D-ICE	Conventional and LS Diesel	478.9	465.6	452.3	439.6	427.2	415.2	401.8	389.1
LDT-D-ICE	CIDI Vehicle: BD20	429.7	417.3	404.9	393.1	381.6	370.5	358.4	347.0
Light Duty Vehicle - CH4 Emission Rates (g/mi)									
LDC-G-ICE	Gasoline Vehicle: CG and RFG	0.564	0.555	0.547	0.539	0.531	0.523	0.521	0.519
LDC-E-FF	EtOH FFV: E85, Corn	0.550	0.541	0.532	0.523	0.514	0.505	0.503	0.501
LDC-D-ICE	Conventional and LS Diesel	0.415	0.403	0.392	0.381	0.370	0.360	0.352	0.344
LDC-D-ICE	CIDI Vehicle: BD20	0.404	0.392	0.381	0.369	0.358	0.348	0.340	0.333
Light Duty Truck - CH4 Emission Rates (g/mi)									
LDT-G-ICE	Gasoline Vehicle: CG and RFG	0.726	0.714	0.701	0.689	0.677	0.665	0.657	0.649
LDT-E-FF	EtOH FFV: E85, Corn	0.709	0.696	0.682	0.669	0.656	0.643	0.635	0.626
LDT-D-ICE	Conventional and LS Diesel	0.535	0.519	0.503	0.489	0.474	0.460	0.445	0.431
LDT-D-ICE	CIDI Vehicle: BD20	0.521	0.505	0.489	0.473	0.459	0.444	0.430	0.417

Table H.4-7. GREET WTW GHG Emission Factors (cont'd)

		2005	2006	2007	2008	2009	2010	2011	2012
Light Duty Truck - N2O Emission Rates (g/mi)									
LDC-G-ICE	Gasoline Vehicle: CG and RFG	0.019	0.020	0.020	0.021	0.022	0.022	0.022	0.022
LDC-E-FF	EtOH FFV: E85, Corn	0.258	0.253	0.248	0.243	0.239	0.234	0.231	0.228
LDC-D-ICE	Conventional and LS Diesel	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
LDC-D-ICE	CIDI Vehicle: BD20	0.021	0.021	0.020	0.020	0.020	0.019	0.019	0.019
Light Duty Vehicle - N2O Emission Rates (g/mi)									
LDT-G-ICE	Gasoline Vehicle: CG and RFG	0.021	0.022	0.023	0.024	0.024	0.024	0.024	0.024
LDT-E-FF	EtOH FFV: E85, Corn	0.203	0.199	0.196	0.192	0.189	0.186	0.185	0.184
LDT-D-ICE	Conventional and LS Diesel	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
LDT-D-ICE	CIDI Vehicle: BD20	0.019	0.019	0.018	0.018	0.018	0.018	0.018	0.017

Table H.4-7. GREET WTW GHG Emission Factors (cont'd)

		2013	2014	2015	2016	2017	2018	2019	2020
Light Duty Vehicle - CO2 Emission Rates (g/mi)									
LDC-G-ICE	Gasoline Vehicle: CG and RFG	421.4	420.1	418.7	418.2	417.8	417.3	416.8	416.5
LDC-E-FF	EtOH FFV: E85, Corn	287.9	286.9	285.9	285.3	284.7	284.0	283.3	282.7
LDC-D-ICE	Conventional and LS Diesel	303.8	297.6	291.7	287.6	283.7	279.8	276.0	272.4
LDC-D-ICE	CIDI Vehicle: BD20	270.9	265.3	259.9	256.3	252.8	249.3	246.0	242.7
Light Duty Truck - CO2 Emission Rates (g/mi)									
LDT-G-ICE	Gasoline Vehicle: CG and RFG	523.1	516.7	510.2	508.4	506.7	505.0	503.3	501.8
LDT-E-FF	EtOH FFV: E85, Corn	357.5	352.9	348.4	346.8	345.3	343.7	342.1	340.6
LDT-D-ICE	Conventional and LS Diesel	377.2	366.0	355.4	349.7	344.1	338.6	333.3	328.2
LDT-D-ICE	CIDI Vehicle: BD20	336.3	326.3	316.7	311.6	306.6	301.7	297.0	292.4

Table H.4-7. GREET WTW GHG Emission Factors (cont'd)

		2013	2014	2015	2016	2017	2018	2019	2020
Light Duty Vehicle - CH4 Emission Rates (g/mi)									
LDC-G-ICE	Gasoline Vehicle: CG and RFG	0.517	0.515	0.513	0.513	0.513	0.513	0.513	0.512
LDC-E-FF	EtOH FFV: E85, Corn	0.499	0.497	0.495	0.494	0.494	0.493	0.492	0.491
LDC-D-ICE	Conventional and LS Diesel	0.337	0.330	0.324	0.320	0.315	0.311	0.307	0.303
LDC-D-ICE	CIDI Vehicle: BD20	0.325	0.319	0.313	0.308	0.304	0.300	0.296	0.292
Light Duty Truck - CH4 Emission Rates (g/mi)									
LDT-G-ICE	Gasoline Vehicle: CG and RFG	0.641	0.633	0.625	0.624	0.622	0.620	0.619	0.617
LDT-E-FF	EtOH FFV: E85, Corn	0.618	0.611	0.603	0.601	0.598	0.596	0.594	0.592
LDT-D-ICE	Conventional and LS Diesel	0.418	0.406	0.394	0.388	0.382	0.376	0.370	0.365
LDT-D-ICE	CIDI Vehicle: BD20	0.404	0.392	0.381	0.375	0.369	0.363	0.357	0.352
Light Duty Truck - N2O Emission Rates (g/mi)									
LDC-G-ICE	Gasoline Vehicle: CG and RFG	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
LDC-E-FF	EtOH FFV: E85, Corn	0.224	0.221	0.218	0.217	0.215	0.214	0.213	0.211
LDC-D-ICE	Conventional and LS Diesel	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
LDC-D-ICE	CIDI Vehicle: BD20	0.019	0.018	0.018	0.018	0.018	0.018	0.018	0.018
Light Duty Vehicle - N2O Emission Rates (g/mi)									
LDT-G-ICE	Gasoline Vehicle: CG and RFG	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
LDT-E-FF	EtOH FFV: E85, Corn	0.183	0.182	0.181	0.180	0.180	0.179	0.178	0.177
LDT-D-ICE	Conventional and LS Diesel	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
LDT-D-ICE	CIDI Vehicle: BD20	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017

Note: GREET Provides emission factors out to 2020. Emission factors from 2020 are used for model years 2021 - 2025.

Appendix H.5. RFS Economic Model

The RFS economic modeling captured the costs associated with increasing the usage of renewable motor fuels in Michigan. Tables H.5-1 through H.5-6 present the key economic implications to increased ethanol production, increased biodiesel production and increased renewable fuel usage in the state. These implications include capital costs to plant construction and consumer level fuel price. Note that the Energy 2020-REMI models capture the associated economy-wide benefits from these modeled costs.

Table H.5-7 and H.5-8 presents the modeled effect on the selected REMI policy variables. The data presented in Table H.5-7 represents an increase or decrease to the baseline value of that REMI variable for the model scenario where conventional gasoline and E85 have reached an energy based price equilibrium. Table H.5-8 presents the increases and decreases to the baseline REMI variable values under the scenario where E85 is more costly to the end consumer on an energy basis. Baseline values are established by REMI. Variable descriptions are included in Appendix D.

Table H.5-1. Baseline Information for Cellulosic Ethanol Production

	Estimated Cost for Reference Facility (Million $)	Proportion of Total	Cost Per Production ($/gal)
Cost of Equipment	$ 74.80	38%	$ 1.079
Cost of Installation (Labor)	$ 38.90	20%	$ 0.561
Other Capital Cost	$ 83.70	42%	$ 1.208
Total	$ 197.40	100%	$ 2.848

Reference facility is 69.3 Million gallon/yr (NREL 2002 Aden, et al). All dollars in US$ 2000.

Table H.5-2. Baseline Information for Corn Ethanol Production

Corn – typically reported capital cost: $1.40/gallon (DMP) – (Urnanchuk, 2006).
(Applying Cellulosic Ratios to $1.40 Total Capital).

	Proportion of Total	Cost Per Production ($/gal)
Cost of Equipment	38%	$ 0.530
Cost of Installation (Labor)	20%	$ 0.276
Other Capital Cost	42%	$ 0.594
Total	100%	$ 1.40

Table H.5-3. Estimated Regional Wholesale Ethanol Price

Note: 2005 Data pulled from EIA Data, 2006 Data from Chicago Exchange, 2007-2025 projected using the EIA Growth Rate on the 2006 Data Point.

Ethanol Wholesale Price	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
	184.20	289.00	292.04	295.12	298.23	301.37	304.55	307.76	311.00	314.28	317.59
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
	320.93	324.31	327.73	331.18	334.67	338.20	341.76	345.36	349.00	352.68	

Table H.5-4. Estimated Regional Motor Fuel Price

Note: 2005 Data pulled from EIA Data, 2006 Data from Chicago Exchange, 2007-2025 projected using the EIA Growth Rate on the 2006 Data Point.

Motor Gasoline	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
	231.00	301.00	304.54	308.12	311.75	315.41	319.12	322.87	326.67	330.51	334.40
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
	338.33	342.31	346.34	350.41	354.53	358.70	362.92	367.19	371.51	375.88	
Ethanol (E85)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
	210.00	293.00	296.46	299.96	303.50	307.08	310.70	314.37	318.08	321.83	325.63
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
	329.47	333.36	337.29	341.27	345.30	349.37	353.50	357.67	361.89	366.16	
Diesel Fuel	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
	234.00	235.70	210.30	206.70	200.70	195.90	199.10	197.70	199.10	196.90	199.50
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
	199.20	198.90	201.10	200.80	202.50	203.20	203.30	205.80	206.80	207.60	

Table H.5-5. Estimated Cost to the State

Affects of HB-5952/SB-1074 (Renewable Fuels State Tax Reduction).
This program is capped to $2,500,000.

CG/RFG Motor Fuel Tax	($/gal)	0.19
E85 Motor Fuel Tax	($/gal)	0.12
Petroleum Diesel Motor Fuel Tax	($/gal)	0.15
Biodiesel Motor Fuel Tax	($/gal)	0.12

		2005	2006	2007	2008	2009	2010
Annual Income Loss to Increased E85 Sales	thousand $	0.00	0.00	11.56	1925.33	0.00	0.00
Annual Income Loss to Increased Biodiesel Sales	thousand $	0.00	0.00	99.76	463.36	0.00	0.00
Cumulative Cost	thousand $	0.00	0.00	111.32	2500.00	2500.00	2500.00

Table H.5-6. Michigan Refueling Station Modifications for E85

Baseline Michigan refueling Stations	5089
Estimated Number of Pumps Per Station	6
Estimated Baseline Number of Refueling Pumps	30534
Estimated Cost to Convert Refueling Stations	$ 10,000

	2005	**2006**	**2007**	**2008**	**2009**
Estimated Number of New E85 Refueling Pumps	0	0	0	275	409
State-wide Cost to Convert E85 Refueling Stations	$0	$0	$0	$2,750,000	$4,090,000
	2010	**2011**	**2012**	**2013**	**2014**
Estimated Number of New E85 Refueling Pumps	1008	212	239	271	306
State-wide Cost to Convert E85 Refueling Stations	$10,080,000	$2,120,000	$2,390,000	$2,710,000	$3,060,000
	2015	**2016**	**2017**	**2018**	**2019**
Estimated Number of New E85 Refueling Pumps	344	386	434	485	544
State-wide Cost to Convert E85 Refueling Stations	$3,440,000	$3,860,000	$4,340,000	$4,850,000	$5,440,000
	2020	**2021**	**2022**	**2023**	**2024**
Estimated Number of New E85 Refueling Pumps	609	314	331	351	370
State-wide Cost to Convert E85 Refueling Stations	$6,090,000	$3,140,000	$3,310,000	$3,510,000	$3,700,000
	2025				
Estimated Number of New E85 Refueling Pumps	389				
State-wide Cost to Convert E85 Refueling Stations	$3,890,000				

Table H.5-7. Michigan RFS Modeled REMI Variables – CG/E85 Price Equilibrium Scenario 2000 Fixed $ Million

Variable	Sector	2005	2006	2007	2008	2009	2010	2011	2012
Exogenous Final Demand	Petroleum, Coal Prod Mfg.	0	0	-89.28	-171.867	-249.581	-334.162	-435.273	-531.677
Exogenous Final Demand	Chemical Mfg.	0	0	89.28	171.867	249.581	334.162	435.273	531.677
Intermediate Demand	Chemical Mfg.	0	0	0	0	0	0	0	0
Farm Compensation	Farm	0	0	0	0	0	0	0	0
Consumer Spending	Gasoline and Oil	0	0	0	0	0	0	0	0
Consumption Reallocation	All Consumption Sectors	0	0	0	0	0	0	0	0
Exogenous Final Demand	Construction	0	0	0	2.2	3.272	8.064	1.696	1.912
Exogenous Final Demand	Machinery Mfg.	0	0	0	0.55	0.818	2.016	0.424	0.478
Production Cost	Petroleum, Coal Prod Mfg.	0	0	0	-2.75	-4.09	-10.08	-2.12	-2.39

Table H.5-7. Michigan RFS Modeled REMI Variables – CG/E85 Price Equilibrium Scenario 2000 Fixed $ Million (cont'd)

Variable	Sector	2013	2014	2015	2016	2017	2018	2019	2020
Exogenous Final Demand	Petroleum, Coal Prod Mfg.	-627.576	-725.819	-825.433	-940.34	-1056.2	-1170.75	-1284.5	-1390.68
Exogenous Final Demand	Chemical Mfg.	627.576	725.819	825.433	940.34	1056.203	1170.75	1284.5	1390.675
Intermediate Demand	Chemical Mfg.	0	0	0	0	0	0	0	0
Farm Compensation	Farm	0	0	0	0	0	0	0	0
Consumer Spending	Gasoline and Oil	0	0	0	0	0	0	0	0
Consumption Reallocation	All Consumption Sectors	0	0	0	0	0	0	0	0
Exogenous Final Demand	Construction	2.168	2.448	2.752	3.088	3.472	3.88	4.352	4.872
Exogenous Final Demand	Machinery Mfg.	0.542	0.612	0.688	0.772	0.868	0.97	1.088	1.218
Production Cost	Petroleum, Coal Prod Mfg.	-2.71	-3.06	-3.44	-3.86	-4.34	-4.85	-5.44	-6.09

Table H.5-7. Michigan RFS Modeled REMI Variables – CG/E85 Price Equilibrium Scenario 2000 Fixed $ Million (cont'd)

Variable	Sector	2021	2022	2023	2024	2025
Exogenous Final Demand	Petroleum, Coal Prod Mfg.	-1504.71	-1613.07	-1713.25	-1818.49	-1934.59
Exogenous Final Demand	Chemical Mfg.	1504.706	1613.073	1713.245	1818.487	1934.594
Intermediate Demand	Chemical Mfg.	0	0	0	0	0
Farm Compensation	Farm	0	0	0	0	0
Consumer Spending	Gasoline and Oil	0	0	0	0	0
Consumption Reallocation	All Consumption Sectors	0	0	0	0	0
Exogenous Final Demand	Construction	2.512	2.648	2.808	2.96	3.112
Exogenous Final Demand	Machinery Mfg.	0.628	0.662	0.702	0.74	0.778
Production Cost	Petroleum, Coal Prod Mfg.	-3.14	-3.31	-3.51	-3.7	-3.89

Table H.5-8. Michigan RFS Modeled REMI Variables – E85 Price Premium Scenario 2000 Fixed $ Million

Variable	Sector	2005	2006	2007	2008	2009	2010	2011	2012
Exogenous Final Demand	Petroleum, Coal Prod Mfg.	0	0	-89.28	-171.867	-249.581	-334.162	-435.273	-531.677
Exogenous Final Demand	Chemical Mfg.	0	0	110.4273	212.2059	308.748	414.304	540.8319	661.9975
Intermediate Demand	Chemical Mfg.	0	0	0	0	0	0	0	0
Farm Compensation	Farm	0	0	0	0	0	0	0	0
Consumer Spending	Gasoline and Oil	0	0	21.14727	40.33887	59.16704	80.14198	105.5589	130.3205
Consumption Reallocation	All Consumption Sectors	0	0	-21.1473	-40.3389	-59.167	-80.142	-105.559	-130.32
Exogenous Final Demand	Construction	0	0	0	2.2	3.272	8.064	1.696	1.912
Exogenous Final Demand	Machinery Mfg.	0	0	0	0.55	0.818	2.016	0.424	0.478
Production Cost	Petroleum, Coal Prod Mfg.	0	0	0	-2.75	-4.09	-10.08	-2.12	-2.39

Table H.5-8. Michigan RFS Modeled REMI Variables – E85 Price Premium Scenario 2000 Fixed $ Million (cont'd)

Variable	Sector	2020	2013	2014	2015	2016	2017	2018	2019
Exogenous Final Demand	Petroleum, Coal Prod Mfg.	-1390.68	-627.576	-725.819	-825.433	-940.34	-1056.2	-1170.75	-1284.5
Exogenous Final Demand	Chemical Mfg.	1755.219	782.9828	907.3223	1033.791	1179.842	1327.535	1473.987	1619.821
Intermediate Demand	Chemical Mfg.	0	0	0	0	0	0	0	0
Farm Compensation	Farm	0	0	0	0	0	0	0	0
Consumer Spending	Gasoline and Oil	364.5438	155.4068	181.5033	208.3578	239.5025	271.3318	303.2373	335.3209
Consumption Reallocation	All Consumption Sectors	-364.544	-155.407	-181.503	-208.358	-239.502	-271.332	-303.237	-335.321
Exogenous Final Demand	Construction	4.872	2.168	2.448	2.752	3.088	3.472	3.88	4.352
Exogenous Final Demand	Machinery Mfg.	1.218	0.542	0.612	0.688	0.772	0.868	0.97	1.088
Production Cost	Petroleum, Coal Prod Mfg.	-6.09	-2.71	-3.06	-3.44	-3.86	-4.34	-4.85	-5.44

Table H.5-8. Michigan RFS Modeled REMI Variables – E85 Price Premium Scenario 2000 Fixed $ Million (cont'd)

Variable	Sector	2021	2022	2023	2024	2025
Exogenous Final Demand	Petroleum, Coal Prod Mfg.	-1504.71	-1613.07	-1713.25	-1818.49	-1934.59
Exogenous Final Demand	Chemical Mfg.	1900.737	2039.301	2167.683	2302.65	2449.67
Intermediate Demand	Chemical Mfg.	0	0	0	0	0
Farm Compensation	Farm	0	0	0	0	0
Consumer Spending	Gasoline and Oil	396.0309	426.2276	454.4379	484.1628	515.0757
Consumption Reallocation	All Consumption Sectors	-396.031	-426.228	-454.438	-484.163	-515.076
Exogenous Final Demand	Construction	2.512	2.648	2.808	2.96	3.112
Exogenous Final Demand	Machinery Mfg.	0.628	0.662	0.702	0.74	0.778
Production Cost	Petroleum, Coal Prod Mfg.	-3.14	-3.31	-3.51	-3.7	-3.89

Table H.5-9. Michigan RFS Modeled REMI Outputs – E85 Price Equilibrium Scenario

	2007	2008	2009	2010	2011	2012	2013	2014	2015	
Employment (Thousand)	0.2378	0.4336	0.6978	0.7256	0.9043	1.073	1.239	1.406	1.566	
Gross State Product (Billion Fixed 2000$)	0.02792	0.05344	0.08347	0.1007	0.1303	0.1579	0.1857	0.2139	0.243	
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Employment (Thousand)	1.749	1.931	2.103	2.269	2.36	2.504	2.638	2.752	2.873	2.946
Gross State Product (Billion Fixed 2000$)	0.2761	0.3096	0.3428	0.376	0.4027	0.4349	0.4655	0.4939	0.5239	0.5525

Table H.5-10. Michigan RFS Modeled REMI Outputs – E85 Price Premium Scenario

	2007	2008	2009	2010	2011	2012	2013	2014	2015	
Employment (Thousand)	0.1602	0.3477	0.4961	0.7266	0.728	0.8501	0.958	1.064	1.165	
Gross State Product (Billion Fixed 2000$)	0.03098	0.06308	0.09344	0.1326	0.1625	0.1977	0.2327	0.2685	0.3053	
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Employment (Thousand)	1.283	1.396	1.504	1.605	1.704	1.743	1.817	1.877	1.941	2.014
Gross State Product (Billion Fixed 2000$)	0.348	0.3914	0.4348	0.478	0.5192	0.5588	0.5999	0.6378	0.6784	0.7223

Appendix H.6. AVTI GHG Model

The MCCP AVTI GHG Model was developed using Microsoft Excel to calculate the net GHG benefit from promoting the adoption of additional alternative vehicle technologies within the Michigan transportation sector. Figure H.6-1 provides the calculation methodology for the AVTI model and presents the following primary steps for model execution:

- Determine the baseline in-state sales of light duty vehicles for the modeling period (2005-2025) based on an initial year's sales data and four sets of 5-year sales growth figures, presented in Table H.6-1 and Table H.6-2.
- Input the years that the policy will be in effect (2007-2012) and the increase in market share of AVT spurred by the policy.
- Calculate the number of additional AVT purchased because of the policy throughout the modeling period (2005 -2025), additional AVT purchases are distributed based on predicted market shares for individual AVT types under the baseline scenario.
- Calculate the number of displaced conventional vehicle sales as a result of purchased AVT.
- Calculate an annual VMT profile for each additional AVT purchased under the policy and the associated displaced conventional vehicle. The VMT profile was calculated based on weighted average light-duty vehicle annual VMT data provided by U.S. EPA and presented in Table H.6-3. This data allows MCCP to track the benefits from additional AVT on the road throughout the vehicle life. Table H.6-4 provides an example of a vehicle type VMT profile used in this model.
- Apply the WTW GHG emission factor (grams/VMT) to the calculated vehicle type specific-VMT profiles. WTW emission factors were derived using the GREET model. GREET model inputs are included in Table H.6-5 through Table H.6-7. Table H.6-8 presents the GREET emission factors used in this model.
- Calculate the net benefit of displacing conventional fuel at the RFS level with renewable fuel alternatives.

The remainder of this appendix provides the critical pieces of input data used in developing the MCCP AVTI GHG Model.

Figure H.6-1. Well-to-Wheel Greenhouse Gas Emissions Model of Alternative Vehicle Technology Incentive

(Model Years 2005-2025)

Baseline Michigan Light Duty Vehicle Sales – Input Block

- Initial year of vehicle sales for each vehicle type (default is 2005, unless vehicle not available)
- Initial value of vehicle sales for each vehicle type
- Four sets of 5-yr sales growth rates for each vehicle type (2005-10, 2010-15, 2015-20, 2020 – 2025)

Baseline Michigan Light Duty Vehicle Sales – Calculation Block

- 20-yr projection of annual vehicle sales by vehicle type
- 20-yr projection of annual market share of each vehicle type
- 20-yr projection of annual market share within the alternative vehicle sector

Alternative Vehicle Technology Incentive Affect

Input: Years included in the policy
Increased market share of overall alternative vehicle sales above the baseline

Modeled vehicle types sold via incentive: Flex Fuels, Hybrid Electric, Fuel Cells and Electric

Calculation: Weighted average baseline market share of adopted AVT from the policy
Annual alternative vehicles sold above the baseline by vehicle type
Annual conventional vehicle sales displaced by vehicle type

Key GREET Inputs

- EtOH, Biodiesel, Petdiesel, RFG and CG use GREET baseline assumptions for national fuel market, except as follows:
- CG/RFG Market Share Mix from Michigan Specific Estimation of RFG Usage
- Ethanol production in the national market reflects an increasing share of cellulosic ethanol

Assessment of VMT by Vehicle Type

Input: EPA Survivability Profile by Vehicle Age
EPA Age Specific VMT per year

Calculation: VMT per year profile for each alternative vehicle type sold above the baseline
VMT per year profile for each conventional vehicle type displaced

VMT Per Model Year Per Vehicle Type

GREET GHG Emission Factors

CO2, N2O and CH4 emission factors (g/mile) for each model year for each alternative vehicle type sold

CO2, N2O and CH4 emission factors (g/mile) for each model year for each conventional vehicle type displaced

Grams/Mile Per Model Year Per Vehicle Type

Net GHG Benefit Analysis

Calculation: CO2, N2O and CH4 Annual Emissions profile by Vehicle Type

Summary of CO2, N2O and CH4 Emissions from VMT of Alternative Vehicles sold above the baseline
Summary of CO2, N2O and CH4 Emissions from VMT of Conventional Vehicles displaced

Net GHG Emissions (Additional Alternative Fuel less Displaced Conventional Fuel)
Conversion to Million Metric Tons of Carbon Equivalent

Table H.6-1. AVTI GHG Model – BAU Vehicle Sales Input Block

					EIA AEO 2006 Projected National Growth Rates			
Vehicle Type	**Light Duty Vehicle**	**Year of Initial Sales**	**Initial Sales Value**	**Source**	**Average Annual Growth Rate 2005-2010**	**Average Annual Growth Rate 2010 - 2015**	**Average Annual Growth Rate 2015 - 2020**	**Average Annual Growth Rate 2020 - 2025**
LDC-CNG-BF	Compressed Natural Gas Bi-fuel	2005	443	AEO 2006/FHWA	0.09%	-0.45%	0.41%	0.88%
LDC-CNG-ICE	Compressed Natural Gas ICE	2005	8	AEO 2006/FHWA	4.56%	0.00%	1.92%	2.20%
LDC-D-HEV	Electric-Diesel Hybrid	2010	44	AEO 2006/FHWA	N/A	43.85%	-4.52%	-5.40%
LDC-D-ICE	TDI Diesel ICE	2005	1048	AEO 2006/FHWA	4.31%	3.82%	7.01%	7.64%
LDC-E-FF	Ethanol-Flex Fuel ICE	2005	14473	AEO 2006/FHWA	2.92%	-1.06%	-0.17%	0.53%
LDC-E-ICE	Ethanol ICE	2005	22	AEO 2006/FHWA	7.78%	5.08%	4.05%	2.37%
LDC-EV	Electric Vehicle	2005	86	AEO 2006/FHWA	0.23%	-0.46%	0.23%	0.85%
LDC-G-FC	Fuel Cell Gasoline	--	--	AEO 2006/FHWA	N/A	N/A	N/A	N/A
LDC-G-HEV	Electric-Gasoline Hybrid	2005	4180	AEO 2006/FHWA	20.18%	6.52%	5.57%	4.83%
LDC-G-ICE	Gasoline ICE Vehicles	2005	269931	AEO 2006/FHWA	-0.53%	-0.82%	0.02%	0.50%
LDC-H-FC	Fuel Cell Hydrogen	2013	29	AEO 2006/FHWA	N/A	0.00%	15.67%	0.33%
LDC-LPG-BF	Liquefied Petroleum Gas Bi-fuel	2005	1642	AEO 2006/FHWA	0.12%	-0.48%	0.36%	0.88%
LDC-LPG-ICE	Liquefied Petroleum Gas ICE	--	--	AEO 2006/FHWA	N/A	N/A	N/A	N/A
LDC-M-FC	Fuel Cell Methanol	--	--	AEO 2006/FHWA	N/A	N/A	N/A	N/A
LDC-M-FF	Methanol-Flex Fuel ICE	--	--	AEO 2006/FHWA	N/A	N/A	N/A	N/A
LDC-M-ICE	Methanol ICE	--	--	AEO 2006/FHWA	N/A	N/A	N/A	N/A

Table H.6-1. AVTI GHG Model – BAU Vehicle Sales Input Block (cont'd)

					EIA AEO 2006 Projected National Growth Rates			
Vehicle Type	**Light Duty Vehicle**	**Year of Initial Sales**	**Initial Sales Value**	**Source**	**Average Annual Growth Rate 2005-2010**	**Average Annual Growth Rate 2010 - 2015**	**Average Annual Growth Rate 2015 - 2020**	**Average Annual Growth Rate 2020 - 2025**
LDT-CNG-BF	Compressed Natural Gas Bi-fuel	2005	1127	AEO 2006/FHWA	1.43%	1.35%	1.53%	2.01%
LDT-CNG-ICE	Compressed Natural Gas ICE	2005	3	AEO 2006/FHWA	5.92%	8.45%	8.45%	2.67%
LDT-D-HEV	Electric-Diesel Hybrid	2015	14	AEO 2006/FHWA	N/A	N/A	49.63%	-3.05%
LDT-D-ICE	TDI Diesel ICE	2005	12226	AEO 2006/FHWA	7.72%	4.72%	7.21%	6.92%
LDT-E-FF	Ethanol-Flex Fuel ICE	2005	16051	AEO 2006/FHWA	10.95%	0.56%	0.70%	1.25%
LDT-E-ICE	Ethanol ICE	--	--	AEO 2006/FHWA	N/A	N/A	N/A	N/A
LDT-EV	Electric Vehicle	2005	120	AEO 2006/FHWA	1.46%	1.36%	1.55%	2.07%
LDT-G-FC	Fuel Cell Gasoline	--	--	AEO 2006/FHWA	N/A	N/A	N/A	N/A
LDT-G-HEV	Electric-Gasoline Hybrid	2005	2638	AEO 2006/FHWA	27.88%	11.04%	6.70%	5.96%
LDT-G-ICE	Gasoline ICE Vehicles	2005	252931	AEO 2006/FHWA	-0.14%	0.74%	0.71%	1.08%
LDT-H-FC	Fuel Cell Hydrogen	2009	16	AEO 2006/FHWA	N/A	13.49%	18.89%	7.46%
LDT-LPG-BF	Liquefied Petroleum Gas Bi-fuel	2005	3726	AEO 2006/FHWA	1.45%	1.34%	1.53%	2.02%
LDT-LPG-ICE	Liquefied Petroleum Gas ICE	2005	24	AEO 2006/FHWA	23.16%	8.23%	13.23%	-3.11%
LDT-M-FC	Fuel Cell Methanol	--	--	AEO 2006/FHWA	N/A	N/A	N/A	N/A
LDT-M-FF	Methanol-Flex Fuel ICE	--	--	AEO 2006/FHWA	N/A	N/A	N/A	N/A
LDT-M-ICE	Methanol ICE	--	--	AEO 2006/FHWA	N/A	N/A	N/A	N/A

Table H.6-2. Michigan Business as Usual Vehicle Sales Profile

Vehicle Type	New Vehicle Sales	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LDC-CNG-BF	Compressed Natural Gas Bi-fuel	443	443	444	444	445	443	441	439	437	435
LDC-CNG-ICE	Compressed Natural Gas ICE	8	8	9	9	10	10	10	10	10	10
LDC-D-HEV	Electric-Diesel Hybrid	0	0	0	0	0	44	63	91	131	188
LDC-D-ICE	TDI Diesel ICE	1,048	1,093	1,140	1,189	1,241	1,288	1,337	1,388	1,441	1,497
LDC-E-FF	Ethanol-Flex Fuel ICE	14,473	14,895	15,330	15,778	16,238	16,066	15,897	15,728	15,562	15,398
LDC-E-ICE	Ethanol ICE	22	24	26	28	30	31	33	34	36	38
LDC-EV	Electric Vehicle	86	86	86	87	87	86	86	86	85	85
LDC-G-FC	Fuel Cell Gasoline	0	0	0	0	0	0	0	0	0	0
LDC-G-HEV	Electric-Gasoline Hybrid	4,180	5,024	6,038	7,256	8,721	9,289	9,894	10,539	11,226	11,958
LDC-G-ICE	Gasoline ICE Vehicles	269,931	268,493	267,062	265,639	264,223	262,068	259,931	257,811	255,708	253,623
LDC-H-FC	Fuel Cell Hydrogen	0	0	0	0	0	0	0	0	29	29
LDC-LPG-BF	Liquefied Petroleum Gas Bi-fuel	1,642	1,644	1,646	1,648	1,650	1,642	1,634	1,627	1,619	1,611
LDC-LPG-ICE	Liquefied Petroleum Gas ICE	0	0	0	0	0	0	0	0	0	0
LDC-M-FC	Fuel Cell Methanol	0	0	0	0	0	0	0	0	0	0
LDC-M-FF	Methanol-Flex Fuel ICE	0	0	0	0	0	0	0	0	0	0
LDC-M-ICE	Methanol ICE	0	0	0	0	0	0	0	0	0	0

Table H.6-2. Michigan Business as Usual Vehicle Sales Profile (cont'd)

Vehicle Type	New Vehicle Sales	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LDT-CNG-BF	Compressed Natural Gas Bi-fuel	1,127	1,143	1,159	1,176	1,193	1,209	1,225	1,242	1,259	1,276
LDT-CNG-ICE	Compressed Natural Gas ICE	3	3	3	4	4	4	4	5	5	6
LDT-D-HEV	Electric-Diesel Hybrid	0	0	0	0	0	0	0	0	0	0
LDT-D-ICE	TDI Diesel ICE	12,226	13,170	14,186	15,282	16,461	17,238	18,051	18,902	19,793	20,727
LDT-E-FF	Ethanol-Flex Fuel ICE	16,051	17,809	19,760	21,924	24,326	24,463	24,600	24,739	24,878	25,019
LDT-E-ICE	Ethanol ICE	0	0	0	0	0	0	0	0	0	0
LDT-EV	Electric Vehicle	120	122	124	125	127	129	131	132	134	136
LDT-G-FC	Fuel Cell Gasoline	0	0	0	0	0	0	0	0	0	0
LDT-G-HEV	Electric-Gasoline Hybrid	2,638	3,373	4,314	5,516	7,054	7,833	8,698	9,659	10,725	11,910
LDT-G-ICE	Gasoline ICE Vehicles	252,931	252,577	252,223	251,869	251,516	253,374	255,246	257,131	259,030	260,944
LDT-H-FC	Fuel Cell Hydrogen	0	0	0	0	16	18	21	23	27	30
LDT-LPG-BF	Liquefied Petroleum Gas Bi-fuel	3,726	3,780	3,835	3,890	3,947	4,000	4,053	4,108	4,163	4,219
LDT-LPG-ICE	Liquefied Petroleum Gas ICE	24	30	36	45	55	60	65	70	76	82
LDT-M-FC	Fuel Cell Methanol	0	0	0	0	0	0	0	0	0	0
LDT-M-FF	Methanol-Flex Fuel ICE	0	0	0	0	0	0	0	0	0	0
LDT-M-ICE	Methanol ICE	0	0	0	0	0	0	0	0	0	0

Table H.6-2. Michigan Business as Usual Vehicle Sales Profile (cont'd)

Vehicle Type	New Vehicle Sales	2015	2016	2017	2018	2019	2020
LDC-CNG-BF	Compressed Natural Gas Bi-fuel	436	438	440	442	444	448
LDC-CNG-ICE	Compressed Natural Gas ICE	10	10	10	10	11	11
LDC-D-HEV	Electric-Diesel Hybrid	180	172	164	157	149	141
LDC-D-ICE	TDI Diesel ICE	1,601	1,714	1,834	1,962	2,100	2,260
LDC-E-FF	Ethanol-Flex Fuel ICE	15,371	15,345	15,318	15,292	15,265	15,346
LDC-E-ICE	Ethanol ICE	40	41	43	45	46	47
LDC-EV	Electric Vehicle	85	85	85	86	86	87
LDC-G-FC	Fuel Cell Gasoline	0	0	0	0	0	0
LDC-G-HEV	Electric-Gasoline Hybrid	12,624	13,327	14,070	14,853	15,681	16,439
LDC-G-ICE	Gasoline ICE Vehicles	253,661	253,699	253,738	253,776	253,815	255,096
LDC-H-FC	Fuel Cell Hydrogen	34	39	45	52	60	60
LDC-LPG-BF	Liquefied Petroleum Gas Bi-fuel	1,617	1,623	1,628	1,634	1,640	1,654
LDC-LPG-ICE	Liquefied Petroleum Gas ICE	0	0	0	0	0	0
LDC-M-FC	Fuel Cell Methanol	0	0	0	0	0	0
LDC-M-FF	Methanol-Flex Fuel ICE	0	0	0	0	0	0
LDC-M-ICE	Methanol ICE	0	0	0	0	0	0

Table H.6-2. Michigan Business as Usual Vehicle Sales Profile (cont'd)

Vehicle Type	New Vehicle Sales	2015	2016	2017	2018	2019	2020
LDT-CNG-BF	Compressed Natural Gas Bi-fuel	1,295	1,315	1,335	1,356	1,376	1,404
LDT-CNG-ICE	Compressed Natural Gas ICE	6	7	7	8	8	9
LDT-D-HEV	Electric-Diesel Hybrid	14	21	31	47	70	68
LDT-D-ICE	TDI Diesel ICE	22,221	23,823	25,540	27,381	29,355	31,385
LDT-E-FF	Ethanol-Flex Fuel ICE	25,194	25,370	25,547	25,726	25,905	26,229
LDT-E-ICE	Ethanol ICE	0	0	0	0	0	0
LDT-EV	Electric Vehicle	138	140	142	145	147	150
LDT-G-FC	Fuel Cell Gasoline	0	0	0	0	0	0
LDT-G-HEV	Electric-Gasoline Hybrid	12,709	13,561	14,470	15,440	16,475	17,457
LDT-G-ICE	Gasoline ICE Vehicles	262,791	264,651	266,525	268,412	270,312	273,244
LDT-H-FC	Fuel Cell Hydrogen	36	43	51	60	72	77
LDT-LPG-BF	Liquefied Petroleum Gas Bi-fuel	4,283	4,349	4,416	4,483	4,552	4,644
LDT-LPG-ICE	Liquefied Petroleum Gas ICE	93	105	119	135	153	148
LDT-M-FC	Fuel Cell Methanol	0	0	0	0	0	0
LDT-M-FF	Methanol-Flex Fuel ICE	0	0	0	0	0	0
LDT-M-ICE	Methanol ICE	0	0	0	0	0	0

Table H.6-2. Michigan Business as Usual Vehicle Sales Profile (cont'd)

Vehicle Type	New Vehicle Sales	2021	2022	2023	2024	2025
LDC-CNG-BF	Compressed Natural Gas Bi-fuel	451	455	459	464	468
LDC-CNG-ICE	Compressed Natural Gas ICE	11	11	11	12	12
LDC-D-HEV	Electric-Diesel Hybrid	134	127	120	113	107
LDC-D-ICE	TDI Diesel ICE	2,433	2,618	2,818	3,034	3,265
LDC-E-FF	Ethanol-Flex Fuel ICE	15,426	15,507	15,589	15,671	15,753
LDC-E-ICE	Ethanol ICE	49	50	51	52	53
LDC-EV	Electric Vehicle	87	88	89	90	90
LDC-G-FC	Fuel Cell Gasoline	0	0	0	0	0
LDC-G-HEV	Electric-Gasoline Hybrid	17,233	18,065	18,938	19,853	20,813
LDC-G-ICE	Gasoline ICE Vehicles	256,384	257,678	258,979	260,286	261,600
LDC-H-FC	Fuel Cell Hydrogen	60	61	61	61	61
LDC-LPG-BF	Liquefied Petroleum Gas Bi-fuel	1,669	1,684	1,699	1,713	1,729
LDC-LPG-ICE	Liquefied Petroleum Gas ICE	0	0	0	0	0
LDC-M-FC	Fuel Cell Methanol	0	0	0	0	0
LDC-M-FF	Methanol-Flex Fuel ICE	0	0	0	0	0
LDC-M-ICE	Methanol ICE	0	0	0	0	0

Table H.6-2. Michigan Business as Usual Vehicle Sales Profile (cont'd)

Vehicle Type	New Vehicle Sales	2021	2022	2023	2024	2025
LDT-CNG-BF	Compressed Natural Gas Bi-fuel	1,432	1,461	1,491	1,521	1,551
LDT-CNG-ICE	Compressed Natural Gas ICE	9	9	9	10	10
LDT-D-HEV	Electric-Diesel Hybrid	66	64	62	60	58
LDT-D-ICE	TDI Diesel ICE	33,556	35,877	38,358	41,011	43,848
LDT-E-FF	Ethanol-Flex Fuel ICE	26,557	26,888	27,224	27,564	27,909
LDT-E-ICE	Ethanol ICE	0	0	0	0	0
LDT-EV	Electric Vehicle	153	156	159	163	166
LDT-G-FC	Fuel Cell Gasoline	0	0	0	0	0
LDT-G-HEV	Electric-Gasoline Hybrid	18,497	19,599	20,767	22,004	23,315
LDT-G-ICE	Gasoline ICE Vehicles	276,209	279,205	282,234	285,296	288,391
LDT-H-FC	Fuel Cell Hydrogen	83	89	95	102	110
LDT-LPG-BF	Liquefied Petroleum Gas Bi-fuel	4,738	4,834	4,932	5,031	5,133
LDT-LPG-ICE	Liquefied Petroleum Gas ICE	143	139	135	130	126
LDT-M-FC	Fuel Cell Methanol	0	0	0	0	0
LDT-M-FF	Methanol-Flex Fuel ICE	0	0	0	0	0
LDT-M-ICE	Methanol ICE	0	0	0	0	0

Table H.6-3. NWTSA Vehicle Survivability and Mileage Data

Vehicle Age	LDV Avg VMT per Year	Vehicle Survivability	Weighted LDV Avg VMT per Year
0	14,910	1.000	14,910
1	14,174	0.995	14,103
2	13,475	0.988	13,313
3	12,810	0.978	12,528
4	12,178	0.962	11,715
5	11,577	0.938	10,859
6	11,006	0.908	9,993
7	10,463	0.87	9,103
8	9,947	0.825	8,206
9	9,456	0.775	7,328
10	8,989	0.721	6,481
11	8,546	0.644	5,504
12	8,124	0.541	4,395
13	7,723	0.445	3,437
14	7,342	0.358	2,628
15	6,980	0.285	1,989
16	6,636	0.223	1,480
17	6,308	0.174	1,098
18	5,997	0.134	804
19	5,701	0.103	587
20	5,420	0.079	428

Table H.6-4. Example Vehicle Specific Annual VMT Profile: LDC-G-HEV

Vehicle Age	LDV Avg VMT per Year	Vehicle Survivability	Weighted LDV Avg VMT per Year	2005	2006	2007	2008	2009
0	14,910	1.000	14,910	0	0	1,625,190	1,535,730	1,446,270
1	14,174	0.995	14,103		0	0	1,537,241	1,452,622
2	13,475	0.988	13,313			0	0	1,451,150
3	12,810	0.978	12,528				0	0
4	12,178	0.962	11,715					0
5	11,577	0.938	10,859					
6	11,006	0.908	9,993					
7	10,463	0.870	9,103					
8	9,947	0.825	8,206					
9	9,456	0.775	7,328					
10	8,989	0.721	6,481					
11	8,546	0.644	5,504					
12	8,124	0.541	4,395					
13	7,723	0.445	3,437					
14	7,342	0.358	2,628					
15	6,980	0.285	1,989					
16	6,636	0.223	1,480					
17	6,308	0.174	1,098					
18	5,997	0.134	804					
19	5,701	0.103	587					
20	5,420	0.079	428					
			Total Model Year VMT (million)	0.00	0.00	1.63	3.07	4.35

Table H.6-4. Example Vehicle Specific Annual VMT Profile: LDC-G-HEV (cont'd)

Vehicle Age	LDV Avg VMT per Year	Vehicle Survivability	Weighted LDV Avg VMT per Year	2010	2011	2012	2013	2014
0	14,910	1.000	14,910	1,416,450	1,386,630	0	0	0
1	14,174	0.995	14,103	1,368,004	1,339,797	1,311,591	0	0
2	13,475	0.988	13,313	1,371,270	1,291,390	1,264,764	1,238,137	0
3	12,810	0.978	12,528	1,365,572	1,290,403	1,215,233	1,190,177	1,165,121
4	12,178	0.962	11,715	0	1,276,961	1,206,669	1,136,378	1,112,947
5	11,577	0.938	10,859	0	0	1,183,656	1,118,500	1,053,345
6	11,006	0.908	9,993		0	0	1,089,286	1,029,325
7	10,463	0.870	9,103			0	0	992,206
8	9,947	0.825	8,206				0	0
9	9,456	0.775	7,328					0
10	8,989	0.721	6,481					
11	8,546	0.644	5,504					
12	8,124	0.541	4,395					
13	7,723	0.445	3,437					
14	7,342	0.358	2,628					
15	6,980	0.285	1,989					
16	6,636	0.223	1,480					
17	6,308	0.174	1,098					
18	5,997	0.134	804					
19	5,701	0.103	587					
20	5,420	0.079	428					
			Total Model Year VMT (million)	5.52	6.59	6.18	5.77	5.35

Table H.6-4. Example Vehicle Specific Annual VMT Profile: LDC-G-HEV (cont'd)

Vehicle Age	LDV Avg VMT per Year	Vehicle Survivability	Weighted LDV Avg VMT per Year	2015	2016	2017	2018	2019	2020
0	14,910	1.000	14,910	0	0	0	0	0	0
1	14,174	0.995	14,103	0	0	0	0	0	0
2	13,475	0.988	13,313	0	0	0	0	0	0
3	12,810	0.978	12,528	0	0	0	0	0	0
4	12,178	0.962	11,715	1,089,517	0	0	0	0	0
5	11,577	0.938	10,859	1,031,626	1,009,908	0	0	0	0
6	11,006	0.908	9,993	969,364	949,378	929,391	0	0	0
7	10,463	0.870	9,103	937,589	882,973	864,767	846,561	0	0
8	9,947	0.825	8,206	894,484	845,246	796,009	779,596	763,184	0
9	9,456	0.775	7,328	0	798,796	754,825	710,855	696,198	681,541
10	8,989	0.721	6,481	0	0	706,437	667,550	628,664	615,702
11	8,546	0.644	5,504		0	0	599,895	566,873	533,852
12	8,124	0.541	4,395			0	0	479,064	452,694
13	7,723	0.445	3,437				0	0	374,604
14	7,342	0.358	2,628					0	0
15	6,980	0.285	1,989						0
16	6,636	0.223	1,480						
17	6,308	0.174	1,098						
18	5,997	0.134	804						
19	5,701	0.103	587						
20	5,420	0.079	428						
			Total Model Year VMT (million)	4.92	4.49	4.05	3.60	3.13	2.66

Table H.6-4. Example Vehicle Specific Annual VMT Profile: LDC-G-HEV (cont'd)

Vehicle Age	LDV Avg VMT per Year	Vehicle Survivability	Weighted LDV Avg VMT per Year	2021	2022	2023	2024	2025
0	14,910	1.000	14,910	0	0	0	0	0
1	14,174	0.995	14,103	0	0	0	0	0
2	13,475	0.988	13,313	0	0	0	0	0
3	12,810	0.978	12,528	0	0	0	0	0
4	12,178	0.962	11,715	0	0	0	0	0
5	11,577	0.938	10,859	0	0	0	0	0
6	11,006	0.908	9,993	0	0	0	0	0
7	10,463	0.870	9,103	0	0	0	0	0
8	9,947	0.825	8,206	0	0	0	0	0
9	9,456	0.775	7,328	0	0	0	0	0
10	8,989	0.721	6,481	602,739	0	0	0	0
11	8,546	0.644	5,504	522,844	511,837	0	0	0
12	8,124	0.541	4,395	426,323	417,533	408,743	0	0
13	7,723	0.445	3,437	353,984	333,363	326,490	319,616	0
14	7,342	0.358	2,628	286,500	270,729	254,958	249,701	244,445
15	6,980	0.285	1,989	0	216,834	204,898	192,962	188,984
16	6,636	0.223	1,480	0	0	161,301	152,422	143,543
17	6,308	0.174	1,098		0	0	119,638	113,052
18	5,997	0.134	804			0	0	87,592
19	5,701	0.103	587				0	0
20	5,420	0.079	428					0
			Total Model Year VMT (million)	2.19	1.75	1.36	1.03	0.78

Table H.6-5. GREET Input File - AVTI GHG Model

Federal Reformulated Gasoline	
Vehicle Technology	
Spark Ignition Engine	
Grid Independent Hybrid Electric Vehicle engine	
Fuel-Cell Vehicle	
Pathway Options	
FRFG O2 Content (%):	2.3
FRFG Sulfur Level (ppm):	25.5
Conventional Gasoline Oxygenate:	Ethanol
FRFG Ethanol Feedstock: Corn (%):	100
FRFG Ethanol Feedstock: Woody Biomass (%):	0
FRFG Ethanol Feedstock: Herbaceous Biomass (%):	0
Conventional Gasoline	
Vehicle Technology	
Spark Ignition Engine	
Grid Independent Hybrid Electric Vehicle engine	
Pathway Options	
Conventional Gasoline O2 Content (%):	0
Conventional Gasoline Sulfur Level (ppm):	25.5
Conventional Gasoline Oxygenate:	No Oxygenate
Low Sulfur Diesel	
Vehicle Technology	
Compression-Ignition, Direct Injection	
Grid Independent Hybrid Electric Vehicle Compression Ignition, Direct Injection Engine	
Fuel-Cell Vehicle	
Pathway Options	
Low-Sulfur Diesel: Sulfur Level (ppm):	11
Low-Sulfur Diesel Location for Use:	United States
Conventional Diesel	
Vehicle Technology	
Compression-Ignition, Direct Injection	
Grid Independent Compression-Ignition, Direct Injection	
Pathway Options	
Conventional Diesel: Sulfur Level (ppm):	200
Conventional Diesel Location for Use:	United States
Ethanol	
Vehicle Technology	
Flexible-Fuel Vehicle Spark Ignition Engine	
Pathway Options	
Corn Ethanol, Share of Ethanol Plant Type, Dry Milling Plant (%):	70
Corn Ethanol, Share of Ethanol Plant Type, Wet Milling Plant (%):	30
Share of Process Fuels in Dry Mill Ethanol Plant: Natural Gas (%):	80
Share of Process Fuels in Dry Mill Ethanol Plant: Coal (%):	20
Share of Process Fuels in Dry Mill Ethanol Plant: Natural Gas (%):	60
WMP Share of Process Fuels in Dry Mill Ethanol Plant: Coal (%):	40
Ethanol Co-Production Credit Calculation Method:	Displacement

Table H.6-5. GREET Input File - AVTI GHG Model (cont'd)

Electricity	
Vehicle Technology	
Electric Vehicle	
Pathway Options	
NG turbine combined cycle share of total NG power plant capacity (%):	44
Simple-cycle NG turbine share of total NG power plant capacity (%):	36
Advanced coal technology share of total coal power plant capacity (%):	0
Advanced biomass technology share of total biomass power plant capacity (%):	0
LWR Plant Technology Shares for Electricity Production: Gas Diffusion (%):	25
LWR Plant Technology Shares for Electricity Production: Centrifuge (%):	75
HTGR Plant Technology Shares for Electricity Production: Gas Diffusion (%):	25
HTGR Plant Technology Shares for Electricity Production: Centrifuge (%):	75
Woody Biomass Plant Technology Shares for Electricity Production (%):	100
Herbaceous Biomass Plant Technology Shares for Electricity Production (%):	0
Type of Electricity Displaced by Cogeneration of Electricity in NG-Based Fuel Production Plants:	Natural Gas Combined Cycle
Type of Electricity Displaced by Electricity cogenerated in Biomass-Based Fuel Production Plants	Average Electricity Generation Mix
Type of Electricity Displaced by Cogeneration of Electricity in Biomass-Based Fuel Production Plants:	Average Electricity Generation Mix

Liquid Hydrogen: Station	
Vehicle Technology	
Fuel-Cell Vehicle	
Pathway Options	
NG Based Feedstock Source for Liquid H2: Station:	North America Natural Gas

Marginal Generation Mix	
Residual Oil (%):	2.7
Natural Gas (%):	18.9
Coal (%):	50.7
Nuclear Power (%):	18.7
Biomass Electricity (%):	1.3
Others (%):	7.7

Average Generation Mix	
Residual Oil (%):	2.7
Natural Gas (%):	18.9
Coal (%):	50.7
Nuclear Power (%):	18.7
Biomass Electricity (%):	1.3
Others (%):	7.7

Table H.6-5. GREET Input File - AVTI GHG Model (cont'd)

Petroleum	
Items	**Assumptions**
Crude Recovery Efficiency	98.0%
CG Refining Efficiency	86.0%
RFG Refining Efficiency	85.5%
CD Refining Efficiency	89.0%
LSD Refining Efficiency	87.00%

Ethanol	
Items	**Assumptions**
CO2 Emissions from Landuse Change by Corn Farming (g/bushel)	195
Corn Farming Energy Use (Btu/bushel)	22,500
Ethanol Production Energy Use:Dry Mill (Btu/gallon)	36,000
Ethanol Production Energy Use:Wet Mill (Btu/gallon)	45,950
CO2 Emissions Due to Land Use Change by HBiomass Farming (g/dry ton)	-48,500
Herbaceous Biomass Farming Energy Use (Btu/dry ton)	217,230
EtOH Yield from Herbaceous Biomass Fermentation Plant (gallons/dry ton)	95
Electricity Co-Product in Herbaceous Biomass Fermentation Plant (kWh/gallon)	-0.572

Electricity	
Items	**Assumptions**
Residual Oil Utility Boiler Efficiency	34.8%
NG Utility Boiler Efficiency	34.8%
NG Simple Cycle Turbine Efficiency	33.1%
NG Combined Cycle Turbine Efficiency	53.0%
Coal Utility Boiler Efficiency	34.1%
Electricity Transmission and Distribution Loss	8.0%
Energy intensity in HTGR reactors (MWh/g of U-235)	8.704
Energy intensity in LWR reactors (MWh/g of U-235)	6.926
Electricity Use of Uranium Enrichment (kWh/SWU): Gaseous Diffusion Plants for LWR electricity generation	2,400
Electricity Use of Uranium Enrichment (kWh/SWU): Centrifuge Plants for LWR electricity generation	50.0
Electricity Use of Uranium Enrichment (kWh/SWU): Gaseous Diffusion Plants for HTGR electricity generation	2,400
Electricity Use of Uranium Enrichment (kWh/SWU): Centrifuge Plants for HTGR electricity generation	50

Liquid Hydrogen	
Items	**Assumptions**
Refueling Station Production Efficiency: NA NG as feedstock	70.00%
Liquefaction Efficiency: NA NG as feedstock, Refueling Stations	68.00%

Table H.6-6. GREET Input File for LDC Vehicles - AVTI GHG Model

Baseline Vehicles (Model Year 2005)

Items	SI Vehicle: CG and RFG	CIDI Vehicle: CD and LSD
Gasoline Equivalent MPG	24.8	33.73
Exhuast VOC	0.122	0.088
Evaporative VOC	0.058	0
CO	3.745	0.539
NOx	0.141	0.141
Exhuast PM10	0.0081	0.009
Brake and Tire Wear PM10	0.0205	0.0205
CH4	0.0146	0.0026
N2O	0.012	0.012

MPG and Emission Ratios: AFV/GV (Model Year 2005)

Items	CIDI Vehicle: CD and LSD	SI Vehicle: EtOH FFV	GI HEV: CG and RFG	GI HEV: CD and LSD	Electric Vehicle	Hydrogen Fuel-Cell Vehicle	Gasoline Fuel-Cell Vehicle	Diesel Fuel-Cell Vehicle
Gasoline Equivalent MPG	1.360	1.050	1.520	1.740	3.500	2.320	1.480	1.480
Exhuast VOC		100.0%	54.0%	78.0%	0.0%	0.0%	20.0%	20.0%
Evaporative VOC		85.0%	100.0%	0.0%	0.0%	0.0%	70.0%	0.0%
CO		100.0%	100.0%	100.0%	0.0%	0.0%	20.0%	20.0%
NOx		100.0%	84.0%	87.0%	0.0%	0.0%	20.0%	20.0%
Exhuast PM10		100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
Brake and Tire Wear PM10		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
CH4		100.0%	47.0%	100.0%	0.0%	0.0%	20.0%	20.0%
N2O		100.00%	100.00%	100.00%	0.00%	0.00%	20.00%	20.00%

Table H.6-7. GREET Input File for LDT Vehicles - AVTI GHG Model

Baseline Vehicles (Model Year 2005)		
Items	SI Vehicle: CG and RFG	CIDI Vehicle: CD and LSD
Gasoline Equivalent MPG	19.4	26.38
Exhuast VOC	0.144	0.13
Evaporative VOC	0.069	0
CO	3.916	0.412
NOx	0.229	0.291
Exhuast PM10	0.012	0.014
Brake and Tire Wear PM10	0.021	0.021
CH4	0.016	0.003
N2O	0.012	0.012

MPG and Emission Ratios: AFV/GV (Model Year 2005)								
Items	CIDI Vehicle: CD and LSD	SI Vehicle: EtOH FFV	GI HEV: CG and RFG	GI HEV: CD and LSD	Electric Vehicle	Hydrogen Fuel-Cell Vehicle	Gasoline Fuel-Cell Vehicle	Diesel Fuel-Cell Vehicle
Gasoline Equivalent MPG	1.360	1.050	1.520	1.740	3.500	2.320	1.480	1.480
Exhuast VOC		100.0%	54.0%	78.0%	0.0%	0.0%	20.0%	20.0%
Evaporative VOC		85.0%	100.0%	0.0%	0.0%	0.0%	70.0%	0.0%
CO		100.0%	100.0%	100.0%	0.0%	0.0%	20.0%	20.0%
NOx		100.0%	84.0%	87.0%	0.0%	0.0%	20.0%	20.0%
Exhuast PM10		100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%
Brake and Tire Wear PM10		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
CH4		100.0%	47.0%	100.0%	0.0%	0.0%	20.0%	20.0%
N2O		100.00%	100.00%	100.00%	0.00%	0.00%	20.00%	20.00%

Table H.6-8. GREET WTW GHG Emission Factors

Light Duty Car - CO2 Emission Rates (g/mi)		2005	2006	2007	2008	2009	2010	2011	2012
LDC-D-HEV	Grid-Independent CIDI HEV: Conventional and LS Diesel	460.1	398.1	349.7	311.3	279.9	253.9	252.9	251.9
LDC-D-ICE	CIDI Vehicle: Conventional and LS Diesel	371.1	361.5	351.9	342.6	333.6	324.8	317.4	310.4
LDC-E-FF	EtOH FFV: E85, Corn	318.5	313.4	308.2	299.7	292.3	280.3	258.1	241.3
LDC-EV	Electric Vehicle	366.3	349.0	332.5	317.3	303.1	289.8	288.0	286.3
LDC-G-HEV	Grid-Independent SI HEV: CG and RFG	467.7	416.9	374.0	338.4	308.1	282.0	280.4	278.8
LDC-G-ICE	Gasoline Vehicle: CG and RFG	467.7	460.2	451.8	443.9	436.2	428.7	426.1	423.8
LDC-H-FC	FCV: L.H2	1,024.2	794.1	643.2	537.2	458.7	398.3	394.1	390.0
		2013	2014	2015	2016	2017	2018	2019	2020
LDC-D-HEV	Grid-Independent CIDI HEV: Conventional and LS Diesel	251.1	250.4	249.8	244.2	238.9	233.8	228.9	224.1
LDC-D-ICE	CIDI Vehicle: Conventional and LS Diesel	303.8	297.6	291.7	287.6	283.7	279.8	276.0	272.4
LDC-E-FF	EtOH FFV: E85, Corn	223.2	212.5	196.5	183.1	172.0	162.5	154.4	147.7
LDC-EV	Electric Vehicle	284.7	283.3	281.8	280.9	279.9	278.9	277.9	276.9
LDC-G-HEV	Grid-Independent SI HEV: CG and RFG	277.6	276.8	276.0	270.4	264.9	259.6	254.6	249.7
LDC-G-ICE	Gasoline Vehicle: CG and RFG	421.9	420.7	419.5	419.0	418.6	418.0	417.5	417.1
LDC-H-FC	FCV: L.H2	386.1	382.5	379.0	370.5	362.3	354.3	346.5	339.0

Table H.6-8. GREET WTW GHG Emission Factors (cont'd)

Light Duty Car - CH4 Emission Rates (g/mi)		2005	2006	2007	2008	2009	2010	2011	2012
LDC-D-HEV	Grid-Independent CIDI HEV: Conventional and LS Diesel	0.514	0.444	0.390	0.346	0.311	0.282	0.281	0.280
LDC-D-ICE	CIDI Vehicle: Conventional and LS Diesel	0.415	0.403	0.392	0.381	0.370	0.360	0.352	0.344
LDC-E-FF	EtOH FFV: E85, Corn	0.550	0.542	0.533	0.518	0.504	0.483	0.442	0.411
LDC-EV	Electric Vehicle	0.480	0.459	0.440	0.422	0.405	0.389	0.390	0.390
LDC-G-HEV	Grid-Independent SI HEV: CG and RFG	0.562	0.500	0.450	0.408	0.371	0.340	0.339	0.339
LDC-G-ICE	Gasoline Vehicle: CG and RFG	0.562	0.553	0.545	0.537	0.529	0.521	0.520	0.518
LDC-H-FC	FCV: L.H2	2.429	1.890	1.537	1.289	1.104	0.963	0.957	0.951
		2013	2014	2015	2016	2017	2018	2019	2020
LDC-D-HEV	Grid-Independent CIDI HEV: Conventional and LS Diesel	0.279	0.278	0.278	0.272	0.266	0.260	0.255	0.250
LDC-D-ICE	CIDI Vehicle: Conventional and LS Diesel	0.337	0.330	0.324	0.320	0.315	0.311	0.307	0.303
LDC-E-FF	EtOH FFV: E85, Corn	0.378	0.358	0.328	0.303	0.282	0.264	0.249	0.237
LDC-EV	Electric Vehicle	0.390	0.391	0.392	0.391	0.391	0.390	0.389	0.389
LDC-G-HEV	Grid-Independent SI HEV: CG and RFG	0.338	0.337	0.335	0.329	0.323	0.317	0.311	0.305
LDC-G-ICE	Gasoline Vehicle: CG and RFG	0.517	0.515	0.513	0.513	0.513	0.512	0.512	0.512
LDC-H-FC	FCV: L.H2	0.946	0.941	0.936	0.918	0.899	0.882	0.865	0.848

Table H.6-8. GREET WTW GHG Emission Factors (cont'd)

Light Duty Car - N2O Emission Rates (g/mi)		**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
LDC-D-HEV	Grid-Independent CIDI HEV: Conventional and LS Diesel	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
LDC-D-ICE	CIDI Vehicle: Conventional and LS Diesel	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
LDC-E-FF	EtOH FFV: E85, Corn	0.203	0.199	0.196	0.192	0.189	0.185	0.181	0.177
LDC-EV	Electric Vehicle	0.005	0.005	0.005	0.005	0.004	0.004	0.004	0.004
LDC-G-HEV	Grid-Independent SI HEV: CG and RFG	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018
LDC-G-ICE	Gasoline Vehicle: CG and RFG	0.017	0.017	0.018	0.019	0.019	0.020	0.021	0.021
LDC-H-FC	FCV: L.H2	0.009	0.007	0.006	0.005	0.004	0.004	0.004	0.004
		2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
LDC-D-HEV	Grid-Independent CIDI HEV: Conventional and LS Diesel	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
LDC-D-ICE	CIDI Vehicle: Conventional and LS Diesel	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
LDC-E-FF	EtOH FFV: E85, Corn	0.173	0.171	0.167	0.163	0.160	0.157	0.155	0.152
LDC-EV	Electric Vehicle	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
LDC-G-HEV	Grid-Independent SI HEV: CG and RFG	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018
LDC-G-ICE	Gasoline Vehicle: CG and RFG	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
LDC-H-FC	FCV: L.H2	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003

Table H.6-8. GREET WTW GHG Emission Factors (cont'd)

Light Duty Truck - CO2 Emission Rates (g/mi)		**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
LDT-D-HEV	Grid-Independent CIDI HEV: Conventional and LS Diesel	593.8	512.7	449.5	399.4	358.5	324.5	320.1	315.8
LDT-D-ICE	CIDI Vehicle: Conventional and LS Diesel	478.9	465.6	452.3	439.6	427.2	415.2	401.8	389.1
LDT-E-FF	EtOH FFV: E85, Corn	411.1	403.7	396.2	384.6	374.3	358.4	326.7	302.5
LDT-EV	Electric Vehicle	472.7	449.5	427.5	407.1	388.1	370.4	364.5	358.8
LDT-G-HEV	Grid-Independent SI HEV: CG and RFG	603.6	536.9	480.8	434.1	394.5	360.6	354.9	349.5
LDT-G-ICE	Gasoline Vehicle: CG and RFG	603.6	592.7	580.8	569.5	558.6	548.0	539.4	531.2
LDT-H-FC	FCV: L.H2	1,321.8	1,022.7	826.7	689.2	587.4	509.2	498.8	488.8
		2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
LDT-D-HEV	Grid-Independent CIDI HEV: Conventional and LS Diesel	311.7	308.0	304.3	296.9	289.8	282.9	276.3	270.0
LDT-D-ICE	CIDI Vehicle: Conventional and LS Diesel	377.2	366.0	355.4	349.7	344.1	338.6	333.3	328.2
LDT-E-FF	EtOH FFV: E85, Corn	277.1	261.6	239.4	222.6	208.7	196.6	186.4	177.9
LDT-EV	Electric Vehicle	353.4	348.4	343.4	341.5	339.5	337.5	335.6	333.6
LDT-G-HEV	Grid-Independent SI HEV: CG and RFG	344.6	340.4	336.3	328.7	321.3	314.2	307.4	300.9
LDT-G-ICE	Gasoline Vehicle: CG and RFG	523.8	517.4	511.1	509.4	507.7	505.8	504.1	502.5
LDT-H-FC	FCV: L.H2	479.3	470.5	461.8	450.4	439.4	428.7	418.4	408.4

Table H.6-8. GREET WTW GHG Emission Factors (cont'd)

Light Duty Truck - CH4 Emission Rates (g/mi)		**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
LDT-D-HEV	Grid-Independent CIDI HEV: Conventional and LS Diesel	0.662	0.571	0.500	0.444	0.398	0.360	0.355	0.351
LDT-D-ICE	CIDI Vehicle: Conventional and LS Diesel	0.535	0.519	0.503	0.489	0.474	0.460	0.445	0.431
LDT-E-FF	EtOH FFV: E85, Corn	0.709	0.696	0.683	0.662	0.644	0.614	0.557	0.514
LDT-EV	Electric Vehicle	0.619	0.592	0.566	0.542	0.519	0.498	0.493	0.489
LDT-G-HEV	Grid-Independent SI HEV: CG and RFG	0.724	0.643	0.577	0.521	0.474	0.433	0.428	0.424
LDT-G-ICE	Gasoline Vehicle: CG and RFG	0.724	0.710	0.698	0.686	0.675	0.663	0.656	0.648
LDT-H-FC	FCV: L.H2	3.134	2.435	1.976	1.653	1.414	1.231	1.211	1.192
		2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
LDT-D-HEV	Grid-Independent CIDI HEV: Conventional and LS Diesel	0.346	0.342	0.338	0.330	0.322	0.315	0.308	0.301
LDT-D-ICE	CIDI Vehicle: Conventional and LS Diesel	0.418	0.406	0.394	0.388	0.382	0.376	0.370	0.365
LDT-E-FF	EtOH FFV: E85, Corn	0.468	0.440	0.399	0.368	0.342	0.320	0.301	0.285
LDT-EV	Electric Vehicle	0.485	0.481	0.477	0.476	0.474	0.472	0.470	0.468
LDT-G-HEV	Grid-Independent SI HEV: CG and RFG	0.419	0.414	0.409	0.400	0.391	0.383	0.375	0.368
LDT-G-ICE	Gasoline Vehicle: CG and RFG	0.640	0.632	0.625	0.623	0.622	0.620	0.618	0.617
LDT-H-FC	FCV: L.H2	1.174	1.157	1.141	1.116	1.091	1.067	1.044	1.022

Table H.6-8. GREET WTW GHG Emission Factors (cont'd)

Light Duty Truck - N2O Emission Rates (g/mi)		**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
LDT-D-HEV	Grid-Independent CIDI HEV: Conventional and LS Diesel	0.014	0.013	0.013	0.013	0.013	0.013	0.013	0.013
LDT-D-ICE	CIDI Vehicle: Conventional and LS Diesel	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
LDT-E-FF	EtOH FFV: E85, Corn	0.258	0.253	0.249	0.243	0.239	0.233	0.226	0.219
LDT-EV	Electric Vehicle	0.007	0.006	0.006	0.006	0.006	0.005	0.005	0.005
LDT-G-HEV	Grid-Independent SI HEV: CG and RFG	0.019	0.018	0.019	0.019	0.019	0.019	0.019	0.020
LDT-G-ICE	Gasoline Vehicle: CG and RFG	0.019	0.019	0.020	0.021	0.022	0.022	0.023	0.024
LDT-H-FC	FCV: L.H2	0.012	0.009	0.008	0.006	0.005	0.005	0.004	0.004
		2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
LDT-D-HEV	Grid-Independent CIDI HEV: Conventional and LS Diesel	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
LDT-D-ICE	CIDI Vehicle: Conventional and LS Diesel	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
LDT-E-FF	EtOH FFV: E85, Corn	0.212	0.207	0.201	0.196	0.192	0.188	0.184	0.181
LDT-EV	Electric Vehicle	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
LDT-G-HEV	Grid-Independent SI HEV: CG and RFG	0.020	0.020	0.020	0.020	0.020	0.019	0.019	0.019
LDT-G-ICE	Gasoline Vehicle: CG and RFG	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
LDT-H-FC	FCV: L.H2	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004

Appendix H.7. AVTI Economic Modeling Data

The MCCP team was unable to leverage the Energy 2020 and REMI Insight Policy Tool to accurately model the economic affects of the AVTI policy. However, the MCCP team was able to understand the overall costs associated with administering tax credits for various AVT types. Table H.7-1 presents a summary of the calculated tax credits.

These tax credits were developed largely based on the AVT tax credits defined in the U.S. Energy Policy Act of 2005 (EPAct2005). In EPAct2005 two key attributes of vehicle technology were accounted for in determining a tax credit:

- Purchase price relative to comparable traditional vehicle.
- Fuel economy on a gasoline equivalent basis compared to a traditional vehicle.

Through the modeling of alternative vehicle adoption, as described in Appendix H.6, the MCCP team is able to apply the tax credits listed in Table H.7-1 to determine an estimated cost to the state for this program.

Table H.7-1. Summary of Modeled Tax Credits

		Michigan	
		Average Tax Credit Per Vehicle ($)	**Maximum Tax Credit Per Vehicle ($)**
LDC-D-HEV	Electric-Diesel Hybrid	$1,580	$3,400
LDC-E-FF	Ethanol-Flex Fuel ICE	$496	$5,000
LDC-EV	Electric Vehicle	$4,000	$4,000
LDC-G-HEV	Electric-Gasoline Hybrid	$1,580	$3,400
LDC-H-FC	Fuel Cell Hydrogen	$10,500	$12,000
LDT-D-HEV	Electric-Diesel Hybrid	$1,456	$3,400
LDT-E-FF	Ethanol-Flex Fuel ICE	$1,493	$5,000
LDT-EV	Electric Vehicle	$4,000	$4,000
LDT-G-HEV	Electric-Gasoline Hybrid	$1,456	$3,400
LDT-H-FC	Fuel Cell Hydrogen	$9,500	$12,000

Appendix I. Carbon Sequestration

Appendix I.1. Carbon Sequestration GHG Model

The MCCP Carbon Sequestration model was developed using Microsoft Excel to calculate the net GHG benefits from increased tree-plantings on marginal agricultural land. Figure 4A-1 provides the methodology for calculating annual carbon sequestration levels. Since it is unlike that 1% or 10% of total magland acres would be planted in the same year, staggered planting was assumed. The MCCP team modeled the planting of trees over the 10-year period of the program. Each year, one-tenth of the scenario's acres were planted and carbon sequestration levels were calculated accordingly.

NOTE: This model was fully explained in the full-text of the document.

Appendix I.2. Total Cost of Tree Plantings

In order to model the economic effects of the tree-planting program, the total cost of the program, for the duration of the modeling timeframe, needed to be estimated. To do this, the MCCP team used the State Forest Land Enhancement Program (FLEP) to serve as a basis for the necessary steps and corresponding costs required to plant trees on marginal agricultural land.

Marginal agricultural land (magland) refers to several types of agricultural land. Therefore, the MCCP team used a definition of magland that has been used by the Midwest Regional Carbon Sequestration Partnership (MRCSP). Magland is defined as follows: severely-eroded prime cropland, non-eroded marginal cropland, severely-eroded marginal cropland, severely-eroded pastureland, non-eroded marginal pastureland, severely-eroded marginal pastureland and barren land. The U.S. Geological Survey (USGS) 1992 National Land Cover Dataset was used to identify land use in the MRCSP region and the U.S. Department of Agriculture- Natural Resources Conservation Service State Soil Geographic database was the source for determination of land quality (i.e. prime- or marginal-farmland). The combination of the two datasets was used to reclassify the land use with different land qualities.

Since magland is an aggregate of land types with various degrees of land quality, it is possible that some land would require additional steps and costs not identified here. A more detailed analysis of the total program costs would break down maglands according to land quality and calculate tree-planting costs accordingly. The intent of the following estimate is to provide a starting figure by which future considerations for carbon sequestration programs, using tree-plantings, can be based. The cost per acre is constant, regardless of the number of acres planted. The steps and associated costs are in Table I.2-1.

Table I.2-1. Cost of Planting Trees on Magland

Practice	**$/acre of magland**
Site preparation (medium level, mechanical)	108
Planting (700 seedlings and planting)	400
Follow-up weed control 2nd year (chemical)	85
Follow-up weed control 3rd year (mechanical)	77
Total	670

Medium level, mechanical site preparation was used to account for the afforestation of magland. The number of trees planted per acre was determined by spacing needs for white spruce and red pine. Recommendations for white spruce suggest 600-800 trees per acre. The most common recommendations to plant red pines are about 700 to 900 seedlings per acre. However, research has shown that maximum cubit-foot volume growth of red pine is attained with a stand averaging 800-1,000 established trees per acre.[2] Based on the range of plantings per acre for the two tree species, the MCCP modeled the planting of 700 trees. Two methods of weed control were included to address to potential need to utilize different methods of weed prevention.

The 10% planting of trees of magland requires 303,933 acres, resulting in a total program cost of $203,635,110. Moreover, the 1% planting of trees requires 30,393 acres and results in a total program cost of 20,363,310. However, as addressed in the Results and Discussion section, a price on carbon could reduce the total cost of the program if sequestered carbon was sold as offsets. The Chicago Climate Exchange has traded CO_2 since 2003, at a price range of $1-$5/$MTCO_2$. Considering the 10.3 MMTCE sequestered by planting 10% of marginal agricultural land with conifers this policy could generate $37.8 million to $189 million through the trading of forest carbon forestry offsets. Additionally, the revenue from timber was not included in the economic modeling as it was not possible to determine the percentage of program participants that would harvest the planted trees.

Appendix I.3. Carbon Sequestration Economic Model

The economic model of a tree-planting program used the REMI model to capture the economic costs associated the policy. Tables I.3-1 through I.3-4 present the REMI input variables and the modeled effects on these variables. The total program costs of tree plantings at the 10% and 1% magland level were the main input into the REMI model (See Appendix I.2 for Total Program Costs). The economic modeling results for GSP (million US$ 2000) and Employment (Job-Years) are in Tables I.3-5 through I.3-8.

Table I.3-1. REMI Input Variables: 1% Magland State Funded 2005-2025

Variable	Sector	Units	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Firm Sales	Forestry et al	2000 Fixed $ Million	0	0	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04
Government Spending	State	2000 Fixed $ Million	0	0	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81	-0.81
Farm Compensation	Farm	2000 Fixed $ Million	0	0	-1.22	-1.22	-1.22	-1.22	-1.22	-1.22	-1.22	-1.22	-1.22
Variable	**Sector**	**Units**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
Firm Sales	Forestry et al	2000 Fixed $ Million	2.04	0	0	0	0	0	0	0	0	0	
Government Spending	State	2000 Fixed $ Million	-0.81	0	0	0	0	0	0	0	0	0	
Farm Compensation	Farm	2000 Fixed $ Million	-1.22	0	0	0	0	0	0	0	0	0	

Table I.3-2. REMI Input Variables: 10% Magland State Funded 2005-2025

Variable	Sector	Units	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Firm Sales	Forestry et al	2000 Fixed $ Million	0	0	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4
Government Spending	State	2000 Fixed $ Million	0	0	-8.15	-8.15	-8.15	-8.15	-8.15	-8.15	-8.15	-8.15	-8.15
Farm Compensation	Farm	2000 Fixed $ Million	0	0	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2
Variable	**Sector**	**Units**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
Firm Sales	Forestry et al	2000 Fixed $ Million	20.4	0	0	0	0	0	0	0	0	0	
Government Spending	State	2000 Fixed $ Million	-8.15	0	0	0	0	0	0	0	0	0	
Farm Compensation	Farm	2000 Fixed $ Million	-12.2	0	0	0	0	0	0	0	0	0	

Table I.3-3. REMI Input Variables: 1% Magland Federally Funded 2005-2025

Variable	Sector	Units	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Firm Sales	Forestry et al	2000 Fixed $ Million	0	0	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04
Government Spending	State	2000 Fixed $ Million	0	0	0	0	0	0	0	0	0	0	0
Farm Compensation	Farm	2000 Fixed $ Million	0	0	-1.22	-1.22	-1.22	-1.22	-1.22	-1.22	-1.22	-1.22	-1.22
Variable	**Sector**	**Units**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
Firm Sales	Forestry et al	2000 Fixed $ Million	2.04	0	0	0	0	0	0	0	0	0	
Government Spending	State	2000 Fixed $ Million	0	0	0	0	0	0	0	0	0	0	
Farm Compensation	Farm	2000 Fixed $ Million	-1.22	0	0	0	0	0	0	0	0	0	

Table I.3-4. REMI Input Variables: 10% Magland Federally Funded 2005-2025

Variable	Sector	Units	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Firm Sales	Forestry et al	2000 Fixed $ Million	0	0	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4
Government Spending	State	2000 Fixed $ Million	0	0	0	0	0	0	0	0	0	0	0
Farm Compensation	Farm	2000 Fixed $ Million	0	0	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2
Variable	**Sector**	**Units**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
Firm Sales	Forestry et al	2000 Fixed $ Million	20.4	0	0	0	0	0	0	0	0	0	
Government Spending	State	2000 Fixed $ Million	0	0	0	0	0	0	0	0	0	0	
Farm Compensation	Farm	2000 Fixed $ Million	-12.2	0	0	0	0	0	0	0	0	0	

Appendix I.4. Carbon Sequestration Economic Model

Table I.4-5. REMI Results: 1% Magland State Funded

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Employment (Job-Years)	-59.1	-59.6	-61.5	-60.6	-61.0	-61.0	-61.5	-60.6	-58.1	-58.6
GSP (million fixed 2000$)	-9.34	-9.37	-9.77	-9.77	-9.74	-9.98	-10.1	-10.0	-10.2	-10.3
	2017	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
Employment (Job-Years)	-1.5	0.59	0.49	0.98	0.98	-1.47	-0.49	-1.47	-1.95	
GSP (million fixed 2000$)	-0.06	0.06	0.06	0.12	0.06	0	0	-0.06	-0.18	

Table I.4-6. REMI Results: 1% Magland Federally Funded

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Employment (Job-Years)	-40.0	-39.6	-41.5	-39.1	-40.0	-38.6	-38.6	-39.6	-38.1	-39.6
GSP (million fixed 2000$)	-8.36	-8.45	-8.70	-8.73	-8.67	-8.88	-8.97	-8.88	-9.19	-9.22
	2017	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
Employment (Job-Years)	-1.95	0.98	-0.49	-0.49	0.98	-0.49	-0.49	-2.44	-1.47	
GSP (million fixed 2000$)	-0.12	0	0	0	0	-0.06	-0.18	-0.12	-0.12	

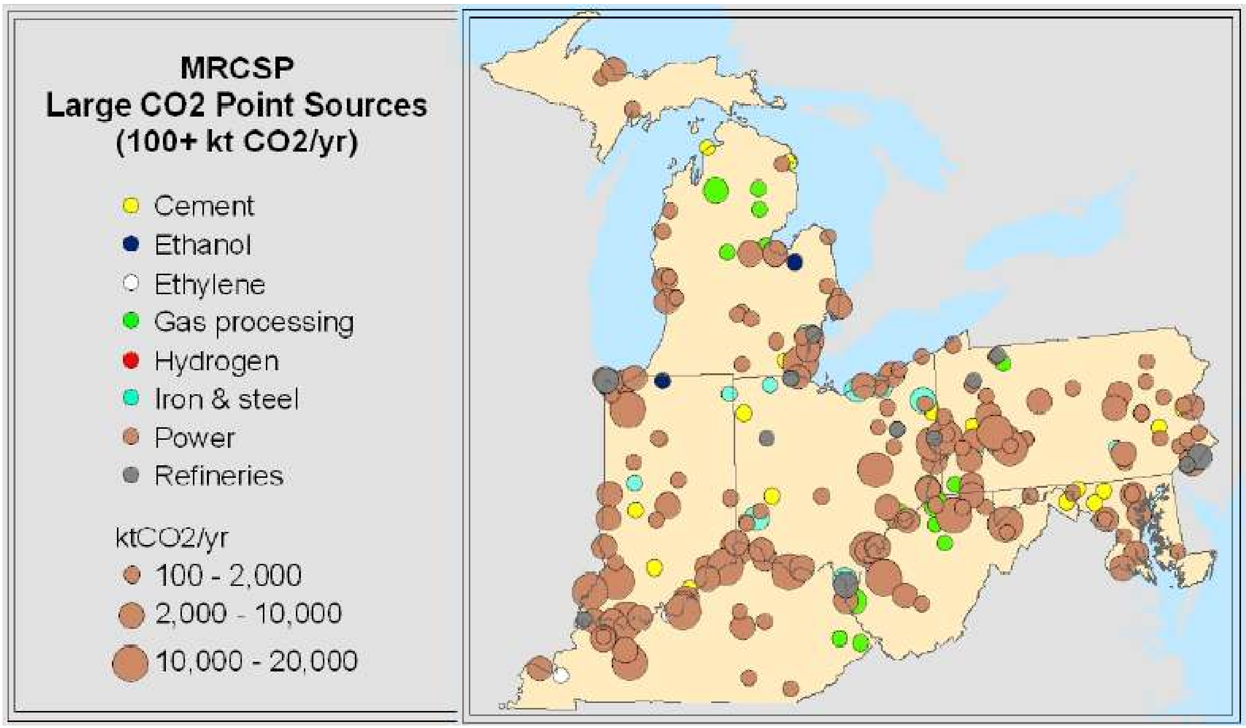
Table I.4-7. REMI Results: 10% Magland Federally Funded

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Employment (Job-Years)	-393	-403	-409	-406	-402	-398	-393	-390	-384	-381
GSP (million fixed 2000$)	-83.4	-85.0	-86.4	-87.2	-87.9	-88.8	-89.3	-89.7	-90.6	-91.2
	2017	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
Employment (Job-Years)	-10.7	1.47	3.91	2.93	-1.95	-8.30	-13.7	-20.0	-23.4	
GSP (million fixed 2000$)	-0.67	0.06	0.31	0.06	-0.37	-0.80	-1.47	-1.83	-2.14	

Table I.4-8. REMI Results: 10% Magland State Funded

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Employment (Job-Years)	-590	-606	-615	-614	-610	-608	-601	-594	-586	-582
GSP (million fixed 2000$)	-93.1	-95.0	-96.7	-97.8	-98.4	-99.5	-100	-101	-101	-102
	2017	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
Employment (Job-Years)	-16.1	-0.98	2.93	-0.49	-8.3	-16.6	-23.0	-31.7	-37.6	
GSP (million fixed 2000$)	-0.07	0.24	0.37	-0.06	-0.73	-1.40	-2.20	-2.75	-3.24	

Appendix I.5. Large Point Sources



Source: MRCSP Third Semi-Annual Progress Report April 2005.[3]

Figure I.5-1. Large Point Sources in the MRCSP Region

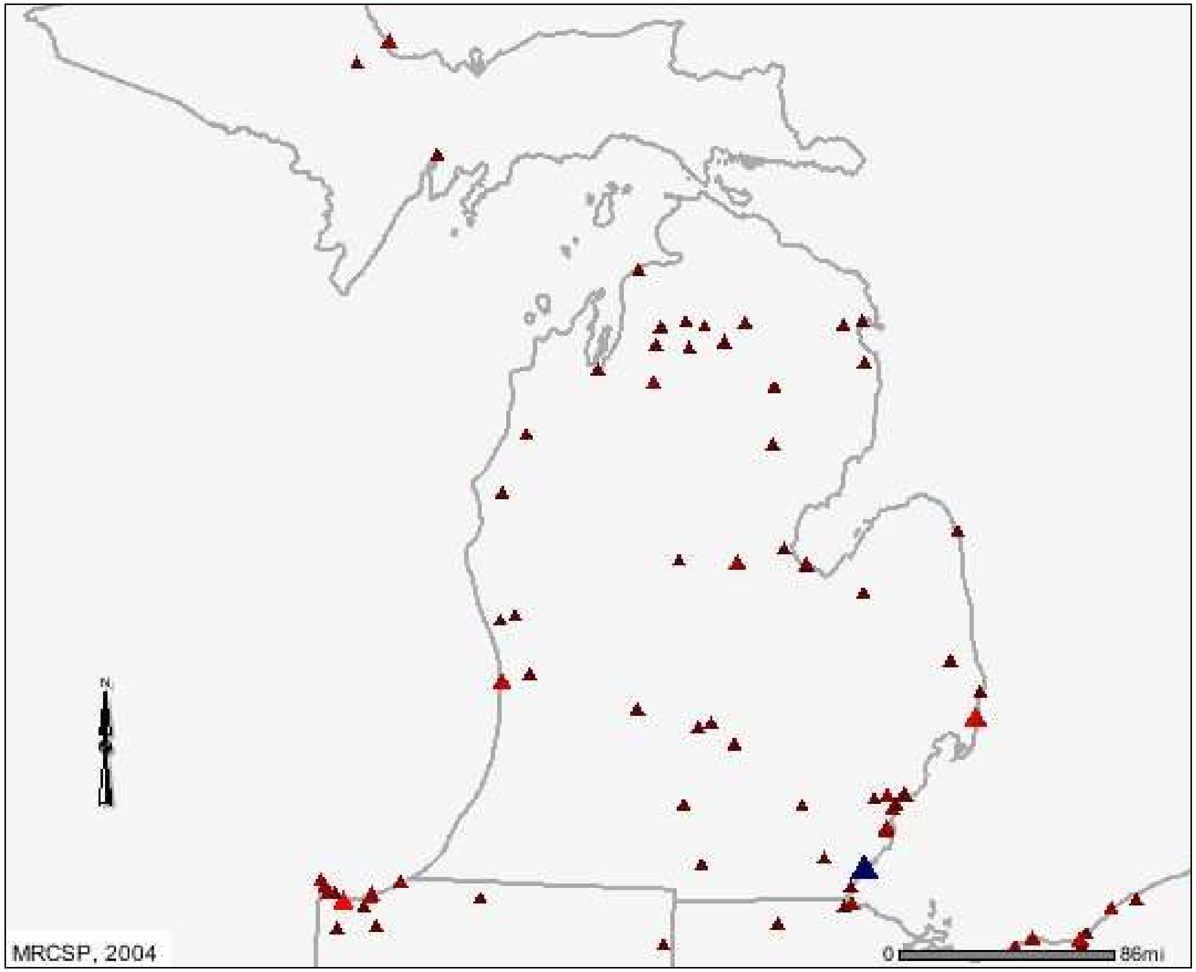


Figure I.5-2. Large Point Sources in Michigan

Figure I.5-3. Large Point Source Legend

Source: Ohio Department of Natural Resources:
http://www.dnr.state.oh.us/website/geosurvey/mrcspgeo/viewer.htm.

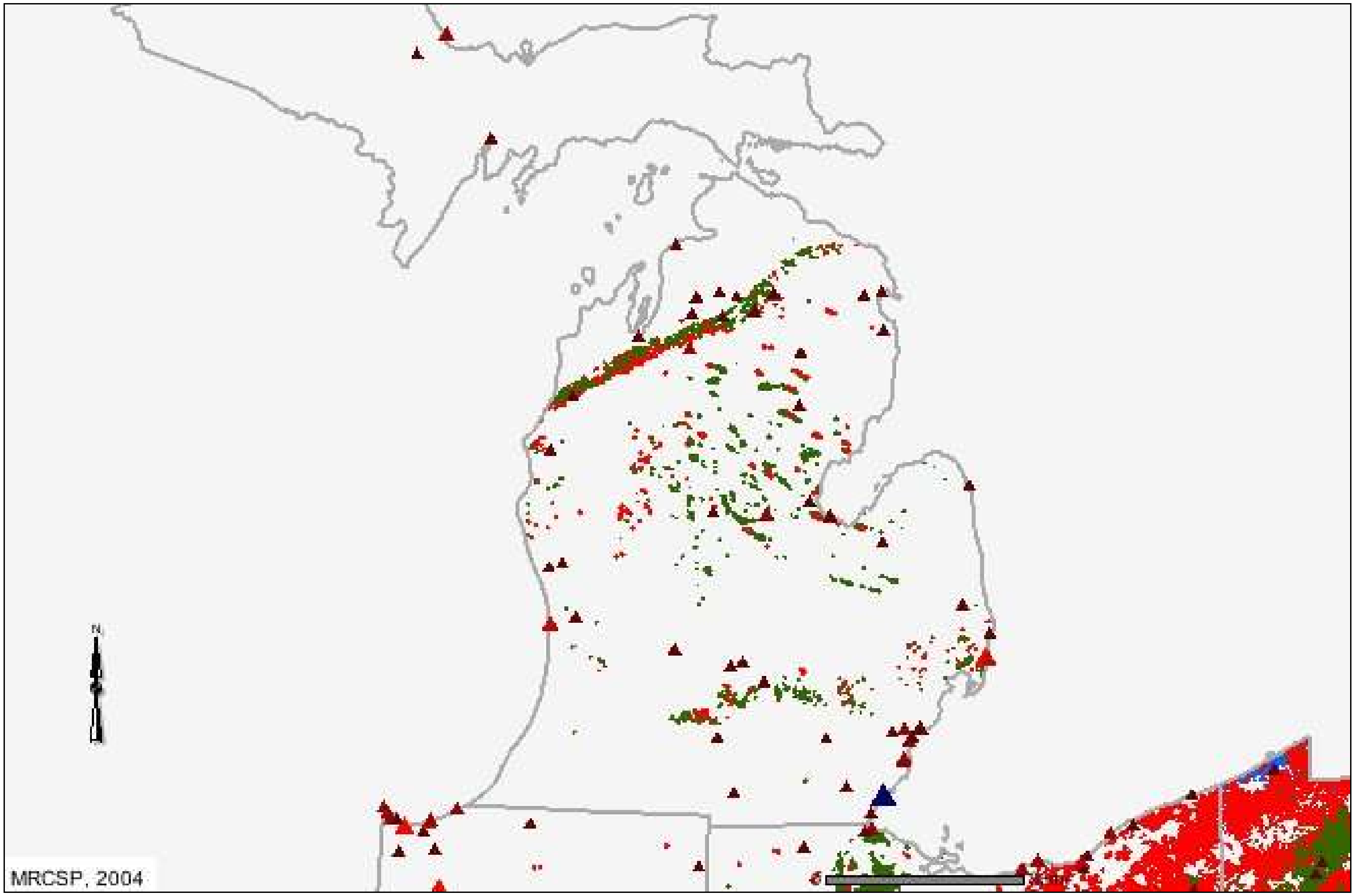


Figure I.5-4. Large Point Sources and Oil and Gas Fields

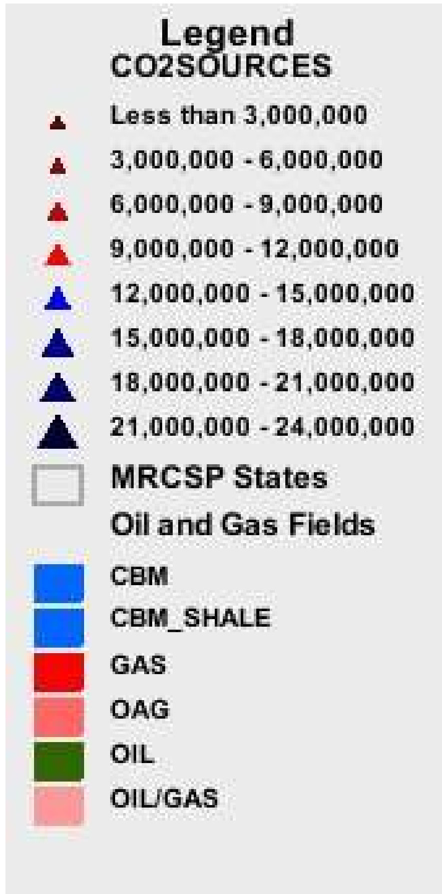


Figure I.5-5. Large Point Sources and Oil and Gas Fields Legend

Source: Ohio Department of Natural Resources:
http://www.dnr.state.oh.us/website/geosurvey/mrcspgeo/viewer.htm.

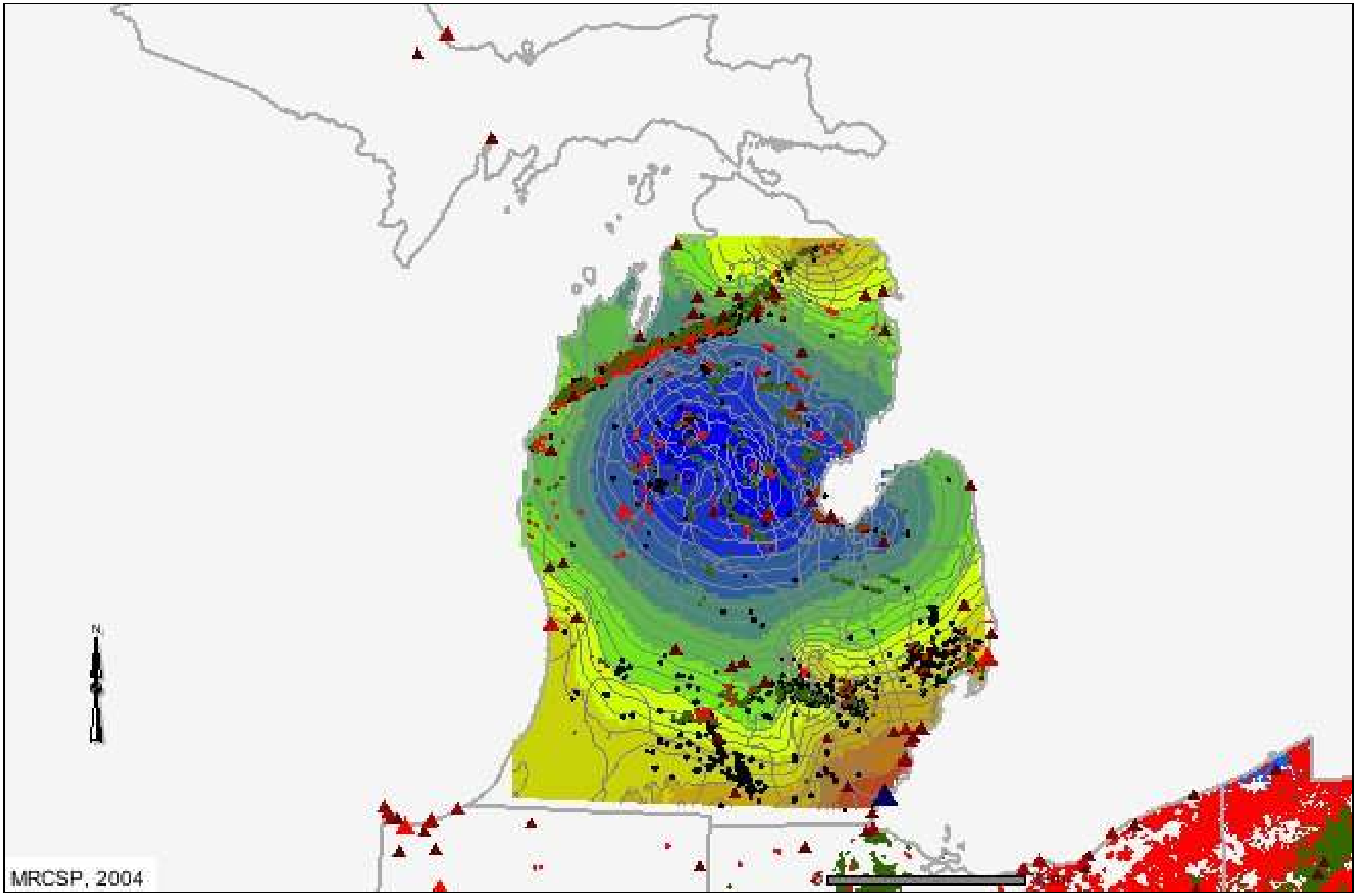


Figure I.5-6. Large Point Sources, Oil and Gas Fields and Sylvania Sandstone Formations

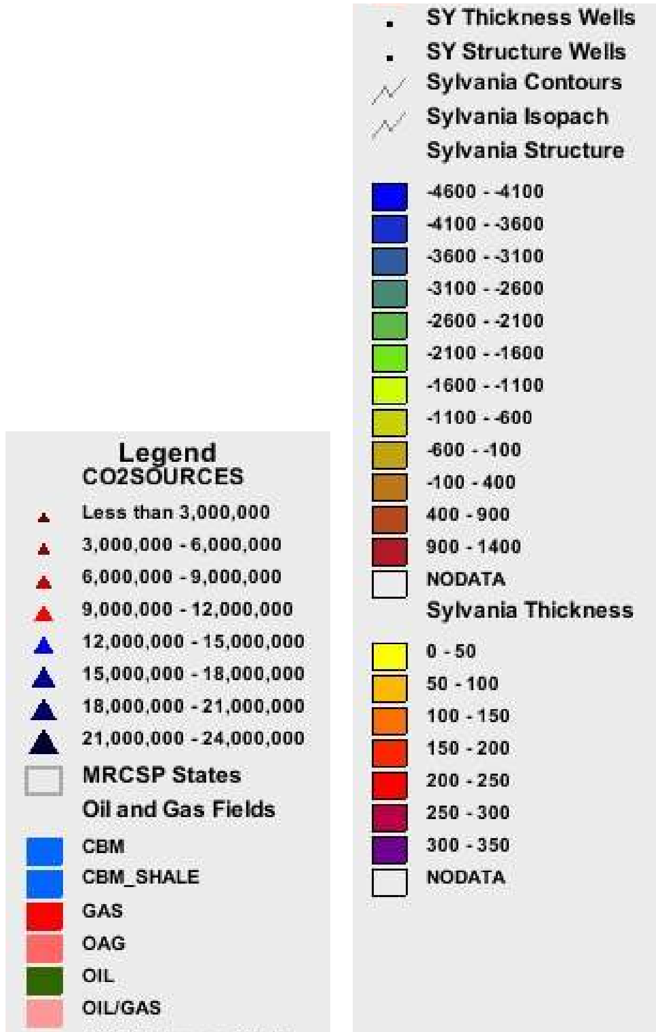
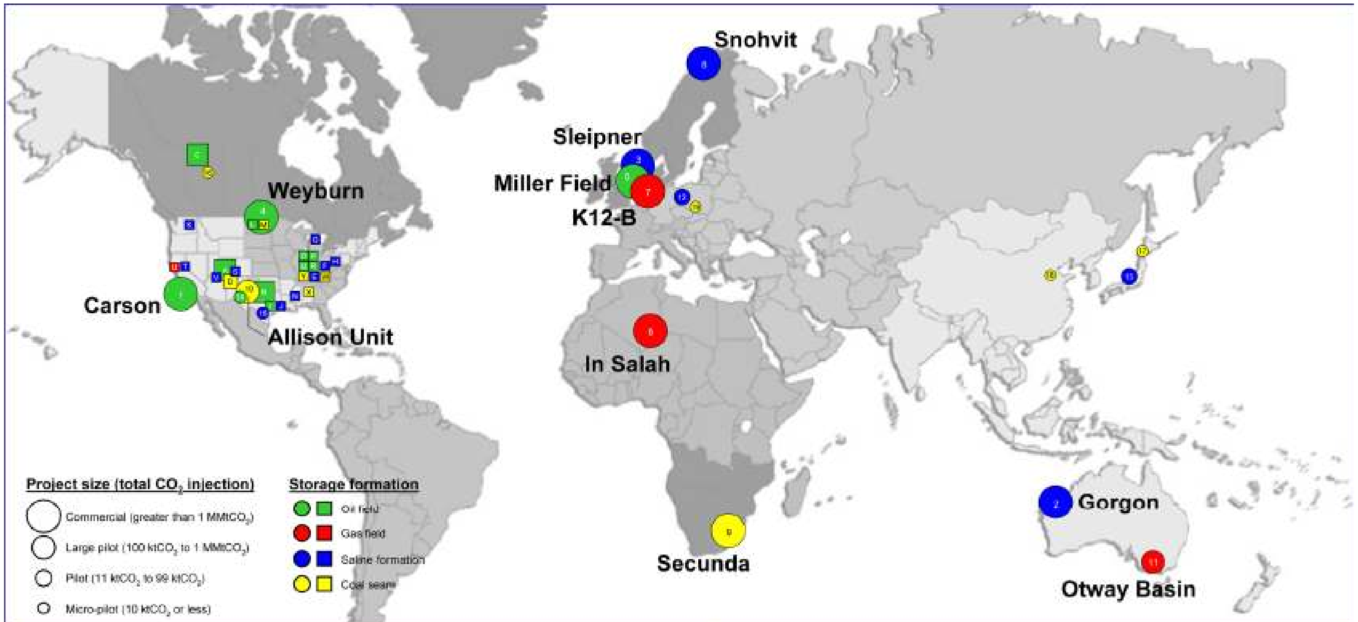


Figure I.5-7. Large Point Sources, Oil and Gas Fields and Sylvania Sandstone Formations Legend

Source: Ohio Department of Natural Resources:

http://www.dnr.state.oh.us/website/geosurvey/mrcspgeo/viewer.htm.

Appendix I.6 Field Projects



Projects that are part of the Regional Carbon Sequestration Partnership

	Partnership	Geologic Province	Total CO_2 Injection (tons CO_2)	Approximate Depth (ft)
A	SRCSP	Paradox Basin	525,000	5,800
B	SRCSP	Permian Basin	300,000	5,700
C	PCOR	Keg River Formation	250,000	4,900
D	SRCSP	San Juan Basin	75,000	3,000
E	MGSC	Illinois Basin	10,000	5,000-10,000
F	MRCSP	Cincinnati Arch	10,000	8,000-10,000
G	MRCSP	Michigan Basin	10,000	4,000
H	MRCSP	Appalachian Basin	10,000	2,500-4,000
I	SECARB	Gulf Coast	7,500	8,000
J	SECARB	Gulf Coast	7,500	10,000
K	Big Sky	Grand Ronde Basalt	3,000	2,700
L	PCOR	Duperow Formation	3,000	1,000
M	PCOR	Williston Basin	3,000	>500
N	SECARB	Mississippi Salt Basin	3,000	7,500
O	MGSC	Illinois Basin	2,500	1,200-2,800
P	MGSC	Illinois Basin	2,500	Up to 3,150
Q	MGSC	Illinois Basin	2,500	2,800-3,150
R	MGSC	Illinois Basin	2,500	2,800-3,150
S	SRCSP	Paradox Basin	2,000	6,000
T	WESTCARB	Central Valley CA	2,000	5,000
U	WESTCARB	Central Valley CA	2,000	4,000
V	WESTCARB	Kaiparowits Basin	2,000	8,000
W	SECARB	Central Appalachian	1,000	1,000
X	SECARB	Black Warrior Basin	1,000	2,300-5,000
Y	MGSC	Illinois Basin	750	1,000

Worldwide CO_2 Storage Projects

	Project Name	Injection Start Date	Total CO_2 Injection (tons CO_2)	Approximate Depth (ft)
1	Carson	2011	40,000,000[a]	TBD
2	Gorgon	2009	>36,000,000[b]	7,500
3	Sleipner	1996	20,000,000	2,600-3,300
4	Weyburn	2000	20,000,000	4,800
5	Miller Field	2009	18,000,000[c]	13,000
6	In Salah	2004	17,000,000	5,900
7	K12B	2004	8,000,000	13,000
8	Snohvit	2006	>7,000,000[d]	8,500
9	Secunda	2010	TBD	TBD
10	Allison Unit	1995	360,000	3,100
11	Otway Basin	2006	100,000	6,500
12	Ketzin	2006	60,000	2,300
13	Minami-Nagaoka	2002	10,000	3,600
14	West Pearl Queen	2002	2,100	TBD
15	Frio	2004	1,600	4,900
16	Fenn Big Valley	1998	200	4,300
17	Yubari	2004	200	2,950
18	Qinshui Basin	2003	150	1,650
19	RECOPOL	2003	10	3,600

[a] 4 MMt/yr * 10 yrs | [b] 10,000 t/d * 365 * 10 yrs | [c] 1.2 MMt/yr * 15 yrs | [d] 2,000 t/d * 365 * 10 yrs

Figure I.6-2. Worldwide CO_2 Storage Projects[4]

Appendix I.7. Michigan Counties

Figure I.7-1. Map of Michigan Counties

Source: Census Finder http://www.censusfinder.com/mapmi.htm.

Appendix I.8. IGCC Technology

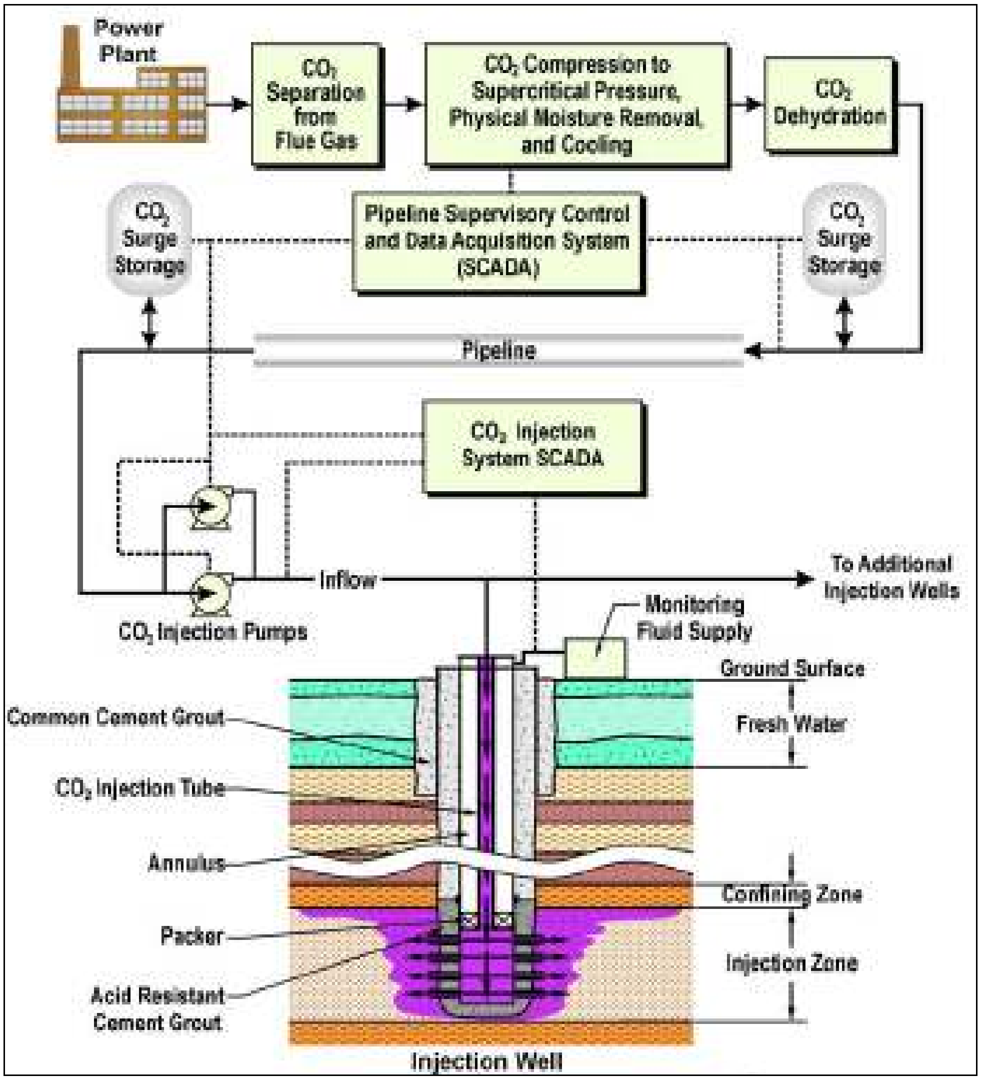


Figure I.8-1. Carbon Capture, Compression, Storage, Transportation and Storage Technology

Source: Neeraj Gupta Presentation February 2003. [5]

Appendix J. Building Codes

Appendix J.1: Other Codes and Energy Efficiency Programs

National Commercial Codes
For commercial buildings, the most recent are the 2004 ASHRAE standards. Ohio and Washington were the early adopters. About half the states have 2003 IECC or ASHRAE 90.1 2001 or better. Michigan is in the middle of the pack with ASHRAE 1999 standards.

Table 4.61 provides a summary of five Midwest states and the existing residential and commercial codes in place.

TableJ.1-1. Midwest States' Energy Codes

State	Residential Code	Commercial Code	Date Updated (resid/comm)
Michigan	Less than MEC 1992	ASHRAE 90.1-1999	March 1999/April 2003
Ohio	2003 IECC	2003 IECC and ASHRAE 90.1-2004	September 2005
Illinois	None	2001 IECC	None/April 2006
Indiana	Less than MEC 1995	2004 IECC	1992, Under review/January 2006
Wisconsin	95 MEC, 2000 IECC*	IECC 2000	July 2002/March 2006

*95 MEC applies to 1 and 2 family units, 2000 IECC to multi-unit buildings.

National Voluntary Programs: LEED and Energy Star
Leadership in Energy and Environmental Design and Energy Star are both National Programs, the first run by the US Green Building Council, and the later by U.S. Environmental Protection Agency and U.S. Department of Energy. Both programs have demonstrated substantial energy savings with their standards, more than by either the IECC or ASHRAE codes. "Since 1995 more than 350,000 of the nation's new homes have earned the ENERGY STAR label, saving homeowners an estimated $200 million and eliminating approximately 4 million pounds of GHG emissions, equivalent to the emissions of about 150,000 vehicles."[6]

National Compliance
More detailed analysis of the compliance issue is needed to understand the actual energy savings from building codes compared with theoretical estimates. Various studies have indicated that compliance with building energy codes may not be high. A study at the University of Washington of state building energy code administrators, funded by the National Science Foundation, surveyed 33 states with 5 broad-based code authority. The respondents indicated that "energy codes are too complex and design professionals do not pay sufficient attention." Another study of building energy codes in California, Washington, and Oregon conducted by Lawrence Berkeley National Laboratory found

"that many homes do not meet energy codes....". A 1995 statewide study by Minnesota of their energy code found that "The full energy-saving benefits of the code changes are not being realized because in many cases they are not being implemented." A Massachusetts study found that checking of window and wall areas in building plan view by code officials was "uncommon" and site inspections of component areas were "very rare".[7]

Additional Programs

Ohio is an example of a Midwest state that has implemented innovative methods to increase energy efficiency. Ohio's Energy Efficiency Revolving Loan Fund provides low interest loans for renovation projects that increase energy efficiency.[8] It is funded by a fee rider on electric bills and thus does not need to be funded by the government. Ohio also has different mechanisms for supporting low-income residents with weatherization assistance or bill payment. Qualified Ohioans can apply to their utility for a Percentage of Income Payment Plan (PIPP). Payment is based on percentage of income and the State covers the rest. There is an extensive weatherization provider training program which ensures installation is done correctly leading to the most energy efficient results. [9]

In North Dakota, a household can have an in home energy audit and discussion with an expert about how to increase their homes energy efficiency.

Michigan Commercial Codes

A study was conducted in 2002 by Pacific Northwest National Laboratory to analyze the potential benefits and costs of adopting ASHRAE 90.1 1999 standard as the Michigan Commercial building energy code compared with the existing ASHRAE 90A-1980 based code. The study found that there was an economic justification for using the 1999 standard, primarily because of the changes required in the building envelope provided energy savings. The lighting requirements were also highly cost-effective. "When lighting and envelope requirements are combined, all of the buildings simulated display savings in energy use, annual fuel costs, and life-cycle costs."[10] Shortly thereafter, April 2003, the commercial codes were updated to the ASHRAE 90.1 1999 standards. The Pacific Northwest study demonstrated the benefits to updating building codes providing higher energy efficiency.

Michigan: LEED and Energy Star

Like many other states the Michigan government does not have a formal program for assisting residents and businesses meet the compliance standards of LEED or EnergyStar. However, a list of energy star builders is listed on the state's website.[11] Additionally, five grants, up to $8,000 each were made available in 2005 to encourage builders to try to meet the Five Star Rating, 86-100 on the HERS scale.

The US Green Building Council has two chapters in Michigan, the Western Chapter and the Detroit Regional Chapter. The US GBC helps promote LEED as a mechanism for energy efficient buildings in the state. LEED includes energy standards for new commercial buildings and a standard for residential is underway. Utilizing the 7/17 LEED criteria for energy, a project in Austin realized 41% energy savings.[12] One of the benefits of LEED, compared to traditional building codes, is the synergies realized in combining energy savings with water-use reduction and material selection.

Compliance in Michigan

Compliance and enforcement of building codes in Michigan is the responsibility of the Department of Construction Codes and Fire Safety's division of Local Government and Consumer Services. Oversight is conducted by two branches of building officials, Plan Reviewers and Building Inspector. Officials are broken down into four categories: Mechanical, Electrical, Building, Plumbing Energy evaluations fall under the Building category. The Local Government and Consumer Services provide registration and training for building officials.

Additional Michigan Programs

The Home Energy Payment Assistance Program

HEPAP is administered by the local Family Independence Agency and covers heating fuel, electricity and home repairs. "Payment for heating fuel has an annual maximum of $350 to $700 depending on the fuel type. Energy-related home repairs have a $1,500 lifetime limit per household."[13] Assistance is based on a needs assessment and the applicant must meet eligibility criteria.

Weatherization Assistance

Weatherization Assistance is a federal program run through local Community Action Agencies, 35 which are certified in Michigan Community Action Agencies can. help provide wall, attic, and foundation insulation. Eligibility is based on household income being at or below 150% of the federal poverty guidelines. "According to national studies, households that receive weatherization services can expect heating costs to be reduced 20 to 25 percent. At today's fuel cost, that amounts to about a $300 savings. As fuel costs continue to rise, even greater savings will result."[14]

Demand Side Management (DSM)

DSM Programs are addressed in a separate portion of the MCCP report.

Energy Efficiency Mortgages

The following companies provide energy efficiency mortgages or energy improvement mortgages: Chase Manhattan, GMAC Mortgage, Rock Financial, Indigo Financial Group, Wells Fargo Home Mortgage, Countrywide Home Loans, Independent Bank MSB, Glenwood Financial I, Inc.[15] An energy efficient mortgage allows the buyer to get an "income stretch," i.e. the lender can increase the debt-to-income ratio by as much as 2% or more

Home Energy Rating Service

There are 29 providers of HERS listed on the Energy Office's website that conduct home energy ratings. These providers analyze homes to find energy leaks and identify options to increase energy conservation and efficiency.[16] This service is provided for a fee.

Michigan has a plan to reduce energy consumption in state facilities by 10% by the end of 2008 (based on 2002 utility expenditures of approximately $16 million on DMB managed and owned buildings). Also, statute PA 122 of 1989 provides the legislative authorization to employ multi-year, performance contracts to purchase and install proven and cost-effective energy efficient technologies in state-owned buildings. The Energy Office and DMB Acquisition Services staff assist state agencies with the performance contracting process. Other technical assistance, training, and project support services are offered based on expressed needs and resource availability. (Energy Office Website)

Urban Options
Urban Options is a Lansing based non-profit that provides information, trainings, and workshops for consumers highlighting energy efficiency and services like a home energy rating service. Additionally, Urban Options provides information on for-fee programs and services to schools and other interested groups.

THAW Fund
The Heat and Warmth Fund is a private foundation that supports low-income Michigan families and individuals with funds to prevent heat or lighting from being turned off or to restore service. In the 2003-2004 heating season, THAW provided over $4.5 million to Michigan households.

Appendix J.2. Number of New Home Permits Per County and Assigned Climate Zone

Table J.2-1. Michigan New Home Permits by County and Climate Zone

County	Climate Zone	2001	2002	2003	2004	2005	5 yr. average
Keweenaw, MI	7	25	24	26	28	26	26
Ontonagon, MI	7	16	30	27	34	22	26
Baraga, MI	7	43	25	42	37	37	37
Gogebic, MI	7	53	44	51	36	46	46
Manistee, MI	6	52	45	47	56	39	48
Alpena, MI	6	97	42	38	44	51	54
Luce, MI	7	54	53	57	59	56	56
Oscoda, MI	6	73	65	56	67	53	63
Gratiot, MI	5	63	64	60	83	55	65
Iron, MI	7	79	59	61	50	76	65
Arenac, MI	6	68	89	86	97	62	80
Missaukee, MI	6	79	85	90	79	84	83
Montmorency, MI	6	97	80	96	79	69	84
Dickinson, MI	7	76	74	103	73	97	85
Alcona, MI	6	129	119	79	67	62	91
Alger, MI	7	59	72	85	210	76	100
Osceola, MI	6	192	101	95	108	80	115
Crawford, MI	6	87	109	108	115	166	117
Presque Isle, MI	6	125	133	145	117	83	121
Lake, MI	6	113	113	121	131	132	122
Menominee, MI	7	124	125	119	126	116	122
Branch, MI	5	101	129	138	132	120	124
Schoolcraft, MI	7	166	177	191	67	50	130
Ogemaw, MI	6	132	137	147	98	148	132
Clare, MI	6	142	128	128	145	129	134

County	Climate Zone	2001	2002	2003	2004	2005	5 yr. average
Kalkaska, MI	6	147	113	151	152	111	135
Delta, MI	7	181	33	164	167	149	139
Houghton, MI	7	129	193	124	134	131	142
Oceana, MI	6	135	19	112	230	216	142
Iosco, MI	6	165	136	145	145	123	143
Chippewa, MI	5	220	155	145	132	89	148
Mackinac, MI	7	109	82	193	197	184	153
Tuscola, MI	5	174	202	131	112	151	154
Huron, MI	5	162	180	173	154	117	157
Mason, MI	6	144	147	161	178	159	158
Shiawassee, MI	5	218	103	126	218	207	174
Otsego, MI	6	303	176	181	187	102	190
St. Joseph, MI	5	266	163	209	160	171	194
Cheboygan, MI	6	208	208	181	199	192	198
Wexford, MI	6	172	189	206	212	227	201
Antrim, MI	6	250	253	298	137	142	216
Midland, MI	6	251	238	239	211	198	227
Marquette, MI	7	187	190	257	272	237	229
Leelanau, MI	6	252	220	249	240	209	234
Gladwin, MI	6	274	241	249	225	187	235
Montcalm, MI	5	206	232	241	275	230	237
Benzie, MI	6	274	209	298	211	222	243
Hillsdale, MI	5	249	258	274	241	199	244
Cass, MI	5	291	232	255	221	250	250
Newaygo, MI	6	249	235	264	284	235	253
Emmet, MI	6	235	276	268	268	225	254
Mecosta, MI	6	247	244	257	289	282	264
Ionia, MI	5	226	263	287	278	304	272
Charlevoix, MI	6	436	208	226	267	265	280

County	Climate Zone	2001	2002	2003	2004	2005	5 yr. average
Roscommon, MI	6	366	348	342	290	206	310
Bay, MI	6	329	353	393	327	300	340
Isabella, MI	6	278	239	286	522	406	346
Calhoun, MI	5	316	356	388	354	330	349
Barry, MI	5	342	381	381	371	341	363
St. Clair, MI	5	66	61	70	948	770	383
Van Buren, MI	5	397	389	428	474	454	428
Lapeer, MI	5	461	493	489	569	502	503
Eaton, MI	5	491	466	610	515	440	504
Clinton, MI	5	485	567	607	463	437	512
Lenawee, MI	5	538	499	548	533	454	514
Sanilac, MI	5	803	880	897	115	91	557
Saginaw, MI	5	490	605	652	604	484	567
Berrien, MI	5	522	608	588	685	689	618
Grand Traverse, MI	6	533	609	704	692	727	653
Jackson, MI	5	727	653	673	688	669	682
Muskegon, MI	5	816	680	739	703	590	706
Allegan, MI	5	644	628	736	833	703	709
Ingham, MI	5	666	735	740	839	719	740
Monroe, MI	5	678	805	992	1077	870	884
Kalamazoo, MI	5	954	1031	1104	1084	1087	1,052
Ottawa, MI	5	1598	1601	1706	1706	1696	1,661
Livingston, MI	5	1741	1765	1857	2158	1454	1,795
Genesee, MI	5	1864	1900	2029	2033	1756	1,916
Washtenaw, MI	5	1813	2285	2153	1994	1441	1,937
Kent, MI	5	2938	2879	3008	3049	2632	2,901
Wayne, MI	5	3006	3388	3729	4211	3138	3,494
Macomb, MI	5	3793	4296	4634	4621	3717	4,212
Oakland, MI	5	4205	4386	4728	5017	4050	4,477
Total # new homes		40465	41406	44471	45609	38602	42,111

Appendix J.3. U.S. Census Data for the Midwest (% distribution by sq. ft)

Year	under 1200	1,200-1,599	1,600-1999	2000-2399	2400-2999	over 3000
2001	6%	22%	22%	17%	16%	17%
2002	5%	24%	22%	17%	16%	16%
2003	6%	22%	22%	17%	16%	17%
2004	6%	22%	22%	17%	16%	17%
2005	5%	20%	22%	17%	16%	20%

Appendix J.4. House Configurations in LBL Energy Savers Model

The following presents a detailed summary of the input parameters to the HSE model. Those items highlighted in yellow were modified during the different runs. The other configurations were left as constants.

General House Information

- Year Built: 2005
- Locations:
  - Detroit,
  - Grand Rapids
  - Sault Ste. Marie
- Number of Occupants: 3 (Ages 6-13: 1, Ages 14-64: 2)

House Shape and Size

- Orientation: North
- House Shape: Rectangular
- Number of Stories/floor size:
  - 1200 sq. ft: 1 story/25 ft x 44 ft
  - 2200 sq. ft: 2 stories/25 ft x 44 ft
  - 3500 sq. ft: 2 stories/31.81 ft x 55 ft
- Ceiling height: 9 ft

Exterior Shading

- Roof Eaves: all sides 1 ft

Airtightness

- Weatherstripping to prevent air leaks:
  - 1999 code: No
  - 2004 code: No
  - 2006 code: Yes

Foundation and Floor

- Foundation Type: Basement
- Basement insulation:
  - 1999 Code: R-0
  - 2004, 2006 Codes, Climate 5,6: R-11

  - 2004, 2006 Codes, Climate 7: R-19
- Floor insulation:
  - 1999 code, Climate 5: R-21
  - 1999 code, Climate 6,7: R-30
  - 2004 code, All Climates: R-21
  - 2006 code, All Climates: R-30

Walls
- Construction type: Wood Frame
- Exterior finish: Wood Siding
- Exterior wall surface color: Medium (absorption 0.70)
- Wall Insulation R-value:
  - Code 1999, Climate 5: R-13
  - Code 1999, Climate 6: R-15
  - Code 1999, Climate 7: R-19
  - Code 2004, All Climates: R-21
  - Code 2006, Climate 5, 6: R-21
  - Code 2006, Climate 7: R-26 (used R-27 for model, as R-26 was not available)

Doors and Windows
- Doors: 1 front, 1 back
- Window Area: front 72, right 36, back 72, left 36
- Window U-value (inverse of R-values):
  - 1999 Code: U-.5
  - 2004 Code: U-.35
  - 2006 Code: U-.35

Skylights
- Skylight: None

Roof and Attic
- Exterior roof: Composition Shingles
- Insulation R-value: R-0
- Roof Pitch: 3:12
- Shade of the exterior surface of the roof: Medium dark (absorption 0.85).
- Attic or ceiling type: Unconditioned attic
- Attic floor insulation:
  - 1999 Code, Climate 5: R-30
  - 1999 Code, Climates 6, 7: R-38
  - 2004 Code: R-49
  - 2006 Code: R-49

Ducts, Pipes, and Thermostats
- Duct location: Unconditioned basement
- Duct insulation: Yes
- Duct sealing:
  - 1999 Code: No
  - 2004 Code: No
  - 2006 Code: Yes
- Boiler pipes insulation: No

Thermostat

- Thermostat type: Standard
  Settings and start times (military time):

	Weekdays	
	Daytime	**Nighttime**
Heating:	**70 degrees F, 8:00**	**68 degrees F, 17:00**
Cooling:	**78 degrees F, 8:00**	**74 degrees F, 17:00**
	Weekends & holidays	
	Daytime	**Nighttime**
Heating:	**70 degrees F, 8:00**	**68 degrees F, 17:00**
Cooling:	**74 degrees F, 8:00**	**74 degrees F, 17:00**

Heating Equipment

- Heating system type: Central Gas furnace
- Boiler/water heater arrangement type: Separate boiler and water heater
- Heating system efficiency: 80
- Percentage of floor space heated by the heating system: 100%

Cooling Equipment

- Cooling system type: Central air conditioner
- Cooling system efficiency: 11
- Percentage of floor space cooled by the cooling system: 100%
- Ceiling Fans: Yes; Number of Ceiling fans: 2

Other Home Attributes:
Do not contribute to heating or cooling costs and savings

Water Heater

- Water heater fuel: Piped Natural Gas
- Energy Factor: .54
- Recovery Efficiency: .76
- Rated Input: 38000
- Tank Size: 40
- Location: Garage

Refrigerators and Freezers

- First Refrigerator Year: 2005; Size: Large (19-21 cu ft)

Cooking and Dishwasher

- Stove Fuel: Electricity; Amount of time each day stove is used: 1 hour/day
- Oven Fuel: Electricity; Amount of time each day Oven is used: 2 hours/week
- Dishwasher: Yes; Loads per week washed: 6

Laundry
- Clothes washer: Yes; Loads per week washed: 7; Weekly loads are washed/rinsed at the following temperatures: Hot/Warm: 0; Hot/Cold: 0; Warm/Warm: 3; Warm/Cold: 3; Cold/Cold: 1
- Clothes dryer fuel: Electricity; Loads per week dried: 7

Entertainment
- Answering Machine: Yes
- Audio System: Large System - < 3 hours/day use
- Cable Box: Yes
- Color TV: Yes; Hours per day of TV use (all sets combined): 7
- VCR: Yes
- Video Game: Yes

Home Office
- Computer: Yes
- Printer: Inkjet Printer

Miscellaneous Kitchen Equipment
- Coffee Machine - Drip: Yes; Microwave Oven: Yes; Toaster: Yes

Other Miscellaneous Equipment
- Home Care -- Upright Vacuum Cleaner: Yes
- Miscellaneous Electrical Uses -- Doorbell: Yes; Garage Door Opener: Yes; Hair Dryer: Yes; Iron: Yes

Lighting
The following number of lighting fixtures for these areas:
Kitchen: 2 fixtures;
Dining Room: 1 fixtures;
Living Room: 3 fixtures;
Family Room: 1 fixtures;
Master Bedroom: 2 fixtures;
Hall: 2 fixtures;
Bedroom(s) - total for all bedrooms: 2 fixtures;
Bathroom(s) - total for all bathrooms: 2 fixtures;
Closet(s) - total for all closets: 0 fixtures;
Utility Room: 0 fixtures;
Garage: 1 fixtures;
Outdoor Lighting: 2 fixtures;

Appendix J.5. Breakdown kWh and Therms Usage by Home's Size, Region, and Code

1999 Code	Sq. Feet	approx % homes	# of homes	kWh cooling	kWh heating	Therms
Climate 5	1200	4.1%	1,724	837	142	763
Climate 5	2200	61.4%	25,865	897	229	1123
Climate 5	3500	16.4%	6,897	897	317	1587
Climate 6	1200	0.7%	313	808	142	750
Climate 6	2200	11.2%	4,702	838	229	1138
Climate 6	3500	3.0%	1,254	838	317	1606
Climate 7	1200	0.2%	68	277	175	934
Climate 7	2200	2.4%	1,016	218	234	1349
Climate 7	3500	0.6%	271	159	351	1815
Total		100.0%	42,111	36,358,403	10,217,824	50,833,405
Grand Total					46,576,227	50,833,405
2004 Code	Sq. Feet	approx % homes	# of homes	kWh cooling	kWh heating	Therms
Climate 5	1200	4.1%	1,724	808	112	568
Climate 5	2200	61.4%	25,865	838	171	877
Climate 5	3500	16.4%	6,897	808	259	1270
Climate 6	1200	0.7%	313	749	113	611
Climate 6	2200	11.2%	4,702	749	172	941
Climate 6	3500	3.0%	1,254	719	260	1361
Climate 7	1200	0.2%	68	277	145	806
Climate 7	2200	2.4%	1,016	218	234	1216
Climate 7	3500	0.6%	271	159	322	1757
Total		100.0%	42,111	33,582,334	7,907,435	40,120,233
Grand Total					41,489,769	40,120,233

2006 Code	Sq. Feet	approx % homes	# of homes	kWh cooling	kWh heating	Therms
Climate 5	1200	4.1%	1,724	779	112	526
Climate 5	2200	61.4%	25,865	808	171	817
Climate 5	3500	16.4%	6,897	808	230	1182
Climate 6	1200	0.7%	313	720	113	518
Climate 6	2200	11.2%	4,702	690	143	776
Climate 6	3500	3.0%	1,254	690	231	1250
Climate 7	1200	0.2%	68	277	116	673
Climate 7	2200	2.4%	1,016	218	175	855
Climate 7	3500	0.6%	271	159	263	1441
Total			42,111	32,433,510	7,456,776	37,310,707
Grand Total					39,890,286	37,310,707

Appendix J.6. 2004 MI Residential House Heating Fuel[17]

Fuel	**% of Residences**
Natural Gas	78.22%
LP Gas or Propane	9.44%
Electricity	6.64%
Fuel or Kerosene	3.46%
Coal or Coke	0.02%
Wood	1.44%
Solar Energy	0.02%
Other Fuel	0.49%
No Fuel Used	0.28%
Total	100%

Appendix J.7. Economic Effects of MCCP Code by 2025 on Sectors

Sector	Units	2007	2008	2009	2010	2011	2012	2013	2014	2015
Housing	Percent	2%	2%	2%	2%	2%	2%	2%	2%	2%
Utilities	2000 Fixed $ Million	-2.701	-4.487	-6.513	-8.644	-10.364	-11.746	-12.879	-13.846	-15.09
Petroleum, coal prod Mfg.	2000 Fixed $ Million	0.033	-0.072	-0.213	-0.371	-0.561	-0.692	-0.751	-0.771	-0.79
Utilities	2000 Fixed $ Million	-2.269	-4.058	-5.288	-6.804	-8.675	-9.893	-10.979	-12.253	-14.208
Household Operation	2000 Fixed $ Million	-9.7119	-19.2137	-28.03	-36.52	-45.112	-52.249	-57.292	-60.819	-64.944
All Consumption Sectors	2000 Fixed $ Million	5.82714	11.52822	16.818	21.912	27.0672	31.3494	34.3752	36.4914	38.9664
Broadcasting, Internet, Telecomm	2000 Fixed $ Million	3.88476	7.68548	11.212	14.608	18.0448	20.8996	22.9168	24.3276	25.9776
Construction	2000 Fixed $ Million	67.0373	56.4852	54.97	55.635	56.74	57.1624	56.8586	60.6984	64.1714
Electrical Equip, appliance Mfg.	2000 Fixed $ Million	0.07057	0.08392	0.09537	0.0968	0.09489	0.09251	0.08965	0.08249	0.07248

Sector	Units	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Housing	Percent	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Utilities	2000 Fixed $ Million	-17.308	-19.516	-21.57	-23.471	-25.466	-27.402	-29.346	-31.196	-33.175	-34.871
Petroleum, coal prod Mfg.	2000 Fixed $ Million	-0.809	-0.806	-0.792	-0.74	-0.658	-0.549	-0.406	-0.245	-0.06	0.151
Utilities	2000 Fixed $ Million	-14.497	-20.182	-35.686	-43.226	-47.14	146.075	-55.043	-46.331	-40.454	-38.707
Household Operation	2000 Fixed $ Million	-70.124	-77.286	-87.861	-95.568	-101.322	-49.413	-110.934	-111.325	-112.916	-115.458
All Consumption Sectors	2000 Fixed $ Million	42.0744	46.3716	52.7166	57.3408	60.7932	29.6478	66.5604	66.795	67.7496	69.2748
Broadcasting, Internet, Telecomm	2000 Fixed $ Million	28.0496	30.9144	35.1444	38.2272	40.5288	19.7652	44.3736	44.53	45.1664	46.1832
Construction	2000 Fixed $ Million	63.0814	66.6482	69.1243	75.638	80.816	97.523	98.311	98.3482	102.3048	107.297
Electrical Equip, appliance Mfg.	2000 Fixed $ Million	-2.75318	-2.77941	-2.87907	-0.1292	1.3113	2.4977	2.9763	0.05054	-0.00382	-0.03719

Appendix J.8. Sector Stakeholders

Those in the list below were contacted in relation to the building codes research.

Organization
SE Building Industry Association
Urban Options/Warm Training
Pulte
Greater Lansing Home Builders Association
WARM Training
WARM Training
AIA Michigan
MI Manufactured Housing Association
Michigan Environmental Council
MI State Building and Construction Trades Council
Urban Options
Construction Codes and Fire Safety
Energy and Environmental Buildings Association
DLEG Energy Office
Kalamazoo Department of Human Services
City of Ann Arbor
THAW Fund
Alliance to Save Energy
Newman Consulting Group
Dow Chemical Company
WA Building Code
DLEG Energy Office
Paz Homes
Walbridge Aldinger
Michigan Environmental Council
DLEG Energy Office
DLEG Energy Office- Rebuild Michigan
Public Service Commission
Oakland Livingston Human Service Agency
Odeena Development
MW Energy Efficiency Alliance
Building Codes Assistance Project
Indigo Financial Group

Appendix K. Mass Transit

Appendix K.1. BAU Scenario

For both the GHG and economic modeling, the MCCP team used historical fuel consumption (Table K.1-1) data from the Federal Transit Administration's (FTA) primary database for statistics on the transit industry and the National Transit Database (NTD). Historical diesel and biodiesel fuel consumed by Michigan mass transit buses was extrapolated from the 1997-2004 annual reports (Table K.1-1).[xiv] Using the 1997-2004 data, the MCCP team calculated the average annual changes (percent) in diesel and biodiesel fuel consumption and used these percentages to establish a BAU scenario for the modeling period of 2007-2025. Diesel and biodiesel were the only two fuels used in estimating the total fuel demand; gasoline, CNG and other fuels were not included in the policy parameters since vehicles powered by these other fuels are unable to run on biodiesel. The BAU annual increases were used as follows:

- 0.84 % for Petroleum Diesel
- 4.23 % B20

Table K.1-2 presents annual the fuel requirements to fulfill Michigan's projected demand (based on the annual VMT), during the modeling timeframe. The BAU and Fuel-Switch scenario require (Appendix K.2) the same volume of fuel (assumed similar fuel economy). However, the ratio of diesel to biodiesel differs from the BAU scenario to the policy scenario.

Table K.1-1. Historical Fuel Usage in Michigan Transit Buses 1997- 2004 (gallons)

	1997	1998	1999	2000	2001	2002	2003	2004
Petroleum Diesel	12,512	13,397	13,877	13,896	13,759	13,246	12,676	13,197
Biodiesel (B20)	0	0	0	0	0	220	225	239

Source: NTD 1997-2004
Note: U of MI Transportation Services was the only transit agency reporting the use of biodiesel from 1997-2004.

[xiv] NTD indicates that extensive efforts have been made to assure the quality of information contained in the reports, but that it is impossible to achieve complete accuracy and consistency. Reported data do not include all relevant information generally necessary to explain apparent differences in performance (e.g., climate, unusual events such as strikes, and topography). However, this was the best dataset available to MCCP team.

Table K.1-2. BAU Michigan Transit Bus Fuel Usage 2005-2025 (gallons)

	2005	2006	2007	2008	2009	2010	2011
Petro Diesel	13,307,619	13,419,403	13,532,126	13,645,796	13,760,420	13,876,008	13,992,566
Biodiesel (B20)	248,963	259,494	270,470	281,911	293,836	306,265	319,221
Total Motor Fuel	13,556,582	13,678,897	13,802,596	13,927,707	14,054,257	14,182,273	14,311,787
Total Petro Diesel	13,506,789	13,626,998	13,748,502	13,871,325	13,995,489	14,121,020	14,247,943
Total Biodiesel (B100)	49,793	51,899	54,094	56,382	58,767	61,253	63,844

	2012	2013	2014	2015	2016	2017	2018
Petro Diesel	14,110,104	14,228,629	14,348,149	14,468,674	14,590,211	14,712,768	14,836,356
Biodiesel (B20)	332,724	346,798	361,467	376,757	392,694	409,305	426,619
Total Motor Fuel	14,442,827	14,575,427	14,709,617	14,845,431	14,982,905	15,122,073	15,262,974
Total Petro Diesel	14,376,283	14,506,067	14,637,323	14,770,080	14,904,366	15,040,212	15,177,651
Total Biodiesel (B100)	66,545	69,360	72,293	75,351	78,539	81,861	85,324

	2019	2020	2021	2022	2023	2024	2025
Petro Diesel	14,960,981	15,086,653	15,213,381	15,341,174	15,470,039	15,599,988	15,731,028
Biodiesel (B20)	444,665	463,474	483,079	503,513	524,812	547,011	570,150
Total Motor Fuel	15,405,646	15,550,127	15,696,460	15,844,687	15,994,851	16,146,999	16,301,178
Total Petro Diesel	15,316,713	15,457,432	15,599,844	15,743,984	15,889,889	16,037,597	16,187,148
Total Biodiesel (B100)	88,933	92,695	96,616	100,703	104,962	109,402	114,030

Appendix K.2. Fuel-Switch GHG Model

The MCCP Mass Transit Fuel- Switch model was developed using Microsoft Excel to calculate the net GHG benefit from switching from petroleum diesel to biodiesel (B20). Figure 6A-2 provides the calculation methodology for the Fuel-Switch model and presents the following primary steps for model execution:

- Determine the affected urban mass transit agencies.
- Determine the baseline fuel usage for the affected urban mass transits agencies for the modeling period (2007- 2025) presented in Table K.1-2.
- Determine the fuel usage under the fuel-switch policy (Table K.2-1).
- Determine the vehicle miles traveled (VMT) by the urban mass transit buses using the biodiesel.
- Convert DOE/USDA Urban Bus Emission Factors (g/bhp-hr Table K.2-2) to WTW GHG Emission Factors (g/mi Table K.2-4, K.2-5 and K.2-6) using EPA Diesel Transit Bus Conversion Factors (bhp-hr/mi Table K.2-3). To get WTW GHG emission factors.
- Apply the WTW GHG emission factors (g/mi) to the calculated vehicle mile traveled with a fuel-switch.
- Calculate the net benefit of displacing petroleum diesel with biodiesel.

The following section provides the input data used in developing the MCCP Mass Transit Fuel-Switching GHG Model.

Table K.2-1. Michigan Transit Bus Fuel Usage 2007-2025 under the Fuel-Switch (gallons)

	2007	2008	2009	2010	2011	2012	2013
Petro Diesel	0	0	0	0	0	0	0
Biodiesel (B20)	13,802,596	13,927,707	14,054,257	14,182,273	14,311,787	14,442,827	14,575,427
Total Motor Fuel	13,802,596	13,927,707	14,054,257	14,182,273	14,311,787	14,442,827	14,575,427
Total Petro Diesel	11,042,077	11,142,166	11,243,405	11,345,819	11,449,429	11,554,262	11,660,341
Total Biodiesel (B100)	2,760,519	2,785,541	2,810,851	2,836,455	2,862,357	2,888,565	2,915,085

	2014	2015	2016	2017	2018	2019	2020
Petro Diesel	0	0	0	0	0	0	0
Biodiesel (B20)	14,709,617	14,845,431	14,982,905	15,122,073	15,262,974	15,405,646	15,550,127
Total Motor Fuel	14,709,617	14,845,431	14,982,905	15,122,073	15,262,974	15,405,646	15,550,127
Total Petro Diesel	11,767,693	11,876,345	11,986,324	12,097,659	12,210,379	12,324,517	12,440,102
Total Biodiesel (B100)	2,941,923	2,969,086	2,996,581	3,024,415	3,052,595	3,081,129	3,110,025

	2021	2022	2023	2024	2025
Petro Diesel	0	0	0	0	0
Biodiesel (B20)	15,696,460	15,844,687	15,994,851	16,146,999	16,301,178
Total Motor Fuel	15,696,460	15,844,687	15,994,851	16,146,999	16,301,178
Total Petro Diesel	12,557,168	12,675,749	12,795,881	12,917,599	13,040,942
Total Biodiesel (B100)	3,139,292	3,168,937	3,198,970	3,229,400	3,260,236

Table K.2-2. EPA Diesel Transit Bus Conversion Factors (bhp-hr/mi) 1987-2025

1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
4.595	4.602	4.609	4.617	4.625	4.635	4.645	4.655	4.667	4.679

1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
4.688	4.698	4.707	4.716	4.726	4.735	4.744	4.754	4.763	4.772

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
4.782	4.791	4.800	4.810	4.819	4.828	4.838	4.847	4.856	4.866

2017	2018	2019	2020	2021	2022	2023	2024	2025
4.875	4.884	4.894	4.903	4.912	4.922	4.931	4.940	4.950

Note: Conversion factors for 1997-2025 were calculated using linear regression
Source: U.S. EPA 1998 Update Heavy-Duty Engine Emission Conversion Factors for MOBILE6 Table 26

Table K.2-3. DOE/USDA Emission Factors for Soy Biodiesel in an Urban Bus (g/bhp-hr)

Fuel	CO_2	CH_4	N_2O
Petroleum Diesel	633.275	0.203	0.007
B100	136.447	0.198	0.002
B20	534.100	0.202	0.006

Source: U.S. DOE and USDA 1998 Lifecycle Inventory of Biodiesel and Petroleum Diesel for Use in Urban Buses, May 1998.

Table K.2-4. CO_2 WTW Emission Factors (g/mi)

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Diesel	2,910	2,914	2,919	2,924	2,929	2,935	2,942	2,948	2,955	2,963
B100	627	628	629	630	631	632	634	635	637	638
B20	2,454	2,458	2,462	2,466	2,470	2,476	2,481	2,486	2,493	2,499

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Diesel	2,969	2,975	2,981	2,987	2,993	2,999	3,004	3,010	3,016	3,022
B100	640	641	642	644	645	646	647	649	650	651
B20	2,504	2,509	2,514	2,519	2,524	2,529	2,534	2,539	2,544	2,549

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Diesel	3,028	3,034	3,040	3,046	3,052	3,058	3,064	3,069	3,075	3,081
B100	652	654	655	656	658	659	660	661	663	664
B20	2,554	2,559	2,564	2,569	2,574	2,579	2,584	2,589	2,594	2,599

	2017	2018	2019	2020	2021	2022	2023	2024	2025
Diesel	3,087	3,093	3,099	3,105	3,111	3,117	3,123	3,129	3,135
B100	665	666	668	669	670	672	673	674	675
B20	2,604	2,609	2,614	2,619	2,624	2,629	2,634	2,639	2,644

Note: Conversion factors for 1996-2025 were calculated using linear regression.

Table K.2-4. CH_4 WTW Emission Factors (g/mi)

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Diesel	0.932	0.933	0.935	0.937	0.938	0.940	0.942	0.944	0.947	0.949
B100	0.908	0.909	0.911	0.912	0.914	0.916	0.918	0.920	0.922	0.925
B20	0.927	0.929	0.930	0.932	0.933	0.935	0.937	0.939	0.942	0.944

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Diesel	0.951	0.953	0.955	0.957	0.959	0.960	0.962	0.964	0.966	0.968
B100	0.926	0.928	0.930	0.932	0.934	0.936	0.938	0.939	0.941	0.943
B20	0.946	0.948	0.950	0.952	0.954	0.955	0.957	0.959	0.961	0.963

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Diesel	0.970	0.972	0.974	0.976	0.977	0.979	0.981	0.983	0.985	0.987
B100	0.945	0.947	0.949	0.950	0.952	0.954	0.956	0.958	0.960	0.962
B20	0.965	0.967	0.969	0.971	0.972	0.974	0.976	0.978	0.980	0.982

	2017	2018	2019	2020	2021	2022	2023	2024	2025
Diesel	0.989	0.991	0.993	0.995	0.996	0.998	1.000	1.002	1.004
B100	0.963	0.965	0.967	0.969	0.971	0.973	0.974	0.976	0.978
B20	0.984	0.986	0.987	0.989	0.991	0.993	0.995	0.997	0.999

Note: Conversion factors for 1996-2025 were calculated using linear regression.

Table K.2-5. N_2O WTW Emission Factors (g/mi)

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Diesel	0.031	0.031	0.031	0.031	0.031	0.031	0.032	0.032	0.032	0.032
B100	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
B20	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.028

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Diesel	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
B100	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
B20	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Diesel	0.032	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
B100	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
B20	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.029	0.029	0.029

	2017	2018	2019	2020	2021	2022	2023	2024	2025
Diesel	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.034	0.034
B100	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
B20	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029

Note: Conversion factors for 1996-2025 were calculated using linear regression.

Appendix K.3. Fuel-Switch Economic Model

The economic modeling of a Fuel-Switch in Mass Transit Buses used the Energy 2020 and REMI models to capture the economic costs associated with additional production of in-state biodiesel. The prices of petroleum diesel and biodiesel were assumed to be the same during the model timeframe of 2007-2025. Table K.3-1 presents the key economic implications to increased biodiesel production in the state and this includes capital costs to plant construction. The Energy 2020 and REMI models capture the associated economy-wide benefits from these modeled costs.

Table K.3-1. Biodiesel Capital Investment--Plant Base Equipment and Acid Esterification

	Estimated Cost for a $5 million gallon/yr Reference Facility (Million $)	Percent of Total Estimated Cost
Cost of Equipment Purchase	2.4	29%
Cost of Construction	4.6	56%
Other Capital Costs	0.5	6%
Project Development Costs	0.7	9%
Total Capital Investment	8.2	100%

Source: Michigan Department of Agriculture 2006a.[18]

The main input for the Energy 2020 model was the historical and projected fuel consumption for the model timeframe. This was the same information used in the GHG model (Tables K.1-2 and K.2-1). Table K.3-2 presents the modeled effect on the selected REMI policy variables. The data presented in Table K.3-2 represents an increase or decrease to the baseline value of that REMI variable. Baseline values are established by REMI. Variable descriptions are included in Appendix D and Table K.3-3 presents the outputs from the REMI model.

Table K.3-2. Mass Transit Fuel-Switch REMI Input Variables - 2000 Fixed $ Million

Variable	Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Exogenous Final Demand	Petroleum, Coal Product Manufacturing	0.00	0.00	-5.39	-5.42	-5.46	-5.50	-5.54	-5.57	-5.61	-5.65	-5.69
Industry Sales/International Exports	State	0.00	0.00	5.39	5.42	5.46	5.50	5.54	5.57	5.61	5.65	5.69
Firm Sales	Construction	0.00	5.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Firm Sales	Electrical Equipment, Appliance	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Variable	**Sector**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
Exogenous Final Demand	Petroleum, Coal Product Manufacturing	-5.73	-5.77	-5.81	-5.85	-5.89	-5.93	-5.97	-6.01	-6.05	-6.09	
Industry Sales/International Exports	State	5.73	5.77	5.81	5.85	5.89	5.93	5.97	6.01	6.05	6.09	
Firm Sales	Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Firm Sales	Electrical Equipment, Appliance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

Table K.3-3. Mass Transit Fuel-Switch REMI Output

Economic Effect	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Employment (Job-Years)	67.9	34.2	33.2	33.7	32.7	31.3	29.3	29.3	28.8	26.9
GSP (million fixed 2000$)	5.68	4.24	4.12	4.18	4.43	4.21	4.24	4.33	4.24	4.27
Economic Effect	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
Employment (Job-Years)	27.3	27.8	26.3	26.9	27.8	26.9	28.8	26.4	27.3	
GSP (million fixed 2000$)	4.40	4.33	4.46	4.52	4.52	4.58	4.76	4.76	4.82	

Appendix K.4. Maps of TSM and 5 Build Alternatives

Figure K.4-1. TSM Alternative (Premium Bus)

Figure K.4-2. BRT 5 – Michigan Avenue

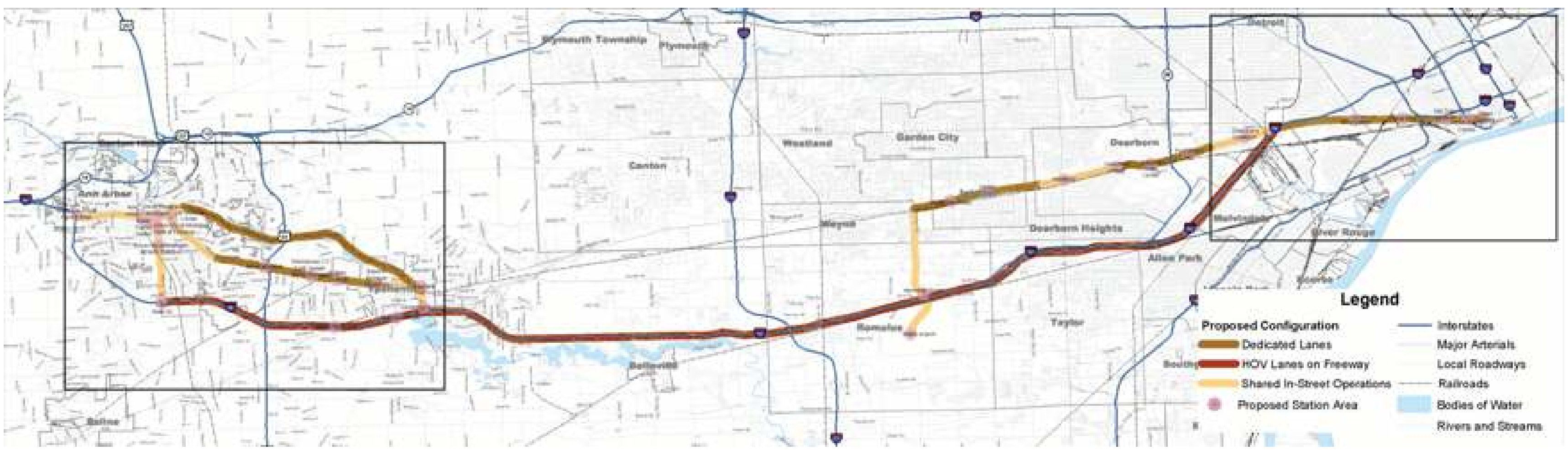


Figure K.4-3. BRT 6 – I-94/Michigan Avenue

Figure K.4-4. LRT 5 – Michigan Avenue

Figure K.4-5. CRT 1 – Norfolk Southern Michigan Line

Figure K.4-6. CRT 2 NS Detroit Division with BRT on I-94

Source: SEMCOG. Ann Arbor to Downtown Detroit Alternatives Analysis and Draft Environmental Impact Statement. December 2006. http://www.annarbordetroitrapidtransitstudy.com/news/pdfs/pub_mtng_1206.pdf.

Appendix K.5. Summary of Ann Arbor to Detroit Rapid Transit Study Results

Table K.5.1. Summary of Results

Goal/Measure		TSM	BRT 5	BRT 6	LRT 5	CRT 1	CRT 2
Daily transit trips using alternative		6,200	5,800	3,200	3,400	2,100	600
Capital costs ($M)	**Low**	$43	$879	$918	$2,641	$618	$1,107
	High		$969	$964	$2,870	$1,474	$1,432
Total annual O&M costs ($M)	**Low**	$25	$23	$26	$54	$93	$35
	High		$24	$27	$59	$111	$42

Source: SEMCOG. Ann Arbor to Downtown Detroit Alternatives Analysis and Draft Environmental Impact Statement. December 2006. http://www.annarbordetroitrapidtransitstudy.com/news/pdfs/pub_mtng_1206.pdf.

Appendix L. Renewable Energy Production Tax Credit

The Renewable Energy Production Tax Credit Appendix includes tables on the state electricity mix and calculations of coal and natural gas displaced by renewable energy before finally converting the mega-watt hours into million metric tons of carbon equivalents.

Table L-1. Michigan's Net MWh Generation by Energy			
Fuel Source	**MWh Sales Operating Year 2004**	**%**	**Total Generation accounting for 10% distribution losses**
Coal	67,777,483	0.61	75,308,314
Petroleum	1,063,893	0.01	1,182,103
Natural Gas	11,374,544	0.10	12,638,382
Other Gases	2,193	0.00	2,437
Nuclear	27,953,563	0.25	31,059,514
Hydroelectric Conventional	1,385,823	0.01	1,539,803
Other Renewables	2,806,807	0.03	3,118,674
Total	111,347,060	1.00	124,849,229

Source: (EIA-906)

Table L-2. Mega-Watt Hours Under BAU and PTC Scenarios and the Differences

Basecase (MWh)		**% renewable**	**0.025**	**0.025**	**0.025**	**0.025**
Fuel Source	**2004**	**%**	**2007**	**2008**	**2009**	**2010**
Coal	75,308,314	0.60	78,798,897	79,988,864	81,191,922	82,408,212
Natural Gas	12,638,382	0.10	13,206,617	13,400,332	13,596,179	13,794,180
Petroleum	1,182,103	0.01	1,182,103	1,182,103	1,182,103	1,182,103
Other Gases	2,436.67	0.00	2,437	2,437	2,437	2,437
Nuclear	31,059,514	0.25	31,059,514	31,059,514	31,059,514	31,059,514
Hydro Conventional	1,539,803	0.01	1,539,803	1,539,803	1,539,803	1,539,803
Other Renewables	3,118,674	0.02	3,225,368	3,260,848	3,296,717	3,332,981
Total	124,849,228	1.00	129,014,740	130,433,902	131,868,675	133,319,230
PTC (MWh)		**% renewable**	**0.030**	**0.035**	**0.040**	**0.045**
Fuel Source	**2004**	**%**	**2007**	**2008**	**2009**	**2010**
Coal	75,308,314.44	0.60	78,798,897	79,427,999	80,057,851	80,688,394
Natural Gas	12,638,382.22	0.10	13,206,617	13,309,028	13,411,563	13,514,209
Petroleum	1,182,103.33	0.01	1,182,103	1,182,103	1,182,103	1,182,103
Other Gases	2,436.67	0.00	2,437	2,437	2,437	2,437
Nuclear	31,059,514.44	0.25	31,059,514	31,059,514	31,059,514	31,059,514
Hydro Conventional	1,539,803.33	0.01	1,539,803	1,539,803	1,539,803	1,539,803
Other Renewables	3,118,674.44	0.02	3,225,368	3,913,017	4,615,404	5,332,769
Total	124,849,228.89	1.00	129,014,740	130,433,902	131,868,675	133,319,230
Difference Between BAU and Policy (MWh)						
Fuel Source	**2004**		**2007**	**2008**	**2009**	**2010**
Coal	75,308,314.44		0	560,866	1,134,071	1,719,818
Natural Gas	12,638,382.22		0	91,304	184,616	279,970
Petroleum	1,063,893.00		0	0	0	0
Other Gases	2,193.00		0	0	0	0
Nuclear	27,953,563.00		0	0	0	0
Hydro Conventional	1,385,823.00		0	0	0	0
Other Renewables	2,806,807.00		0	-652,170	-1,318,687	-1,999,788
Total	111,347,060.00		0	652,170	1,318,687	1,999,788

Table L-2. Mega-Watt Hours Under BAU and PTC Scenarios and the Differences (cont'd)

Basecase (MMh)	**% renewable**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**
Fuel Source		**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Coal		83,637,882	84,881,079	86,137,950	87,408,647	88,693,322	89,992,128
Natural Gas		13,994,358	14,196,739	14,401,346	14,608,204	14,817,337	15,028,770
Petroleum		1,182,103	1,182,103	1,182,103	1,182,103	1,182,103	1,182,103
Other Gases		2,437	2,437	2,437	2,437	2,437	2,437
Nuclear		31,059,514	31,059,514	31,059,514	31,059,514	31,059,514	31,059,514
Hydro Conventional		1,539,803	1,539,803	1,539,803	1,539,803	1,539,803	1,539,803
Other Renewables		3,369,644	3,406,710	3,444,183	3,482,069	3,520,372	3,559,096
Total		134,785,742	136,268,385	137,767,337	139,282,778	140,814,889	142,363,852
PTC (Mwh)	**% renewable**	**0.045**	**0.050**	**0.050**	**0.050**	**0.050**	**0.050**
Fuel Source		**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Coal		81,319,567	81,951,308	83,175,952	84,414,067	85,665,802	86,931,305
Natural Gas		13,616,958	13,719,800	13,919,160	14,120,714	14,324,485	14,530,497
Petroleum		1,182,103	1,182,103	1,182,103	1,182,103	1,182,103	1,182,103
Other Gases		2,437	2,437	2,437	2,437	2,437	2,437
Nuclear		31,059,514	31,059,514	31,059,514	31,059,514	31,059,514	31,059,514
Hydro Conventional		1,539,803	1,539,803	1,539,803	1,539,803	1,539,803	1,539,803
Other Renewables		6,065,358	6,813,419	6,888,367	6,964,139	7,040,744	7,118,193
Total		134,785,742	136,268,385	137,767,337	139,282,778	140,814,889	142,363,852
Difference Between BAU and Policy (MWh)							
Fuel Source		**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Coal		2,318,315	2,929,770	2,961,998	2,994,580	3,027,520	3,060,823
Natural Gas		377,400	476,939	482,186	487,490	492,852	498,273
Petroleum		0	0	0	0	0	0
Other Gases		0	0	0	0	0	0
Nuclear		0	0	0	0	0	0
Hydro Conventional		0	0	0	0	0	0
Other Renewables		-2,695,715	-3,406,710	-3,444,183	-3,482,069	-3,520,372	-3,559,096
Total		2,695,715	3,406,710	3,444,183	3,482,069	3,520,372	3,559,096

Table L-2. Mega-Watt Hours Under BAU and PTC Scenarios and the Differences (cont'd)

Basecase (MWh)	**% renewable**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**
Fuel Source		**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Coal		91,305,221	92,632,758	93,974,898	95,331,801	96,703,631	98,090,550
Natural Gas		15,242,530	15,458,640	15,677,128	15,898,020	16,121,341	16,347,118
Petroleum		1,182,103	1,182,103	1,182,103	1,182,103	1,182,103	1,182,103
Other Gases		2,437	2,437	2,437	2,437	2,437	2,437
Nuclear		31,059,514	31,059,514	31,059,514	31,059,514	31,059,514	31,059,514
Hydro Conventional		1,539,803	1,539,803	1,539,803	1,539,803	1,539,803	1,539,803
Other Renewables		3,598,246	3,637,827	3,677,843	3,718,299	3,759,201	3,800,552
Total		143,929,855	145,513,083	147,113,727	148,731,978	150,368,030	152,022,078
PTC (MWh)	**% renewable**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
Fuel Source		**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Coal		88,210,729	89,504,227	90,811,953	92,134,064	93,470,718	94,822,075
Natural Gas		14,738,775	14,949,345	15,162,230	15,377,458	15,595,053	15,815,041
Petroleum		1,182,103	1,182,103	1,182,103	1,182,103	1,182,103	1,182,103
Other Gases		2,437	2,437	2,437	2,437	2,437	2,437
Nuclear		31,059,514	31,059,514	31,059,514	31,059,514	31,059,514	31,059,514
Hydro Conventional		1,539,803	1,539,803	1,539,803	1,539,803	1,539,803	1,539,803
Other Renewables		7,196,493	7,275,654	7,355,686	7,436,599	7,518,401	7,601,104
Total		143,929,855	145,513,083	147,113,727	148,731,978	150,368,030	152,022,078
Difference Between BAU and Policy (MWh)							
Fuel Source		**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Coal		3,094,492	3,128,531	3,162,945	3,197,738	3,232,913	3,268,475
Natural Gas		503,754	509,296	514,898	520,562	526,288	532,077
Petroleum		0	0	0	0	0	0
Other Gases		0	0	0	0	0	0
Nuclear		0	0	0	0	0	0
Hydro Conventional		0	0	0	0	0	0
Other Renewables		-3,598,246	-3,637,827	-3,677,843	-3,718,299	-3,759,201	-3,800,552
Total		3,598,246	3,637,827	3,677,843	3,718,299	3,759,201	3,800,552

Table L-2. Mega-Watt Hours Under BAU and PTC Scenarios and the Differences (cont'd)

Basecase (MWh)		**0.025**	**0.025**	**0.025**
Fuel Source		**2023**	**2024**	**2025**
Coal		99,492,726	100,910,325	102,343,518
Natural Gas		16,575,379	16,806,151	17,039,462
Petroleum		1,182,103	1,182,103	1,182,103
Other Gases		2,437	2,437	2,437
Nuclear		31,059,514	31,059,514	31,059,514
Hydro Conventional		1,539,803	1,539,803	1,539,803
Other Renewables		3,842,358	3,884,624	3,927,355
Total		153,694,321	155,384,959	157,094,193
PTC (MWh)		**0.05**	**0.05**	**0.05**
Fuel Source		**2023**	**2024**	**2025**
Coal		96,188,298	97,569,549	98,965,993
Natural Gas		16,037,449	16,262,304	16,489,632
Petroleum		1,182,103	1,182,103	1,182,103
Other Gases		2,437	2,437	2,437
Nuclear		31,059,514	31,059,514	31,059,514
Hydro Conventional		1,539,803	1,539,803	1,539,803
Other Renewables		7,684,716	7,769,248	7,854,710
Total		153,694,321	155,384,959	157,094,193
Difference Between BAU and Policy (Mwh)				
Fuel Source		**2023**	**2024**	**2025**
Coal		3,304,428	3,340,777	3,377,525
Natural Gas		537,930	543,847	549,830
Petroleum		0	0	0
Other Gases		0	0	0
Nuclear		0	0	0
Hydro Conventional		0	0	0
Other Renewables		-3,842,358	-3,884,624	-3,927,355
Total		3,842,358	3,884,624	3,927,355

Table L-3. Total MWh Reduced from 2007-2025	
Coal	49,815,583
Natural Gas	8,109,513
Total	57,925,096

Table L-4. Total MWh Reduced from 2007-2015	
Coal	17,646,937
Natural Gas	2,872,757
Total	20,519,694

Table L-5. Greenhouse Gas Emissions by 2015

Fuel	Total Reduction (MWh)	MBtu	Emission Factor (lbsC/Mbtu)	generation efficiency	Emissions (short ton carbon)	Emissions (MMTCE)
Coal	17,646,937	5,172,021	57.29	0.3791	390,790	0.355
Distillate Fuel	0	0	43.99	0.3333	0	0.000
Petroleum Coke	0	0	61.41	0.3333	0	0.000
Residual Fuel	0	0	47.39	0.3333	0	0.000
Natural Gas	8,109,513	2,376,762	31.91	0.3317	114,338	0.104
						0.458

Fuel	Total Reduction (MWh)	MBtu	CH4 Emission Factor (Mton CH4/BBtu)	generation efficiency	Emissions (Mton CH4)	GWP CH4	CH4 Emissions (MMTCE)
Coal	17,646,937	5,172,021	0.0010	0.3791	6.837	21	0.000
Distillate Fuel	0	0	0.0030	0.3333	0.000	21	0.000
Petroleum Coke	0	0	0.0030	0.3333	0.000	21	0.000
Residual Fuel	0	0	0.0030	0.3333	0.000	21	0.000
Natural Gas	8,109,513	2,376,762	0.0009	0.3317	3.402	21	0.000
							0.000

Fuel	Total Reduction (MWh)	MBtu	N2O Emission Factor (Mton N2O/BBtu)	generation efficiency	Emissions (Mton N2O)	GWP N2O	N2O Emissions (MMTCE)
Coal	17,646,937	5,172,021	0.0014	0.3791	9.572	310	0.001
Distillate Fuel	0	0	0.0006	0.3333	0.000	310	0.000
Petroleum Coke	0	0	0.0006	0.3333	0.000	310	0.000
Residual Fuel	0	0	0.0006	0.3333	0.000	310	0.000
Natural Gas	8,109,513	2,376,762	0.0001	0.3317	0.340	310	0.000
							0.0008

Total	**0.4591**	**MMTCE**

Table L-5. Greenhouse Gas Emissions by 2025

Fuel	Total Reduction (Mwh)	Mbtu	Emission Factor (lbsC/Mbtu)	generation efficiency	Emissions (short ton carbon)	Emissions (MMTCE)
Coal	49,815,583	14,600,112	57.3	0.379	1,103,163	1.001
Distillate Fuel	0	0	44.0	0.333	0	0.000
Petroleum Coke	0	0	61.4	0.333	0	0.000
Residual Fuel	0	0	47.4	0.333	0	0.000
Natural Gas	8,109,513	2,376,762	31.9	0.332	114,338	0.104
						1.105

Fuel	Total Reduction (Mwh)	MBtu	CH4 Emission Factor (Mton CH4/BBtu)	generation efficiency	Emissions (Mton CH4)	GWP CH4	CH4 Emissions (MMTCE)
Coal	49,815,583	14,600,112	0.001	0.379	19.30	21	0.000
Distillate Fuel	0	0	0.003	0.333	0.00	21	0.000
Petroleum Coke	0	0	0.003	0.333	0.00	21	0.000
Residual Fuel	0	0	0.003	0.333	0.00	21	0.000
Natural Gas	8,109,513	2,376,762	0.001	0.332	3.40	21	0.000
							0.000

Fuel	Total Reduction (Mwh)	MBtu	N2O Emission Factor (Mton N2O/BBtu)	generation efficiency	Emissions (Mton N2O)	GWP N2O	N2O Emissions (MMTCE)
Coal	49,815,583	14,600,112	0.001	0.379	27.02	310	0.002
Distillate Fuel	0	0	0.001	0.333	0.00	310	0.000
Petroleum Coke	0	0	0.001	0.333	0.00	310	0.000
Residual Fuel	0	0	0.001	0.333	0.00	310	0.000
Natural Gas	8,109,513	2,376,762	0.000	0.332	0.34	310	0.000
							0.002

Total	**1.11**	**MMTCE**

Appendix M. Combined Heat and Power

Appendix M.1. 21st Century Energy Plan, CHP Report Section

MICHIGAN'S

21ST CENTURY ELECTRIC ENERGY PLAN

SUBMITTED TO

HONORABLE JENNIFER M. GRANHOLM

GOVERNOR OF MICHIGAN

BY

J. PETER LARK

CHAIRMAN, MICHIGAN PUBLIC SERVICE COMMISSION

JANUARY 2007

III. RENEWABLE RESOURCES AND ALTERNATIVE TECHNOLOGIES FOR MICHIGAN

A. Renewable Resource Forecasting

"Renewable energy" means energy generated by solar, wind, geothermal, biomass (including waste-to-energy and landfill gas) or hydroelectric sources.[32] While there is wide variation among the utilities, approximately 3 percent of the total electricity currently sold to Michigan utility customers is generated by renewable energy sources. Twenty-four states currently have a renewable portfolio standard (RPS) program in place, with targets between 1.1 percent and 30 percent, and target years ranging from 2009 to 2022. Ten-thousand MW of new renewable generation was announced in the first eight months of 2006.[33] It is time for Michigan to join these states, to encourage development of wind turbines and biodigesters in Michigan in the near term, and solar and fuel cell applications in the longer term. A required RPS is a win-win proposition. It will encourage the creation of in-state jobs, reduce pollution and dependence on fossil fuels, and provide a measure of protection from potential expensive future emissions regulations.

The more renewable resources are present to improve fuel diversity, the less the price of electricity will increase in response to increased coal and natural gas costs. Fuel diversity and the use of indigenous resources – especially those not subject to price volatility and shortages – represent valuable safeguards to utility ratepayers. Renewable and alternative energy technologies also produce less air pollution and greenhouse gases than the existing fleet of

[32] MCL 460.10g(1)(f). Michigan does not have access to geothermal sources of power. Hydro-power was not modeled for the Plan because the small scale of such projects does not, at present, justify the expense associated with permitting. Likewise, solar power was not modeled. The comparatively high capital costs and low capacity factor make it difficult to forecast solar energy market potential in Michigan at this time. However, it is noteworthy that United Solar Ovonic LLC and Hemlock Semiconductor Corporation, two manufacturers of solar-related products, have recently expanded production capability in Michigan, and the market across the country is growing. As the scale of operations and technology continue to improve, the cost and performance of solar applications will likely lead to their growth in Michigan.

[33] Fitch Ratings, "Wholesale Power Market Update," October 25, 2006, p. 9.

central station power plants. For example, wind and solar energy produce zero emissions during normal operations.

Modeling indicates a potential for at least 1,100 MW, and up to 2,700 MW, of new electric power capacity development in Michigan from renewable resources with another 180 MW available from combined heat and power, or CHP.[34] Forecasting in this area is particularly problematic, in light of the rapid pace of technological advancements and policy changes that will affect renewables. It is thus important to revisit renewable resource modeling on a regular basis, and to expand the renewable portfolio when appropriate.

For purposes of the Plan, modeling was performed for biomass and wind resources. Electricity can be produced from three major sources of biomass: (1) combustion of cellulose-containing biomass such as wood and cornstalks; (2) anaerobic digestion of wastewater treatment plant waste, and cattle, swine and poultry waste; and (3) combustion of landfill gas.

Wind energy production from utility-scale wind generators was also modeled. Uncertainties about markets, interconnection and production costs, and renewable energy policy have currently slowed new wind development in Michigan, but this area shows great potential. Estimates for Michigan's wind energy resources were based on data that generally depict wind regimes in the state, but should be supplemented by local wind studies. Based on units in the MISO queue and discussions with wind energy participants in Michigan, a minimum of 525 MW of wind resources should be available in Michigan over the next few years. A more robust estimate based on policy changes contemplated in this Plan could yield 2,400 MW of wind capacity.

Renewable resource assessment modeling for the Plan shows that Michigan's electric supply portfolio can achieve 7-10 percent renewable energy by the end of 2015. Based on the

[34] CHP is useful when there is need for both electricity and process steam at a location. CHP facilities use fuel to make steam to turn an electric generator, and then use the leftover steam in the factory's processes.

energy forecast, this amounts to approximately 5,200 to 9,200 GWh of additional renewable energy by December 31, 2015. The resource assessment conducted for the Plan demonstrates that Michigan has ample resources available to meet this level of renewable energy for electricity production.

B. Renewable Portfolio Standard

The Plan proposes an RPS that requires all load serving entities[35] (LSEs) in Michigan to gradually increase the percentage of renewable energy in their electric generation resource portfolios, until a minimum of 10 percent of total electricity generation requirement is met from qualifying renewable resources by the end of 2015.[36] This proposal calls for passage of enabling legislation in 2007, and would require all LSEs to obtain 3 percent of their generation requirements from qualifying renewable resources by the end of 2009. From that time forward, each LSE would be expected to increase the percentage of new[37] renewable resources utilized to meet their generation needs, until the 10 percent level is reached by the end of 2015.[38] If an LSE is already above the three percent level, then it must obtain the next 7 percent from new sources by the end of 2015. Prior to 2015, the Commission will review the performance and impact of the RPS, and contingent upon the results of this review, the Plan recommends that the Commission be authorized to require a further goal of a 20 percent RPS to be met by 2025.

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[35] The term Load Serving Entity (LSE) encompasses all entities providing electric retail sales service to Michigan customers. This includes investor owned utilities, cooperatively owned utilities, municipal utilities, and alternative electric suppliers with retail sales. The Commission does not have regulatory authority over municipal utilities, or utilities engaged only in wholesale sales. While the Plan recommends a renewable portfolio standard for municipal utilities, the Plan does not contemplate that the Commission would enforce such a standard.

[36] The quantity of renewable energy needed to achieve renewable portfolio targets will be based on each LSE's annual retail sales, measured in MWh.

[37] Pre-existing in-state renewable resources can be used until the utility meets the initial 3 percent target. The remaining seven percent must be obtained from new renewable sources.

[38] The proposed RPS would not require specific proportions of different renewable resource types, nor would it establish special treatment for any types. Instead, it would simply require LSEs to meet an overall percentage of qualifying renewable resources in their supply mix, and then let the LSEs achieve that goal by any means they find effective.

Under this RPS proposal, the risk of cost increases is reduced by allowing for: (1) rate impact limits, established by customer class; (2) one-year deferrals for LSEs that can demonstrate hardship in meeting the RPS target; and (3) reasonable alternate compliance payments (ACP) for LSEs with fewer than 100,000 customers, and for LSEs with more than 100,000 customers until the end of 2012. The ACP is a payment made to the energy efficiency fund (discussed in the following section) in lieu of meeting the RPS, and will make compliance easier for the smaller utilities.[39] For ease of administration, ACPs will be held in the energy efficiency fund, but will be used only for renewables projects.

The RPS will be met through the use of in-state renewable power. The Commission will develop rules allowing generators to initially self-certify their eligibility as renewable resources. LSEs would be authorized to meet their RPS obligations by building and owning renewable generation, by contracting with in-state renewable generators, or by buying qualifying renewable energy credits (REC) or ACPs. All reasonable compliance costs will be approved for cost recovery.

Most states with RPSs have incorporated REC trading. The Plan recommends that REC trading be approved for the Michigan RPS program. A REC is a unique, independently certified and verifiable record of the production of one megawatt hour of renewable energy. When employed in an RPS program, one REC is retired to represent each MWh of qualifying renewable energy sales to the LSE’s customers. Renewable resources serve to improve Michigan’s economy, help manage fuel costs, and reduce air emissions. To the degree that out-of-state RECs provide the same benefits, they should be recognized for use in Michigan. Thus, RECs may be purchased from out-of-state resources as long as the REC produced an air quality or economic benefit to Michigan. The Plan recommends that the Commission be charged with the task of finalizing details of the REC program.

[39] Twelve other states are experiencing success with ACPs.

ACP receipts, if any, will go into the energy efficiency fund and will thereafter be primarily dedicated to providing financial incentives for renewable energy systems in community-based renewables programs that will serve customers of the LSEs that are paying the ACP. In this way, ACP receipts will work to support the addition of in-state renewable resources and will leverage additional investment.

The Commission should be authorized to defer annual RPS targets for one year at a time if the LSE demonstrates hardship in meeting the target, or if it can be shown that the cumulative rate impact of meeting the RPS target exceeds an amount deemed reasonable by the Commission. The Commission should further be authorized to require remedies, issue and enforce penalties, or revoke licenses in response to LSEs that are found to be in violation of their RPS obligation. Prior to 2015, the Commission will conduct a study to determine the cost and performance impacts of the RPS, along with the availability and cost of renewable resources, and will consider adjustment of the RPS and associated deadlines. Contingent upon the results of this review, the Plan recommends that the Commission be authorized to require a further goal of a 20 percent RPS to be met by 2025.

C. Alternative Technologies and Distribution Reliability

The Alternative Technologies Workgroup concluded that although some alternative generation technologies are already in use, many other alternative technologies will play an important role in the future.[40] Nevertheless, from a regulatory standpoint, it is important that steps are taken now to make it easier to implement promising alternative technologies when they do become available. Thus, the Plan recommends that the Commission review tariff terms, and conditions of service, to identify and remove unnecessary barriers to renewable, alternative, and distributed energy applications.

[40] Alternative technologies include fuel cells, solar photovoltaic resources, and smart grid technologies.

The Plan proposes that net metering tariffs be made available for all qualifying renewable and CHP facilities less than 150 kW in size.[41] This size corresponds to a grade school or middle school. The Plan further recommends that the Commission be authorized to establish tariffs for the use of a utility's distribution system in order to transmit electricity to wholesale market nodes or customers. A fixed monthly service charge could be applied to ensure that net metering customers would continue to pay their fair share of distribution system and utility administrative expenses.

As the scale of solar photovoltaic (PV) production increases and performance continues to improve, solar based applications are likely to grow in Michigan. These applications have a number of benefits including protection from fuel cost increases and harmful air emissions, as well as job creation within Michigan. To encourage adoption of this technology the Plan calls for residential property tax relief for homeowners who add solar PV, wind, fuel cell, or other renewable energy installations to their homes. Because of solar energy's long term potential to meet on-peak energy needs, the Plan further recommends that the Legislature authorize the Commission to conduct a pilot program involving one or more utilities to investigate the impact of solar-generated electricity on distribution reliability and on managing summer power costs in Michigan.

Finally, on the issue of distribution reliability, an ongoing concern is the quality of power delivered to the end user. Distribution lines are particularly vulnerable to disruptions caused by weather or growing trees. Sometimes problems confined to specific circuits or local distribution areas are due to recurring faults on existing lines. At other times they may be due to failure of the circuit to handle growing loads. Customers indicate that distribution failures cost them thousands of dollars of lost product. When major storms occur, distribution outages can be widespread and service restoration may take several days.

[41] Net metering is currently available only to installations less than 30 kW in size.

The transformation of Michigan's economy from traditional manufacturing to computer-assisted, high precision, flexible manufacturing processes, along with the growing role of sophisticated communications, requires better distribution reliability. In the near term, underground placement of distribution lines will harden our infrastructure and reduce distribution vulnerability, as well as enhance the beauty of the state.

Underground wires do a better job of keeping electricity flowing to homes, businesses, and neighborhoods. Currently, underground distribution facilities are required for new residential subdivisions and commercial developments. When roads are dug up for pipeline installation or widening, opportunities are being missed to bury lines at a reduced price. The Plan proposes that the Commission undertake an investigation of the cost of extending the requirement of underground placement to: (1) poorly performing existing circuits, (2) all secondary distribution line extensions and primary lines on the same poles, and (3) all primary and secondary distribution lines that are subject to roadway reconstruction work.[42] If the cost is deemed reasonable, the Plan further recommends that the Commission undertake rulemaking to mandate this extension of the burial requirement. Transmission and sub-transmission lines will not be affected by this effort.

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[42] A primary electrical distribution system delivers electricity from a substation to neighborhoods and back yards. It is operated at a voltage level that is too high for most customers to use. This higher voltage is used for efficiency in delivering electricity over long distances. A primary system, depending on the utility and the circuit, is usually operated at 4,800 volts to 14,400 volts. A secondary electric system is that part of a utility's system that actually connects to customers. Separating a primary system and a secondary system is a transformer that is used to bring the primary voltage down to levels that customers can use. The particular voltage depends on the customer's needs, and could include 480, 277, 240, 208 or 120 volts for a commercial or small industrial customer. Most, if not all, residences are served with a secondary voltage of 120 and 240 volts. Thus, the new standard would cover all residential neighborhoods, and many commercial and small industrial facilities.

Appendix M.2. Existing Boiler GHG Model Calculations: Large Boilers

	Fuel	**BBTU Equiv**	**Emission Factor (CO2)**	**Combustion Efficiency**	**Emissions (short tons) = (BBTU*EF*CF)**	**Emissions (MMTCE)**
	Coal	419	57.3	0.99	23,782	0.022
	Natural Gas	3,584	31.9	0.995	113,799	0.103
CO2	Other Petroleum	335	46.6	0.99	15,450	0.014
	Fuel	**BBTU Equiv**	**Emission Factor (N2O)**	**Combustion Efficiency**	**Emissions (short tons) = (BBTU*EF*CF)**	**Emissions (MMTCE)**
	Coal	419	0.00140	0.99	0.583	0.0000005
	Natural Gas	3,584	0.00009	0.995	0.339	0.0000003
N2O	Other Petroleum	335	0.00060	0.99	0.199	0.0000002
	Fuel	**BBTU Equiv**	**Emission Factor (CH4)**	**Combustion Efficiency**	**Emissions (short tons) = (BBTU*EF*CF)**	**Emissions (MMTCE)**
	Coal	419	0.00100	0.99	0.416	0.0000004
	Natural Gas	3,584	0.00095	0.995	3.386	0.0000031
CH4	Other Petroleum	335	0.00301	0.99	0.996	0.0000009
Total						**0.139**

Appendix M.3. Existing Boiler GHG Model Calculations: Medium Boilers

	Fuel	BBTU Equiv	Emission Factor (CO2)	Combustion Efficiency	Emissions (short tons) = (BBTU*EF*CF)	Emissions (MMTCE)
	Coal	785.1	57.3	0.99	44,529	0.040
	Natural Gas	2,397.1	31.9	0.995	76,108	0.069
CO2	Other Petroleum	18.5	46.6	0.99	855	0.001
	Fuel	**BBTU Equiv**	**Emission Factor (N2O)**	**Combustion Efficiency**	**Emissions (short tons) = (BBTU*EF*CF)**	**Emissions (MMTCE)**
	Coal	785.1	0.00140	0.99	1.091	0.00000099
	Natural Gas	2,397.1	0.00009	0.995	0.226	0.00000021
N2O	Other Petroleum	18.5	0.00060	0.99	0.011	0.00000001
	Fuel	**BBTU Equiv**	**Emission Factor (CH4)**	**Combustion Efficiency**	**Emissions (short tons) = (BBTU*EF*CF)**	**Emissions (MMTCE)**
	Coal	785.1	0.0010	0.99	0.779	0.00000071
	Natural Gas	2,397.1	0.0009	0.995	2.265	0.00000205
CH4	Other Petroleum	18.5	0.0030	0.99	0.055	0.00000005
Total						**0.1102**

Appendix M.4. Existing Boiler GHG Model Calculations: Small Boilers

	Fuel	BBTU Equiv	Emission Factor (CO2)	Combustion Efficiency	Emissions (short tons) = (BBTU*EF*CF)	Emissions (MMTCE)
	Coal	0	57.29	0.99	0	0
	Natural Gas	220	31.91	0.995	6,969	0.0063
CO2	Other Petroleum	56.1	47	0.99	2,590	0.0023
	Fuel	**BBTU Equiv**	**Emission Factor (N2O)**	**Combustion Efficiency**	**Emissions (short tons) = (BBTU*EF*CF)**	**Emissions (MMTCE)**
	Coal	0	0.0014	0.99	0	0
	Natural Gas	220	9.4955E-05	0.995	0.0207	0.00000002
N2O	Other Petroleum	56.1	0.0006	0.99	0.0334	0.00000003
	Fuel	**BBTU Equiv**	**Emission Factor (CH4)**	**Combustion Efficiency**	**Emissions (short tons) = (BBTU*EF*CF)**	**Emissions (MMTCE)**
	Coal	0	0.0010	0.99	0.0000	0.00000000
	Natural Gas	220	0.0009	0.995	0.2074	0.00000019
CH4	Other Petroleum	56.1	0.0030	0.99	0.1670	0.00000015
Total						**0.0087**

Appendix M.5. Existing Boiler GHG Model Calculations: Very Small Boilers

	Fuel	BBTU Equiv	Emission Factor (CO2)	Combustion Efficiency	Emissions (short tons) = (BBTU*EF*CF)	Emissions (MMTCE)
	Coal	0	57.29	0.99	0	0
	Natural Gas	617	31.91	0.995	19,593	0.018
CO2	Other Petroleum	0.829	46.6	0.99	38.3	0.00003
	Fuel	**BBTU Equiv**	**Emission Factor (N2O)**	**Combustion Efficiency**	**Emissions (short tons) = (BBTU*EF*CF)**	**Emissions (MMTCE)**
	Coal	0	0.001	0.99	0	0
	Natural Gas	617	9.4955E-05	0.995	0.058	5.28915E-08
N2O	Other Petroleum	0.829	0.0006	0.99	0.0005	4.47647E-10
	Fuel	**BBTU Equiv**	**Emission Factor (CH4)**	**Combustion Efficiency**	**Emissions (short tons) = (BBTU*EF*CF)**	**Emissions (MMTCE)**
	Coal	0	0.001	0.99	0	0
	Natural Gas	617	0.0009	0.995	0.583	5.28915E-07
CH4	Other Petroleum	0.829	0.003	0.99	0.002	2.23823E-09
Total						**0.018**

Appendix M.6. Existing Boiler GHG Model Calculations: Commercial Boilers

	Fuel	BBTU Equiv	Emission Factor (CO2)	Combustion Efficiency	Emissions (short tons) = (BBTU*EF*CF)	Emissions (MMTCE)
	Coal	0.00	57.29	0.99	0.00	0.00
	Natural Gas	525	31.91	0.995	16,666	0.015
CO2	Other Petroleum	4.28	46.63	0.99	198	0.0002
	Fuel	**BBTU Equiv**	**Emission Factor (N2O)**	**Combustion Efficiency**	**Emissions (short tons) = (BBTU*EF*CF)**	**Emissions (MMTCE)**
	Coal	0.00	0.001	0.99	0.00	0.00
	Natural Gas	525	0.0001	0.995	0.050	0.0000000450
N2O	Other Petroleum	4.28	0.0006	0.99	0.003	0.0000000023
	Fuel	**BBTU Equiv**	**Emission Factor (CH4)**	**Combustion Efficiency**	**Emissions (short tons) = (BBTU*EF*CF)**	**Emissions (MMTCE)**
	Coal	0.00	0.001	0.99	0.00	0.00
	Natural Gas	525	0.0009	0.995	0.496	0.00000045
CH4	Other Petroleum	4.28	0.003	0.99	0.013	0.00000001
Total						**0.015**

Appendix M.7. Existing Boiler GHG Model Calculations: Other Boilers

	Fuel	BBTU Equiv	Emission Factor (CO2)	Combustion Efficiency	Emissions (short tons) = (BBTU*EF*CF)	Emissions (MMTCE)
	Coal	337	57.29	0.99	19,098	0.017
	Natural Gas	2,527	31.91	0.995	80,222	0.073
CO2	Other Petroleum	262	46.63	0.99	12,113	0.011
	Fuel	**BBTU Equiv**	**Emission Factor (N2O)**	**Combustion Efficiency**	**Emissions (short tons) = (BBTU*EF*CF)**	**Emissions (MMTCE)**
	Coal	337	0.001	0.99	0.468	4.24362E-07
	Natural Gas	2,527	9.4955E-05	0.995	0.239	2.16565E-07
N2O	Other Petroleum	262	0.0006	0.99	0.156	1.41725E-07
	Fuel	**BBTU Equiv**	**Emission Factor (CH4)**	**Combustion Efficiency**	**Emissions (short tons) = (BBTU*EF*CF)**	**Emissions (MMTCE)**
	Coal	337	0.001	0.99	0.334	3.03116E-07
	Natural Gas	2,527	0.0009	0.995	2.39	2.16565E-06
CH4	Other Petroleum	262	0.003	0.99	0.781	7.08623E-07
Total						**0.1011**

Appendix M.8. New CHP System GHG Model Calculations: 8760 hrs Utilization

CO_2	Emissions	MWh	MBTU	BBTU	LbsC	Emissions (short ton Carbon)	Emissions (MMTCE)
Natural Gas	*large boilers*	474036	5,856,542	5,857	186,882,269	93,441	0.085
	medium boilers	334726	4,323,037	4,323	137,948,118	68,974	0.063
	Small Boilers	29942	372,067	372	11,872,655	5,936	0.005
	Very Small Boilers	76852	857,149	857	27,351,640	13,676	0.012
	Commercial	64802	714,413	714	22,796,916	11,398	0.010
	Other Boilers	252925	2,788,379	2,788	88,977,168	44,489	0.040
	Ethanol Facilities	54750	698,590	699	22,292,017	11,146	0.010
	Steel Facilities	219000	2,794,361	2,794	89,168,069	44,584	0.040
	Cement Kilns	54750	698,590	699	22,292,017	11,146	0.010
CH_4					Emissions (Metric Tons)	GWP	
Natural Gas	*large boilers*	474036	5,856,542	5,857	5.56	21	3.185E-05
	medium boilers	334726	4,323,037	4,323	4.10	21	2.351E-05
	Small Boilers	29942	386,704	387	0.37	21	2.103E-06
	Very Small Boilers	76852	954,984	955	0.91	21	5.1935E-06
	Commercial	64802	722,757	723	0.69	21	3.9306E-06
	Other Boilers	252925	2,788,379	2,788	2.65	21	1.5164E-05
	Ethanol Facilities	54750	698,590	699	0.66	21	3.7992E-06
	Steel Facilities	219000	2,794,361	2,794	2.65	21	1.5197E-05
	Cement Kilns	54750	698,590	699	0.66	21	3.7992E-06
N_2O					Emissions (Metric Tons)	GWP	
Natural Gas	*large boilers*	474036	5,856,542	556.1	0.556	310	4.7016E-05
	medium boilers	334726	4,323,037	410.5	0.410	310	3.4705E-05
	Small Boilers	29942	372,067	35.3	0.035	310	2.987E-06
	Very Small Boilers	76852	857,149	81.4	0.081	310	6.8812E-06
	Commercial	64802	714,413	67.8	0.068	310	5.7353E-06
	Other Boilers	252925	4,219,801	400.7	0.401	310	3.3877E-05
	Ethanol Facilities	54750	698,590	66.3	0.066	310	5.6083E-06
	Steel Facilities	219000	2,794,361	265.3	0.265	310	2.2433E-05
	Cement Kilns	54750	698,590	66.3	0.066	310	5.6083E-06

Natural Gas Emissions	All Potenital CHP	CO_2	CH_4	N_2O	Total Annual MMTCE
Totals		**0.2765**	**0.0001**	**0.0002**	**0.2768**

Appendix M.9. New CHP System GHG Model Calculations: 6570 hrs Utilization

CO2	**Emissions**	**MWh**	**MBTU**	**BBTU**	**LbsC**	**Emissions (short ton Carbon)**	**Emissions (MMTCE)**
Natural Gas	*large boilers*	355527	4,392,407	4,392	140,161,701	70,081	0.0636
	medium boilers	251044	3,242,278	3,242	103,461,089	51,731	0.0469
	Small Boilers	22456	279,050	279	8,904,492	4,452	0.0040
	Very Small Boilers	57639	642,862	643	20,513,730	10,257	0.0093
	Commercial	48602	535,810	536	17,097,687	8,549	0.0078
	Other Boilers	189694	2,091,284	2,091	66,732,876	33,366	0.0303
	Ethanol Facilities	41063	523,943	524	16,719,013	8,360	0.0076
	Steel Facilities	164250	2,095,771	2,096	66,876,051	33,438	0.0303
	Cement Kilns	41063	523,943	524	16,719,013	8,360	0.0076
CH4					**Emissions (Metric Tons)**	**GWP**	
Natural Gas	*large boilers*	355527	4,392,407	4,392	4.171	21	2.3887E-05
	medium boilers	251044	3,242,278	3,242	3.079	21	1.7633E-05
	Small Boilers	22456	290,028	290	0.275	21	1.5773E-06
	Very Small Boilers	57639	716,238	716	0.680	21	3.8951E-06
	Commercial	48602	542,068	542	0.515	21	2.9479E-06
	Other Boilers	189694	2,091,284	2,091	1.986	21	1.1373E-05
	Ethanol Facilities	41063	523,943	524	0.498	21	2.8494E-06
	Steel Facilities	164250	2,095,771	2,096	1.990	21	1.1398E-05
	Cement Kilns	41063	523,943	524	0.498	21	2.8494E-06
N2O					**Emissions (Metric Tons)**	**GWP**	
Natural Gas	*large boilers*	355527	4,392,407	417	0.417	310	3.5262E-05
	medium boilers	251044	3,242,278	308	0.308	310	2.6029E-05
	Small Boilers	22456	279,050	26	0.026	310	2.2402E-06
	Very Small Boilers	57639	642,862	61	0.061	310	5.1609E-06
	Commercial	48602	535,810	51	0.051	310	4.3015E-06
	Other Boilers	189694	3,164,851	301	0.301	310	2.5407E-05
	Ethanol Facilities	41063	523,943	50	0.050	310	4.2062E-06
	Steel Facilities	164250	2,095,771	199	0.199	310	1.6825E-05
	Cement Kilns	41063	523,943	50	0.050	310	4.2062E-06
	Natural Gas Emissions	**All Potenital CHP**	**CO2**	**CH4**	**N2O**	**Total Annual MMTCE**	
	Totals		**0.2074**	**0.0001**	**0.0001**	**0.2076**	

Appendix M.10. New CHP System GHG Model Calculations: 4380 hrs Utilization

CO2	**Emissions**	**MWh**	**MBTU**	**BBTU**	**LbsC**	**Emissions (short ton Carbon)**	**Emissions (MMTCE)**
Natural Gas	*large boilers*	237018	2,928,271	2,928	93,441,134	46,721	0.0424
	medium boilers	167363	2,161,519	2,162	68,974,059	34,487	0.0313
	Small Boilers	14971	186,033	186	5,936,328	2,968	0.0027
	Very Small Boilers	38426	428,575	429	13,675,820	6,838	0.0062
	Commercial	32401	357,206	357	11,398,458	5,699	0.0052
	Other Boilers	126463	1,394,189	1,394	44,488,584	22,244	0.0202
	Ethanol Facilities	27375	349,295	349	11,146,009	5,573	0.0051
	Steel Facilities	109500	1,397,181	1,397	44,584,034	22,292	0.0202
	Cement Kilns	27375	349,295	349	11,146,009	5,573	0.0051
CH4					**Emissions (Metric Tons)**	**GWP**	
Natural Gas	*large boilers*	237018	2,928,271	2,928	2.781	21	1.5925E-05
	medium boilers	167363	2,161,519	2,162	2.052	21	1.1755E-05
	Small Boilers	14971	193,352	193	0.184	21	1.0515E-06
	Very Small Boilers	38426	477,492	477	0.453	21	2.5968E-06
	Commercial	32401	361,379	361	0.343	21	1.9653E-06
	Other Boilers	126463	1,394,189	1,394	1.324	21	7.5821E-06
	Ethanol Facilities	27375	349,295	349	0.332	21	1.8996E-06
	Steel Facilities	109500	1,397,181	1,397	1.327	21	7.5983E-06
	Cement Kilns	27375	349,295	349	0.332	21	1.8996E-06
N2O					**Emissions (Metric Tons)**	**GWP**	
Natural Gas	*large boilers*	237018	2,928,271	278	0.278	310	2.3508E-05
	medium boilers	167363	2,161,519	205	0.205	310	1.7353E-05
	Small Boilers	14971	186,033	18	0.018	310	1.4935E-06
	Very Small Boilers	38426	428,575	41	0.041	310	3.4406E-06
	Commercial	32401	357,206	34	0.034	310	2.8677E-06
	Other Boilers	126463	2,109,900	200	0.200	310	1.6938E-05
	Ethanol Facilities	27375	349,295	33	0.033	310	2.8041E-06
	Steel Facilities	109500	1,397,181	133	0.133	310	1.1217E-05
	Cement Kilns	27375	349,295	33	0.033	310	2.8041E-06
	Natural Gas Emissions	**All Potenital CHP**	**CO2**	**CH4**	**N2O**	**Total Annual MMTCE**	
	Totals		**0.138**	**0.000**	**0.000**	**0.138**	

Appendix M.11. GHG Emissions from Utility: 8760-hour Scenario

CO2	**Emissions**	**MWh**	**MBTU**	**BBTU**	**LbsC**	**Emissions (short ton Carbon)**	**Emissions (MMTCE)**
Coal	*feasible*	1387584	13,727,382	13,727	786,441,686.5	393220.8433	0.35672761
	full potential	5550336	54,909,526	54,910	3,145,766,746.2	1572883.373	1.42691044
Natural Gas	*feasible*	189216	1,453,803	1,454	46,390,864.9	23195.43246	0.02104276
	full potential	756864	5,815,213	5,815	185,563,459.7	92781.72984	0.08417103
CH4							
					Emissions (Metric Tons)	**GWP**	
Coal	*feasible*	1387584	13,727,382	13,727	13.8	21	7.8802E-05
	full potential	5550336	54,909,526	54,910	55.0	21	0.00031521
Natural Gas	*feasible*	189216	1,453,803	1,454	1.4	21	7.9063E-06
	full potential	756864	5,815,213	5,815	5.5	21	3.1625E-05
N2O							
Coal	*feasible*	1387584	13,727,382	13,727	19.3	310	0.00162856
	full potential	5550336	54,909,526	54,910	77.1	310	0.00651426
Natural Gas	*feasible*	189216	1,453,803	138	0.138	310	1.1671E-05
	full potential	756864	5,815,213	552	0.552	310	4.6685E-05
		Potential Generation (MWh) running 8760 hrs	**CO2**	**CH4**	**N2O**	**Total Annual MMTCE**	
	Coal		0.357	0.0001	0.0016		
	Natural Gas		0.021	0.0000	0.0000		
	Totals		**0.378**	**0.0001**	**0.0016**	**0.379**	

Appendix M.12. GHG Emissions from Utility: 6570-hour Scenario

CO2	**Emissions**	**MWh**	**MBTU**	**BBTU**	**LbsC**	**Emissions (short ton Carbon)**	**Emissions (MMTCE)**
Coal	*feasible*	1040688	10,295,536	10,296	589,831,265	294915.6325	0.2675
	full potential	4162752	41,182,145	41,182	2,359,325,060	1179662.53	1.0702
Natural Gas	*feasible*	141912	1,090,353	1,090	34,793,149	17396.57435	0.0158
	full potential	567648	4,361,410	4,361	139,172,595	69586.29738	0.0631
CH4							
					Emissions (Metric Tons)	**GWP**	
Coal	*feasible*	1040688	10,295,536	10,296	10.32	21	0.000059
	full potential	4162752	41,182,145	41,182	41.28	21	0.0002
Natural Gas	*feasible*	141912	1,090,353	1,090	1.04	21	0.000006
	full potential	567648	4,361,410	4,361	4.14	21	0.000024
N2O							
Coal	*feasible*	1040688	10,295,536	10,296	14.45	310	0.0012
	full potential	4162752	41,182,145	41,182	57.79	310	0.0049
Natural Gas	*feasible*	141912	1,090,353	104	0.104	310	0.000009
	full potential	567648	4,361,410	414	0.414	310	0.000035
	% Potential, Capacity	**180 kw, 5840 hr/yr**	**CO2**	**CH4**	**N2O**	**Total Annual MMTCE**	
	Coal	Feasible	0.2675	0.0001	0.0012		
	Natural Gas	Feasible	0.0158	0.000006	0.000009		
	Totals		**0.2833**	**0.0001**	**0.0012**	**0.2846**	

Appendix M.13. GHG Emissions from Utility: 4380-hour Scenario

CO2	Emissions	MWh	MBTU	BBTU	LbsC	Emissions (short ton Carbon)	Emissions (MMTCE)
Coal	*feasible*	693792	6,863,691	6,864	393,220,843	196,610	0.178
	full potential	2775168	27,454,763	27,455	1,572,883,373	786,442	0.713
Natural Gas	*feasible*	94608	726,902	727	23,195,432	11,598	0.011
	full potential	378432	2,907,607	2,908	92,781,730	46,391	0.042
CH4							
					Emissions (Metric Tons)	**GWP**	
Coal	*feasible*	693792	6,863,691	6,864	6.88	21	3.9401E-05
	full potential	2775168	27,454,763	27,455	27.52	21	0.0002
Natural Gas	*feasible*	94608	726,902	727	0.69	21	3.9531E-06
	full potential	378432	2,907,607	2,908	2.76	21	1.5813E-05
N2O							
Coal	*feasible*	693792	6,863,691	6,864	9.63	310	0.00081
	full potential	2775168	27,454,763	27,455	38.53	310	0.00326
Natural Gas	*feasible*	94608	726,902	69	0.07	310	5.8356E-06
	full potential	378432	2,907,607	276	0.28	310	2.3342E-05
	% Potential, Capacity	**50% Projected Potential Generation (MWh) running 4380 hrs**	**CO2**	**CH4**	**N2O**	**Total Annual MMTCE**	
	Coal	Feasible	0.1784	0.00004	0.00081		
	Natural Gas	Feasible	0.0105	0.00000	0.00001		
	Totals		**0.1889**	**0.00004**	**0.00082**	**0.1897**	

Appendix M.14. Annual REMI Results

Policy	Output Variable	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CHP 4380 - MCCP Design	Employment (Thousand)	0.000	0.000	-0.321	-0.588	-0.806	-0.981	-1.120	-0.135	-0.050	0.017	0.071
	Gross State Product (Billion Fixed 2000$)	0.000	0.000	-0.022	-0.043	-0.059	-0.071	-0.080	-0.029	-0.020	-0.013	-0.008
CHP 6570 - MCCP Design	Employment (Thousand)	0.000	0.000	-0.414	-0.762	-1.047	-1.276	-1.463	-0.031	0.063	0.136	0.195
	Gross State Product (Billion Fixed 2000$)	0.000	0.000	-0.029	-0.055	-0.075	-0.089	-0.099	-0.025	-0.016	-0.008	-0.002
CHP 8760 - MCCP Design	Employment (Thousand)	0.000	0.000	-0.509	-0.936	-1.285	-1.571	-1.805	0.073	0.177	0.257	0.320
	Gross State Product (Billion Fixed 2000$)	0.000	0.000	-0.035	-0.066	-0.090	-0.107	-0.117	-0.021	-0.011	-0.002	0.004
CHP 4380 - No Subsidy	Employment (Thousand)	0.000	0.000	-0.174	-0.312	-0.415	-0.481	-0.517	-0.372	-0.254	-0.153	-0.068
	Gross State Product (Billion Fixed 2000$)	0.000	0.000	0.000	-0.016	-0.033	-0.047	-0.058	-0.067	-0.056	-0.044	-0.033
CHP 6570 - No Subsidy	Employment (Thousand)	0.000	0.000	-0.195	-0.347	-0.458	-0.523	-0.556	-0.385	-0.240	-0.116	-0.011
	Gross State Product (Billion Fixed 2000$)	0.000	0.000	-0.020	-0.040	-0.056	-0.069	-0.079	-0.066	-0.050	-0.037	-0.026
CHP 8760 - No Subsidy	Employment (Thousand)	0.000	0.000	-0.216	-0.383	-0.502	-0.570	-0.596	-0.400	-0.230	-0.082	0.042
	Gross State Product (Billion Fixed 2000$)	0.000	0.000	0.000	-0.024	-0.047	-0.066	-0.080	-0.091	-0.075	-0.057	-0.041

Policy	Output Variable	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
CHP 4380 - MCCP Design	Employment (Thousand)	0.108	0.137	0.159	0.172	0.185	0.192	0.199	0.206	0.209	0.212
	Gross State Product (Billion Fixed 2000$)	-0.004	0.000	0.002	0.004	0.006	0.008	0.009	0.010	0.011	0.012
CHP 6570 - MCCP Design	Employment (Thousand)	0.233	0.263	0.284	0.298	0.312	0.320	0.328	0.335	0.340	0.346
	Gross State Product (Billion Fixed 2000$)	0.003	0.006	0.009	0.012	0.014	0.015	0.017	0.019	0.020	0.022
CHP 8760 - MCCP Design	Employment (Thousand)	0.359	0.391	0.413	0.428	0.441	0.449	0.458	0.465	0.469	0.478
	Gross State Product (Billion Fixed 2000$)	0.009	0.013	0.016	0.019	0.021	0.023	0.025	0.027	0.029	0.030
CHP 4380 - No Subsidy	Employment (Thousand)	-0.003	0.049	0.090	0.120	0.147	0.162	0.176	0.188	0.195	0.202
	Gross State Product (Billion Fixed 2000$)	-0.024	-0.017	-0.011	-0.006	-0.003	0.001	0.003	0.005	0.007	0.009
CHP 6570 - No Subsidy	Employment (Thousand)	0.070	0.136	0.188	0.226	0.258	0.279	0.299	0.313	0.324	0.333
	Gross State Product (Billion Fixed 2000$)	-0.017	-0.010	-0.003	0.002	0.006	0.009	0.012	0.014	0.017	0.019
CHP 8760 - No Subsidy	Employment (Thousand)	0.140	0.219	0.282	0.329	0.367	0.395	0.418	0.436	0.449	0.461
	Gross State Product (Billion Fixed 2000$)	-0.028	-0.017	-0.008	-0.001	0.005	0.011	0.015	0.018	0.021	0.024

Policy	Output Variable	2005-2015 Avg	2005-2015 Cumulative	2005-2025 Avg	2005-2025 Cumulative
CHP 4380 - MCCP Design	Employment (Thousand)	-0.435	-3.914	-0.112	-2.136
	Gross State Product (Billion Fixed 2000$)	-0.038	-0.346	-0.015	-0.287
CHP 6570 - MCCP Design	Employment (Thousand)	-0.511	-4.598	-0.081	-1.539
	Gross State Product (Billion Fixed 2000$)	-0.044	-0.396	-0.014	-0.259
CHP 8760 - MCCP Design	Employment (Thousand)	-0.587	-5.279	-0.049	-0.929
	Gross State Product (Billion Fixed 2000$)	-0.049	-0.445	-0.012	-0.232
CHP 4380 - No Subsidy	Employment (Thousand)	-0.305	-2.746	-0.075	-1.420
	Gross State Product (Billion Fixed 2000$)	0.010	-0.354	-0.021	-0.390
CHP 6570 - No Subsidy	Employment (Thousand)	-0.315	-2.832	-0.021	-0.407
	Gross State Product (Billion Fixed 2000$)	-0.049	-0.443	-0.021	-0.395
CHP 8760 - No Subsidy	Employment (Thousand)	-0.326	-2.936	0.029	0.559
	Gross State Product (Billion Fixed 2000$)	0.027	-0.481	-0.023	-0.440

Appendix M.15. Background on Tax Incentive Programs

Context and Background

The purpose of analyzing tax incentive strategies that directly (or indirectly) address greenhouse gas (GHG) emissions is to provide Michigan with either revenue-neutral or strong programs that affect energy use, emissions output, consumer behavior and market stimulation. In the following section, a variety of current local, regional, national and international regulations are examined in order to draw upon their strengths and weaknesses in developing a set of tax incentive programs tailor-made for Michigan. It is important to note the connection of the following potential tax strategies to the various other strategies reviewed in this full report. Many of the benefits of a tax program are only experienced, if not enhanced, by co-existing with mandatory and voluntary programs such as a renewable portfolio standard, government support of knowledge transfer and demand-side management to name a few.

With the introduction of the Air Pollution Control Act of 1955, and then the following Clean Air Act of 1963 the nation was beginning to develop environmental policies and subsequent tax-incentive programs designed to address pollution. Over the past five decades national and state environmental policy has taken on many forms, from command and control mechanisms regulating criteria pollutants from generators, to emissions cap and trading programs for NOx emissions in Los Angeles. Other policies have included tax-incentive programs (i.e.: renewable energy generators' production tax credit benefit) subsidy programs (e.g. those currently aiding the development of photovoltaic cells for solar energy), and penalty programs (e.g. financial penalties levied on large-scale polluters such as paper pulp mills). The following sections examines past and present programs carried out on various social levels, in order to determine what worked, what didn't, and what financial-based policy options Michigan has for addressing GHG emissions at the state level.

During the Michigan at a Climate Crossroads (MCCP) January 2006 forum, over sixty of Michigan's stakeholders voted to place analysis of potential tax-incentive programs as one of MCCP's top priorities in coming up with a climate change action plan for Michigan.

The following lists various interests raised regarding potential tax-incentive programs:

- Application across numerous public and private sectors.
- Potential to be revenue neutral (e.g.: ecological tax; unbundling property taxes; reducing income tax for organizations that reduce emissions; trading credits).
- Potential to build upon pre-existing tax programs.
- Ability to factor in environmental externalities.
- Potential to affect consumer behavior.

International Programs

European Nations – Tax-incentive programs in the EU

Eco taxes are becoming much more common in Europe. In recent years there has been increased use of such fiscal instruments, and The Netherlands, Belgium, Denmark and Sweden have already begun programs of ecological tax reform, while others, including the UK, Austria and Germany, have introduced some specific eco taxes with varying degrees of success. A study published by the Institute for Public Policy Research (IPPR) estimated that an eco, or, green taxation package that includes a commercial and industrial energy tax, a higher road fuel price escalator, a waste disposal tax, reform of company car taxation and an office parking tax, could create between 250,000 and 575,000 extra jobs in the UK by the year 2005.[xix]

Ireland (Irish Bag Tax)

The Irish government reports that a tax on plastic shopping bags (paid by suppliers) in the Republic of Ireland has cut their use by more than 90% and raised millions of euros in revenue. The tax of 15 cents per bag was introduced in early 2002 in an attempt to curb litter. Irish Environment Minister Martin Cullen said that the 3.5 million euros in extra revenue raised so far would be spent on environmental projects.[xx]

International Database on Energy Efficiency Programmes (INDEEP)

This is a database compiled by a variety of countries (accessible on the web) that displays various Demand Side Management strategies that are currently being used in the world. The database is meant to aid utilities and governments in designing Energy Efficient-Demand Side Management programs.[xxi]

National Programs

<u>Governmental/Non-Governmental Organizations</u>

The following organizations and programs represent both models that can be useful for Michigan as it considers various new tax-incentive programs, as well as existing support mechanisms that may be of assistance in funding and education opportunities.

US Department of Energy (DOE)

The U.S. Department of Energy's (USDOE) overarching mission is to advance the national, economic and energy security of the United States; to promote scientific and technological innovation in support of that mission; and to ensure the environmental cleanup of the national nuclear weapons complex.

Energy Efficiency and Renewable Energy

The Office of Energy Efficiency and Renewable Energy (EERE) leads the Federal government's research, development, and deployment efforts in energy efficiency. EERE's role is to invest in high-risk, high-value research and development that would not be sufficiently conducted by the private sector on its own. The EERE engages in the following programs, among others:

- Building Technologies Program - DOE's Building Technologies Program works to improve the energy efficiency of the nation's buildings through innovative new technologies and better building practices. They engage in research and regulatory activities.[xxii]
- Distributed Energy Program - The Distributed Energy Program supports cost-effective research and development aimed at lowering costs, reducing emissions, and improving reliability and performance to expand opportunities for the installation of distributed energy equipment today and in the future.[xxiii]
- Industrial Technologies Program - The Industrial Technologies Program works with U.S. industry to improve industrial energy efficiency and environmental performance. The program invests in high-risk, high-value R&D to reduce industrial energy use while stimulating productivity and growth.[xxiv]

US Department of Housing and Urban Development (HUD)

HUD's Office of Public and Indian Housing (PIH) has been working actively with local public housing authorities (PHAs) to reduce the cost of utilities. Efforts include: establishing requirements and incentives to encourage lower consumption, providing incentives to use innovative funding techniques and reduce utility rates, providing technical assistance to PHAs to increase their application of cost-effective energy conservation, launching an initiative with DOE to study PHA energy consumption, provide training materials concerning energy conservation measures (ECMs) and funding and conducting field demonstrations, and establishing PHA assessment systems that include evaluation of energy-efficiency efforts. The department may also: conduct energy audits every 5 years, implement all cost-effective ECMs as funds become available, purchase only energy-efficient equipment, individually meter resident units when feasible, and ensure that residents' rent burdens (which include rent and cost of utilities) be no more than 30 percent of their income.[xxv]

US Department of Agriculture (USDA)

The USDA provides leadership on food, agriculture, natural resources, and related issues based on sound public policy, the best available science, and efficient management.[xxvi] The Farm Security and Rural Investment Act of 2002 (the Farm Bill) established the Renewable Energy Systems and Energy Efficiency Improvements Program under Title IX, Section 9006. This program currently funds grants and loan guarantees to agricultural producers and rural small business for assistance with purchasing renewable energy systems and making energy efficiency improvements.[xxvii]

US Environmental Protection Agency (EPA)

The mission of the Environmental Protection Agency is to protect human health and the environment. Since 1970, EPA has been working for a cleaner, healthier environment.[xxviii]

US Small Business Administration (SBA)

The US SBA aims to maintain and strengthen the nation's economy by aiding, counseling, assisting and protecting the interests of small businesses and by helping families and businesses recover from national disasters. They provide businesses with information on how to finance new businesses, and reduce costs by conserving energy, among other things.[xxix]

Database of State Incentives for Renewable Energy (DSIRE)

The Database of State Incentives for Renewable Energy (DSIRE) is a comprehensive source of information on state, local, utility, and selected federal incentives that promote renewable energy. DSIRE now includes state and federal incentives for energy efficiency.[xxx]

American Council for an Energy Efficient Economy (ACEEE)

The American Council for an Energy-Efficient Economy (ACEEE) is a nonprofit organization dedicated to advancing energy efficiency as a means of promoting both economic prosperity and environmental protection. ACEEE fulfills its mission by, conducting in-depth technical and policy assessments, advising policymakers and program managers, working collaboratively with businesses, public interest groups, and other organizations, organizing conferences and workshops, publishing books, conference proceedings, and reports, and educating consumers and businesses. Projects are carried out by staff and selected energy efficiency experts from universities, national laboratories, and the private sector. ACEEE's program areas include Energy Policy, Buildings and Equipment, Utilities, Industry, Transportation, International, and Communications and Conferences. ACEEE collaborates on projects and initiatives with dozens of organizations including federal and state agencies, utilities, research institutions, businesses, and public interest groups.[xxxi]

Interstate Renewable Energy Council (IREC)

The Interstate Renewable Energy Council's mission is to accelerate the sustainable utilization of renewable energy sources and technologies in and through state and local government and community activities. IREC was formed in 1982 as a non-profit organization.[xxxii] The Interstate Renewable Energy Council (IREC) supports market-oriented services targeted at education, coordination, procurement, the adoption and implementation of uniform guidelines and standards, workforce development, and consumer protection.

United States Combined Heat and Power Association (USCHPA)

The U.S. Combined Heat and Power Association (USCHPA) brings together diverse market interests to promote the growth of clean, efficient Combined Heat Power (CHP) in the United States. It is a private, non-profit association, formed in 1999 to promote the merits of CHP and achieve public policy support.[xxxiii]

<u>National Policies</u>

Energy Policy Act of 2005

The Energy Policy Act of 2005 (Public Law 109-58) is a statute that was passed by the United States Congress on July 29, 2005 and signed into law on August 8, 2005. Some of the provisions of the Act include[xxxiv]:

- Provides a tax credit of up to $3,400 for owners of hybrid vehicles
- Authorizes loan guarantees for "innovative technologies" that avoid greenhouse gases, which might include advanced nuclear reactor designs (such as PBMR) as well as clean coal and renewable energy
- Increases the amount of biofuel (usually ethanol) that must be mixed with gasoline sold in the United States to triple the current requirement (7.5 billion gallons by 2012
- Seeks to increase coal as an energy source while also reducing air pollution, through authorizing $200 million annually for clean coal initiatives, repealing the current 160-acre cap on coal leases, allowing the advanced payment of royalties from coal mines and requiring an assessment of coal resources on federal lands that are not national parks
- Authorizes subsidies for wind energy, and other alternative energy producers
- Adds ocean energy sources including wave power and tidal power for the first time as separately identified renewable technologies
- Authorizes $50 million annually over the life of the bill for a biomass grant program
- Contains several provisions aimed at making geothermal energy more competitive with fossil fuels in generating electricity
- Requires the Department of Energy to study and report on existing natural energy resources including wind, solar, waves and tides
- Provides tax breaks for those making energy conservation improvements to their homes
- Provides subsidies for oil companies

Tax exemptions for Energy Efficient Appliances

The Energy Policy Act of 2005 includes, in the Building section, a tax credit for Energy Efficient Appliances. This provides a tax credit for the manufacturer of energy-efficient dishwashers, clothes washers, and refrigerators. Credits vary depending on the efficiency of the unit. This is effective for appliances manufactured in 2006 and 2007. Below is a table of anticipated tax savings and energy savings for energy-efficient home improvements (as of November 2005)[xxxv]:

Product Category	Product Type	Tax Credit Specification	Tax Credit
Windows	Exterior Windows	Meet 2000 IECC & Amendments	10% of cost not to exceed $200 total
	Skylights	Meet 2000 IECC & Amendments	10% of cost not to exceed $200 total
	Exterior Doors	Meet 2000 IECC & Amendments	10% of cost not to exceed $500 total
Roofing	Metal Roofs	Energy Star qualified	10% of cost not to exceed $500 total
Insulation	Insulation	Meet 2000 IECC & Amendments	10% of cost not to exceed $500 total
HVAC	Central AC	EER 12.5/SEER 15 split Systems EER 12/SEER 14 package systems	$300
	Air source heat pumps	HSPF 9 EER 13 SEER 15	$300
	Geothermal heat pump	EER 14.1 COP 3.3 closed loop EER 16.2 COP 3.6 open loop EER 15 COP 3.5 direct expansion	$300
	Gas, oil, propane water heater	Energy Factor 0.80	$300
	Electric heat pump water heater	Energy Factor 2.0	$300
	Gas, oil, propane furnace or hot water boiler	AFUE 95	$150
	Advanced main air circulating fan	No more than 2% of furnace total energy use	$50

Source: USDOE.

Securing America's Future Energy Act of 2001

The general purpose of this Act it to enhance energy conservation, research and development and to provide for security and diversity in the energy supply for the American people, and for other purposes.[xxxvi] The following includes some of the tax credits included in this Act:

- Ten percent credit for the purchase of qualified stationary fuel cell power plants: Any equipment that is used to power your primary residence to generate electricity.
- Alternative Motor Vehicle Credit: This is a credit for the purchase of a new qualified fuel cell motor vehicle, a new qualified hybrid motor vehicle, a new qualified alternative fuel motor vehicle, and a new advanced lean burn technology motor vehicle.
- A fuel cell motor vehicle has a tax credit range of $4,000 to $40,000 depending on the fuel efficiency and over all weight of that model.
- A hybrid motor vehicle has a tax credit range of $250 to $10,000 depending on the fuel efficiency, emissions performance and over all weight of that model.
- An alternative fuel motor vehicle could have up to 50 percent of its cost credited back to the owner plus additional 30 percent of the cost if it meets certain emissions standards with the tax credit range of $5,000 to $40,000 depending on the over all weight of that model.
- A new advanced lean burn technology motor vehicle has a tax credit range of $1,000 to $4,000 depending on the fuel efficiency of that model.
- The deduction of costs for qualified clean fuel vehicle property and clean fuel vehicle refueling property has been extended to December 31st 2007. The tax credit for electric vehicles is no longer limited to $4,000. The tax credit range is for $4,000 to $40,000 depending on the weight of the car and in case of certain models, the driving range.
- Qualified energy efficiency improvements: Up to $2,000 to make energy efficient improvements to your primary residence. It should be new and at least run for five years. It should comply with the 1998 International Energy Conservation Code. These improvements are mainly to do with reducing the loss of heat and gaining heat by properly insulating the home with extra windows, metal roofs, and doors.[xxxvii]

Public Utility Regulatory Policies Act (PURPA)

PURPA was passed in response to the unstable energy climate of the late 1970s. PURPA sought to promote conservation of electric energy. Additionally, PURPA created a new class of non-utility generators, small power producers, from which, along with qualified co-generators, utilities are required to buy power.

PURPA was in part intended to augment electric utility generation with more efficiently produced electricity and to provide equitable rates to electric consumers. Utility companies are required to buy all electricity from "Qfs"--qualifying facilities--at avoided cost. PURPA expanded participation of non-utility generators in the electricity market, and demonstrated that electricity from non-utility generators could successfully be integrated with a utility's own supply. PURPA requires utilities to buy whatever power is produced by Qfs (usually cogeneration or renewable energy). Utilities want these provisions repealed, critics argue that it will decrease competition and impede development of the renewable energy industry. The Fuel Use Act of 1978 (repealed in 1987) also helped Qfs become established. Under FUA, utilities were not allowed to use natural gas to fuel new generating technologies but Qfs which were by definition not utilities, were able to take advantage of abundant natural gas and abundant new technologies (such as combined-cycle). The technologies lowered the financial threshold for entrance into the electricity generation business as well as shortened the lead time for constructing new plants.[xxxviii]

Energy Tax Act

This Act, like PURPA, was passed in response to the unstable energy climate of the 1970s. The ETA encouraged conversion of boilers to coal and investment in cogeneration equipment and solar and wind technologies by allowing a tax credit on top of the investment tax credit. It was later expanded to include other renewable technologies. However, the incentives were curtailed as a result of tax reform legislation in the mid-1980s.[xxxix]

National Energy Conservation Policy Act

This Act required utilities to provide residential consumers conservation services to encourage slower growth of electricity demand. [xl]

Power-plant and Industrial Fuel Use Act

This Act succeeded the Energy Supply and Environmental Coordination Act of 1974, and extended Federal prohibition on use of natural gas and oil in generating electricity.[xli]

Economic Recovery Tax Act

This Act introduced a new methodology for determining allowable tax depreciation deductions. The new methodology, the *Accelerated Cost Recovery System (ACRS)*, set forth rules enabling taxpayers to claim generous depreciation deductions based on the system's permitted depreciable life, method, and salvage value assumptions. The generation, transmission, and distribution plant of regulated electric utilities was categorized as public utility property. Public utility property under ACRS was assigned relatively long depreciable lives.[xlii]

Tax Reform Act of 1986

Under this Act, ACRS was replaced with the *Modified Accelerated Cost Recovery System (MACRS)*. Under MACRS, the disparity in treatment of property between regulated and non-regulated taxpayers was eliminated. The investment credit was also repealed. The investment credit of the Federal income tax law was a dollar-to-dollar offset against the taxes payable by the taxpayer. The investment credit was available for regulated and non-regulated taxpayers and was intended to encourage capital investment by the Nation's businesses. The credit continues to be of importance to regulated utilities, however, because it is generally amortized for ratemaking and financial reporting purposes over the regulatory life of the related property that gave rise to the credit.[xliii]

Cooperative Research and Development Agreements (CRDA)

CRADAs are agreements between the Federal government and private sector participants to work together on a mutually beneficial project. Each partner in the CRADA applies whatever resources are agreed to, such as personnel, equipment, or facilities. While participant dollars may be used to fund portions of the government's effort, the government may not use Federal funds to support the private sector participant.[xliv]

State Programs

Governmental/Non-Governmental Organizations

California

Tax and Credits for Wind and Solar Energy

In California, in the 1970's, wind power was subject to a "boom" and "bust" phenomenon driven by federal and California investment tax credits that was very similar to solar water heating (SWH). In two technology cases, Wind and SWH, large federal and state investment incentives set off a "boom" and "bust" phenomenon. Although the installation boom associated with these investment tax credits was helpful to the diffusion of each technology, unfortunately, that boom was not tied to high-performance technology. The case of SWH demonstrates the adverse effects of allowing such investment subsidies to expire suddenly and prematurely, as well as the danger of policies that provide incentives for installation rather than performance. In Wind, production tax credits have proven more stable than investment tax credits, although they too have expired at inopportune times.[xlv] The following table is a breakdown of technologies studied and the government actions that were important to their development, in Chapter three of the California Climate Change Action Plan.

Government Action	Observation						
	FGD	SCR	Wind	PV	STE	SWH	AEC
Regulatory: Performance-based standard	✔	✔					✔
Regulatory: Cap-and-trade program	✔	✔					
Investment subsidy: tax credit, rebate			✔	✔	✔	✔	
Production subsidy: rate guarantees, production tax credit			✔	✔	✔		
Renewable portfolio standard			✔	✔	✔		
Federal RD&D	✔	✔	✔	✔	✔	✔	✔

(FGD – flue gas desulfurization; SCR – selective catalytic reduction; Wind – wind generated energy; PV – photovoltaic cells; STE – solar thermal electric; SWH – solar water heating; AEC – automotive emission controls.)

California has learned key lessons from observing the effects of timeliness and longevity of subsidy and tax-incentive programs, as well as market uncertainties experienced in the RECLAIM project[15]. In response, the state has crafted a roadmap for moving forward

[15] RECLAIM is a cap and trade program started in the early 1990's aimed at reducing SOx and NOx emissions. Due to various reasons, price spikes for NOx RTC's forced the removal of electricity generating

with climate change policies. Included in California's current climate change action plan are a variety of the above government actions such as a Renewable Portfolio Standard. In addition, California's Emerging Renewables Program is currently governed by the state's Energy Commission which provides cash rebates on eligible grid-connected renewable energy electric-generating systems. Also, Some California government agencies are working with automobile manufacturers, energy providers, fuel cell technology companies and transit authorities in a collaboration known as the California Fuel Cell Partnership. The group aims to explore and facilitate the path to commercialization and increase awareness of fuel cells for transportation. Though California differs greatly from Michigan in terms of geographical, geopolitical, social and economic make-up, its history and future path provide valuable experiences and lessons learned.

California Energy Commission – Demand Response Research Center

This research center is managed by the US Department of Energy Lawrence Berkeley National Laboratory. Their goal is to be able to respond to electricity price signals in real time to enable power-users to save money, reduce energy consumption, and lower energy prices by making the power market more responsive to consumer needs.[xlvi]

Minnesota – Minnesotans for an Energy Efficient Economy (ME3)

ME3's Tax and Incentives Program seeks to combine the goals of environmental improvement with a fair and efficient taxation system. Significant research work has been completed on the economic implications of restructuring Minnesota's tax system to one based, in part, on environmental taxes. Currently, work is focused on bringing ideas into practice through legislative initiatives.[xlvii]

Ohio - Proposed and Existing Legislation

Sub. House Bill 440 (FutureGen Clean Coal Technology)[xlviii] is a $1 billion, 10-year demonstration project to create the world's first coal-based, near-zero emissions electricity and hydrogen power plant. The project will employ two proven, high technologies to generate power with zero emissions: coal gasification technology integrated with combined cycle electricity generation. The Bill makes eligible for construction, operation, or funding by the Ohio Air Quality Development Authority the following additional kinds of "air quality facilities": any property used for the collection, storage, treatment, etc., of a by-product resulting from any method, etc., that reduces or prevents, etc., air contaminants; any coal research and development project; any property or portion of it used for the collection, storage, treatment, processing, etc., of a by-product resulting from a coal research and development project Among other things, the Bill states the intent of the General Assembly to secure the FutureGen project sponsored by the U.S. Department of Energy (USDOE), and appropriates $1 million for the drilling of a test well to help secure the project.

Proposed at the end of 2005, House Bill 247 (Renewable Energy Technology Standard) would require each electric service company supplying retail customers in Ohio to provide an increasing percentage of its power from renewable energy sources, beginning with a minimum of 3% in 2007 and topping off at 20% in 2021 and each year thereafter.

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plants from the program. (Ellerman, A. Denny, David Harrison Jr., Paul Joskow. "Emissions Trading in the US: Experience, Lessons, and Considerations for Greenhouse Gasses" Pew Center on Global Climate Change May, 2003).

Qualifying energy sources include biomass, solar, geothermal, wind, and hydropower. The Bill would enable each electric company to meet its minimum renewable energy technology standard by (a) acquiring renewable energy; (b) reducing its customers' energy consumption with photovoltaic technology systems; (c) connecting to any net metering system located in Ohio that has renewable energy as its primary energy source; and/or (d) using renewable energy credits that it has purchased, earned, or acquired.[xlix,l]

Existing Programs

Midwest Energy Efficiency Alliance (MEEA)

MEEA is partnering with Ecos Consulting to deliver an innovative new program throughout the Midwest. The 80 PLUS program is an electric utility-funded incentive program that integrates power factor corrected energy-efficient power supplies into desktop computers and desktop-derived servers. Power supplies are the devices that convert AC power from utilities into DC power used in most electronics. Efficiency levels for conventional computer power supplies range from 60%-70%. The 80 PLUS program requires that the power supply for a desktop computer or desktop-derived server be at least 80% efficient at 20%, 50% and 100% operating loads, and have a power factor of 0.9 or better at full rated load. Participating utilities provide incentives to cover the increased costs of the more efficient power supplies, fostering a market transformation effort that will motivate the PC industry and get more efficient equipment into the hands of consumers. [li, lii]

Chicago Climate Exchange (CCX)

CCX is a self-regulatory exchange that administers a voluntary, legally binding pilot program for reducing and trading greenhouse gas (GHG) emissions in North America, with participation of Offset Providers from Brazil. The Goals of CCX are: proof of concept, building institutions and expertise, providing leadership and opportunities, enhancing reputations, and informing policy and the public. Members include sources and offset projects in the United States, Canada, Mexico, Brazil and worldwide. CCX target and timetable include emission reduction commitments for years 2003 through 2006, and emission targets at 1% below baseline during 2003, 2% below baseline during 2004, 3% below baseline during 2005, 4% below baseline during 2006. The emissions baseline is the average of annual emissions during years 1998 through 2001.[liii]

Regional Greenhouse Gas Initiative (RGGI)

The Regional Greenhouse Gas Initiative, or RGGI, is a cooperative effort by Northeastern and Mid-Atlantic states to reduce carbon dioxide emissions. RGGI participating states will be developing a regional strategy for controlling emissions. This strategy will more effectively control greenhouse gases, which are not bound by state or national borders. Central to this initiative is the implementation of a multi-state cap-and-trade program with a market-based emissions trading system. The proposed program will require electric power generators in participating states to reduce carbon dioxide emissions.

On December 20, 2005, seven states announced an agreement to implement the Regional Greenhouse Gas Initiative, as outlined in a Memorandum of Understanding (MOU) signed by the Governors of the participating states. The states that agreed to sign the MOU are Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York and

Vermont. The MOU outlines the program in detail, including the framework for a model rule.

On March 23, 2006, the participating states released a draft version of the model rule for public comment. The model set of regulations details the proposed program, as outlined in the MOU. Once finalized, the model rule will form the basis of individual state regulatory and/or statutory proposals to implement the program.[liv]

Michigan Programs

<u>Governmental/Non-Governmental Organizations</u>

NextEnergy, Inc.

NextEnergy was founded to advance the energy technology industry in Michigan. It is a non-profit organization that promotes renewable energy programs and projects and serves as a technical resource for organizations looking to develop such programs. NextEnergy was founded to advance the Alternative Energy Technology (AET) industry in Michigan. This non-profit corporation seeks to enable the commercialization of energy technologies that positively contribute to economic competitiveness, energy security, and the environment.[lv]

Michigan NextEnergy Authority (MNEA)

The MNEA is a seven-member board, comprised of the State Treasurer, the directors of the state departments of Management and Budget and Transportation, and four private-sector members appointed by the Governor. The MNEA is responsible for certifying taxpayers and property as eligible for tax credits against the Michigan Single Business Tax (SBT) or exemptions from the General Property Tax.

The Michigan NextEnergy Authority (MNEA) was created to promote the development of alternative energy technologies and to provide tax incentives for business activities and property related to the research, development, and manufacturing of those technologies.

Michigan Department of Environmental Quality

The Michigan Department of Environmental Quality administers programs and enforces laws that protect public health and promote the appropriate use of, limit the adverse effects on and restore the quality of the environment.[lvi]

Michigan Air Emissions Trading System (MAETS)

Michigan adopted a voluntary statewide air emissions trading program, which took effect on March 16, 1996. Michigan's Emission Trading Registry provides information regarding the generation, use, and trading of Emission Reduction Credits (ERCs) under the Michigan Air Emission Trading Program. This voluntary statewide emissions trading program allows ERCs to be traded or retained for future use based on an emission reductions basis.[lvii] The Michigan Department of Environmental Quality, Air Quality Division (AQD) has entered into a Memorandum of Understanding (MOU) between the States of Michigan and Wisconsin and with Wisconsin Energy Power Company. The

MOU will allow for the trading of oxides of nitrogen emission credits between several of the company's plants in Wisconsin and their plant in Marquette, Michigan.[lviii]

The Emission Trading Registry provides information regarding the generation, use, and trading of Emission Reduction Credits (ERCs) under Michigan's Emission Averaging and Emission Reduction Credit Trading Program (Program).

There has been no emission averaging under the Program to date. However, emission averaging information will also be made publicly available when emission averaging occurs. More information about emissions trading can be found on the MDEQ michigan.gov web portal.[lix]

ERC Generation and AQ Benefit Summary Information[lx]

	Reductions		**AQ Benefit**		**ERCs**	
Pollutant	**Ozone Season**	**Non-Ozone Season**	**Ozone Season**	**Non-Ozone Season**	**Ozone Season**	**Non-Ozone Season**
CO	3054.6	3694.24	305.25	369.21	2749.35	3325.03
NOx	19527.33	9593.53	1952.22	958.84	17575.11	8634.69
Pb	0.48	0.91	0.04	0.08	0.44	0.83
PM10	511.08	552.37	50.86	55.07	460.22	497.3
SO2	6983.24	6447.81	698.17	644.67	6285.07	5803.14
VOC	10259.48	9820.15	1025.04	980.98	9234.44	8839.17

Note: One ERC equals One ton.

Michigan Air Quality Fees

The Clean Air Act requires each state to develop a Title V, Renewable Operating Permit Program that is supported by air quality fees. An annual air quality fee program for Michigan, including the specific fee structure, was established by the legislature in 1993. Based on this legislation, the first air quality fees were assessed in January 1995. In July 2001 the Governor approved major changes to the fee program, increasing both the facility charge and the emissions tonnage charge. Based on the current legislative requirements, annual fee assessments (invoices) are mailed to fee-subject facilities each year prior to January 15. Payment of the invoice is due within 90 days of the mailing. For the current year, fee invoices were assessed January 13, 2006 with payment due April 13, 2006. 1,930 facilities were assessed fees totaling about $11.43 million. The emissions charge used in the fee formula is for Category I or II facilities[16] and is calculated as $45.25 per ton of actual emissions with a maximum of 4,000 tons per facility being subject to the charge. Therefore the maximum emission charge for any one facility is $181,000. However, if a facility has less than 4,000 tons of actual emissions the maximum amount subject to the fee is 1,000 tons per pollutant.[lxi]

[16] Facilities that are "major" under Title I of the Clean Air Act (have the potential to emit 100 tons or more per year of any pollutant) are classified as Category I facilities. Facilities that are "major" under Title III of the Clean Air Act (have the potential to emit 10 tons of any one hazardous air pollutant or 25 tons of any combination of air hazardous pollutants) are classified as Category II facilities.

Michigan Department of Labor and Economic Growth/Energy Office

Michigan Biomass Energy Program

The State of Michigan Energy Office promotes energy efficiency and renewable energy resource development to Michigan's residents, businesses, and public institutions. Located within the Energy Office, the goal of the Michigan Biomass Energy Program (MBEP) is to encourage increased production and use of energy derived from biomass resources through program reports, partnerships, technical assistance, and education.[lxii]

The goal of the MBEP is to encourage increased production and use of energy derived from biomass resources through program reports, partnerships, technical assistance, and education. MBEP receives its primary funding from the Great Lakes Biomass State-Regional Partnership (GLBSRP).

In the last few years program reports have been completed on ethanol and anaerobic digestion. MBEP has partnered with state agencies and other organizations to coordinate workshops, facilitate an ethanol working group, and to increase the bio-fuel infrastructure in Michigan. The program also offers funding for state project grants on a regular basis.[lxiii]

Michigan State Tax Commission (STC)

The STC is comprised of 3-members appointed by the Governor with the advice and consent of the Senate. STC has general supervision of the administration of the Property Tax Laws in Michigan and shall render such assistance and give such advice to assessors, as they deem necessary. The STC also serves on the State Board of Assessors, which is responsible for assessing certain state-assessed properties such as telephone companies and railroads.[lxiv]

Michigan State Public Benefits Fund

Michigan's 2000 restructuring law legislation created the Low-Income Energy and Efficiency (LIEE) fund to provide energy payment assistance and fund energy efficiency programs. In October, 2004, the Michigan Public Service Commission approved grants totaling $8 million for low-income energy efficiency improvements and energy education.

The largest grants were awarded to the Family Independence Agency (FIA), the LIHEAP grantee and METRO Neighborhood Housing & Community Development. FIA received $4.24 million for a statewide partnership program with the community action and weatherization network to assist low-income households to become energy self-sufficient through energy efficiency upgrades and education. METRO received $1.7 million for improving the energy efficiency of urban homes located in 15 statewide communities by providing energy audits, efficiency upgrades, and energy efficiency training of all participants in the program.[lxv]

Michigan Economic Development Corporation

The Michigan Economic Development Corporation (MEDC) is a business assistance resource for any company already in Michigan or considering a location in the State, providing services such as site location selection, permitting assistance, employee recruitment and training, and business incentives. MEDC also houses a wealth of information on Michigan industries including an on-line business guide which lists alternative energy businesses in the State of Michigan.[lxvi] The Michigan Economic Development Corporation is a single point of contact for businesses inquiring about the availability of incentives and location services.[lxvii] Available information includes incentive programs such as Michigan's Brownfield redevelopment, the Renaissance Zone and property tax abatements.

Michigan Land Use Institute

The Michigan Land Use Institute was founded in 1995 to establish an approach to economic development that strengthens communities, enhances opportunity, and protects the state's unmatched natural resources. The Institute's mission is to help Michigan avoid the patterns of suburban sprawl and over-development that cause traffic congestion, pollution, loss of community, rising costs to individuals and governments, and a deteriorating quality of life. The Institute focuses its work on land stewardship, energy development, resource protection, agriculture, transportation, and environmental and economic policy.[lxviii]

Existing Programs in Michigan

There currently exists a wide variety of grants, subsidies and tax-incentive programs directed toward Michigan's renewable technology development and energy efficiency, among other things. Such programs exist for private firms and individuals alike. It is important to note that some of these programs, amidst Michigan's evolving tax infrastructure, may need new funding sources.

Property Tax Exemptions

This program applies to industrial property which is used for, among other purposes, high-technology activities or the creation or synthesis of bio-diesel fuel. "Alternative energy personal property" certified by the NextEnergy Authority and located in the NextEnergy Zone is exempt from personal property taxes. This exemption includes (1) "alternative energy systems," (2) "alternative energy vehicles," (3) the personal property of an "alternative energy technology business" and (4) the personal property of a business not engaged in alternative-energy technology that is used solely for the purpose of researching, developing or manufacturing alternative-energy technologies. The law applies not only to companies engaged in the manufacturing or research and development of alternative energy technologies, but also to end users. Homeowners are non eligible for this exemption. Property must be new to Michigan. The exemption does not include real property, such as land and buildings.

Within 60 days after a company or end user receives notification of certification of "alternative energy personal property," the local school district or local tax-collecting unit may adopt a resolution disallowing exemption of the property from certain taxes.[lxix]

Single Business Tax Act (SBT)

In 1975, the Single Business Tax replaced eight previous taxes including an income tax on corporations and financial institutions, an annual corporation franchise fee, the business portion of the intangibles tax, the property tax on inventories, and various privilege taxes on savings and loans and domestic insurance companies.[lxx] The SBT was seen as a strategy intended to insulate state revenues from the cyclical swings typical of a durable-goods-based economy and assure the availability of the resources needed to address and counter the effects of an economic downturn. Michigan's Single Business Tax remains the only major value-added tax (VAT) in the United States. Value-added taxation uses the value firms add to products, the sales price less the cost of materials, as the tax base.[lxxi] While the SBT is Michigan's only general business tax, 58 percent of Michigan businesses pay $1,000 or less in SBT, and 45 percent of all businesses pay no SBT. A business with annual gross receipts of less than $350,000 has no liability under the SBT.[lxxii] The Act is currently being reformed in a Bill that went to the legislature in 2005, and includes, among other things, changes such as cutting the rate by 37% for all standard filers, changing the appointment of the tax, creating a personal property tax credit, and creating a credit for research and development companies.[lxxiii] Under the Single Business Tax Act, businesses involved with alternative energy technologies may be eligible for two new SBT credits: a nonrefundable credit for "Qualified Business Activity" and a refundable payroll credit.[lxxiv] Opposition to Bills reforming the act cite criticisms such as lack of planning for replacing the estimated $2 Billion (nearly a quarter of the state's general fund budget) in annual revenues that the Act currently supplies Michigan with.[lxxv]

Alternative Energy Personal Property Tax Exemption

Five states—California, Hawaii, Michigan, Montana and Ohio—offer generous corporate tax credits or exemptions in an effort to recruit fuel cell manufacturers.
Michigan and Ohio are the most aggressive states in this category. Under the NextEnergy economic development plan, Michigan offers multiple tax benefits to companies engaged in the research, development or production of fuel cells. Eligible companies receive a full property tax exemption on alternative energy equipment, a full exemption from the state's personal and real property tax, an exemption from the state's education tax, and a personal income tax credit equal to the sum of the state income taxes paid by company employees[lxxvi].

Refundable Payroll Credit

Businesses certified by the NextEnergy Authority that locate in the NextEnergy Zone to develop "alternative energy technologies," as defined by the Michigan Next Energy Authority Act, may claim a credit for their qualified payroll amount. If the credit exceeds the tax liability of the business for the tax year, the portion of the credit exceeding the tax liability will be refunded. This credit is effective through 2022.[lxxvii]
Pursuant to Section 39e of the Single Business Tax Act, certain businesses located within an Alternative Energy Zone may be eligible for a refundable tax credit on its Qualified Payroll. Under this section, a Qualified Alternative Energy Entity can claim a credit for its Qualified Payroll amount. This credit is allowable after all nonrefundable credits under the SBTA. The portion of this credit, if any, that exceeds the tax liability of the entity for the current tax year shall be refunded to the entity.[lxxviii]

Community Energy Project Grants

On an annual basis -- usually in June -- the Michigan Energy Office solicits proposals for community demonstration projects or education programs to help consumers better understand energy efficiency and renewable-energy options. Community Energy Project Grants are available to public and non-profit agencies.

The deadline for 2006 proposals was September 1, 2005. The 2006 round of grants will support solar-energy demonstrations; bioenergy, biofuels and bioproducts education; green-commuting projects, green-building projects; statewide energy conferences; and statewide energy events. (PV systems must have a capacity of at least 1 kilowatt.) These grants cover a one-year period, from January 1, 2006, through December 31, 2006. The maximum individual award is $6,000; approximately 20 grants will be made. Cost share is not required.[lxxix]

Energy Efficiency Grants

Michigan has a public benefits fund that supports energy efficiency projects. Although fuel cell projects with heat recovery applications are potentially eligible for funding in Michigan, solicitations vary[lxxx].

Large Scale Photovoltaic Demonstration Project Grants

Michigan's Large-Scale Photovoltaic Demonstration Project provides funding for public and non-profit organizations to install and demonstrate new photovoltaic (PV) systems with a *minimum* capacity of 10 kilowatts. A total of $150,000 was made available in 2006. The maximum award per project in 2006 is $50,000; an award may not exceed 90% of the cost of PV equipment, materials and supplies. Grant recipients must pay for labor, installation and some equipment costs.[lxxxi]

Proposed and Newly Enacted Legislation

Michigan non-biodegradable plastic shopping bag tax act (Senate Bill 0064, 2005)

This is a bill to provide for the levy, collection, and administration of an excise tax on the privilege of using certain non-biodegradable products; to provide for certain exemptions; to prescribe certain powers and duties of certain state departments; and to provide for the disbursement of certain tax proceeds.[lxxxii] This Bill has not yet passed.

Property Tax Exemption (Senate Bill 251, as introduced 2-24-05)

This bill would amend the General Sales Tax Act. Methane digesters and other thermal decomposing systems used in agricultural operations would be tax exempt. The Act exempts property actually used in agricultural operations. Under the bill, property used in agricultural operations would include a methane digester, a methane digester electric generating system, a biomass gasification system, and a thermal depolymerization system.[lxxxiii] The Bill has passed in the Senate but has not yet passed in the House.

Policy Strategies Considered

Ecological Tax or Green Tax

Land Value Taxation

> Land value is normally one component of the property tax. Property taxes fall on both land value and the value of improvements -- the portion that falls on land value is a land value tax. Such a tax is normally levied not on the rental value of land directly, but rather on the land's assessed market value; but that market value is simply the current capitalized value of the stream of future rents it is anticipated to yield, so unless the rate were to grow high, the normal practice of taxing the price of land is an excellent surrogate for a pure land value tax.

Proponents of the land value tax point out that it has the effect of encouraging more compact development of sites, which leads to more efficient use of urban infrastructure and decreases pressure for suburban sprawl

Although there have been cases of land value taxation proposed as a new revenue source, or as the least disruptive source for revenue when a tax increase is necessary, the canonical form of a land value tax proposal has been revenue neutral -- to urge the reduction or elimination of other taxes simultaneously with the introduction of the land value tax with identical yield. This has usually meant reducing the property tax rate on improvement value, while increasing the property tax rate on land value, rather than artificially holding those two taxes to a single rate. This is what we call the two-rate property tax, or 2R[lxxxiv]

According to research done by Richard England, economics professor at the University of New Hampshire's Whittemore School of Business and Economics, which was is published in the June 2005 issue of National Tax Journal, a system that taxes land values more heavily than building values would encourage building maintenance and new construction. It could stimulate commercial and industrial activity, thereby promoting income and employment growth. The tax structure would also help to preserve open space by encouraging larger buildings on smaller lots[lxxxv]

States that already have a two-rate site value tax: Pennsylvania, New York, Maryland and Washington D.C.[lxxxvi]

Tax on Virgin Materials/Credit for Reduction in Energy Consumption

Any green tax should reflect the true cost of a product to society and should internalize the cost of any direct or indirect environmental effects of that product. A common component of environmental taxation is fiscal neutrality, so that the overall tax burden is not increased. Most policy makers favor using environmental taxation to reduce taxes on labor.[lxxxvii]

An ecological tax reform might call for a revenue neutral tax shift. In other words, it would not add to the total tax burden, and would even be compatible with tax reduction. It would radically shift the target of taxation. A proposal for a non-partisan ecological tax shift would: (1) reduce or eliminate taxes on income, labor, and capital (especially on middle and lower income taxpayers), and (2) tax pollution and depletion of natural resources instead. The basic idea is to gradually shift much of the tax burden away from "goods" like income and labor, and towards "bads" like the rapid loss of natural capital, i.e. fisheries, forest cover, energy and mineral reserves, topsoil, etc. The tax would be entirely revenue neutral, for individuals and business alike, so that every dollar added to energy costs, for example, would be subtracted from income taxes.[lxxxviii]

In response to various SBT reform proposals, John Gear, founder of the Lansing Post-Petroleum Planning Project made the following suggestions for an ecological tax in Michigan: "We can raise over $1.8 billion as follows: add $0.018 to commercial and industrial electric rates, $1.25 per million cubic feet of natural gas delivered to commercial and industrial customers, and $0.33 cents per gallon to all gasoline and diesel sold in Michigan. You limit the effect of the gas tax by providing an annual $160 credit for individual car owners on their Michigan income tax ($160 equals the average Michigan driver's gas usage, 482 gallons, times thirty-three cents)."

<u>Subsidies</u>

As seen in some of the above examples from California's experience and existing programs in Michigan, it can be very useful to utilize subsidy and grant programs to encourage renewable energy technology as well as consumer education. Research and Development (i.e.: for Renewable Energy Technologies, Idle reduction Technologies), Energy Efficiency Programs, Energy Conservation Programs are some of the many eligible efforts that might warrant government-sourced subsidies. In conjunction with potential new ecological taxes, the state may be able to enhance its current grant and subsidy programs.

<u>Credit Trading</u>

Capping allowable emissions rates of specific pollutants (i.e.: CO2) or energy consumption levels (i.e.: excesses of a certain amount of allowable kwh) can create a trading scheme where regulated firms can buy, sell and/or trade credits or certifications. It may be useful to build upon the successes of the current voluntary emissions trading scheme currently in existence in Michigan. Trading schemes can also work by using Renewable Energy Credits generated by a Renewable Portfolio Standard.

<u>Tax Credits and Exemptions</u>

As noted in earlier examples, firms or organizations can receive certain property tax exemptions for engaging in specific technology development projects as well as energy efficiency and conservation projects. An example would be a reduction in tax on consumer products that were manufactured by a certified energy efficient manufacturer or that are energy efficient themselves. Combined Heat and Power is a method for saving energy that manufacturers can incorporate into their processes. Production Tax Credits can be given to generator of renewable energy. Accelerated Depreciation is a method for reducing taxable property in exchange for engaging in some of the aforementioned programs. Investment Tax Credits are another way to create incentives for investment in renewable energy sources and technologies among other things.

Potential Roadblocks

Like any new form of law or regulation, taxes are often met with opposition. Michigan is a particularly sensitive to the effects of taxing consumer goods and emissions, as it faces a slow, and slowing, economy. For this reason it is important to consider potential roadblocks faced by taxes and tax-incentive programs. As stated earlier, any new or improved grant, subsidy or credit program will likely need new and equivalent sources. The following briefly lists a set of potential roadblocks faced by new tax-incentive programs:

- Initial high cost
- Market uncertainty
- Lack of consumer awareness
- Alternative Minimum Tax
- Maximum Allowable Business Credit (Section 38 c.)
- Program Longevity (Does it have the right timeline?)
- Avoid “picking a winner”
- Costs/Ability to Monitor/Enforce Programs

Appendix End Notes

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