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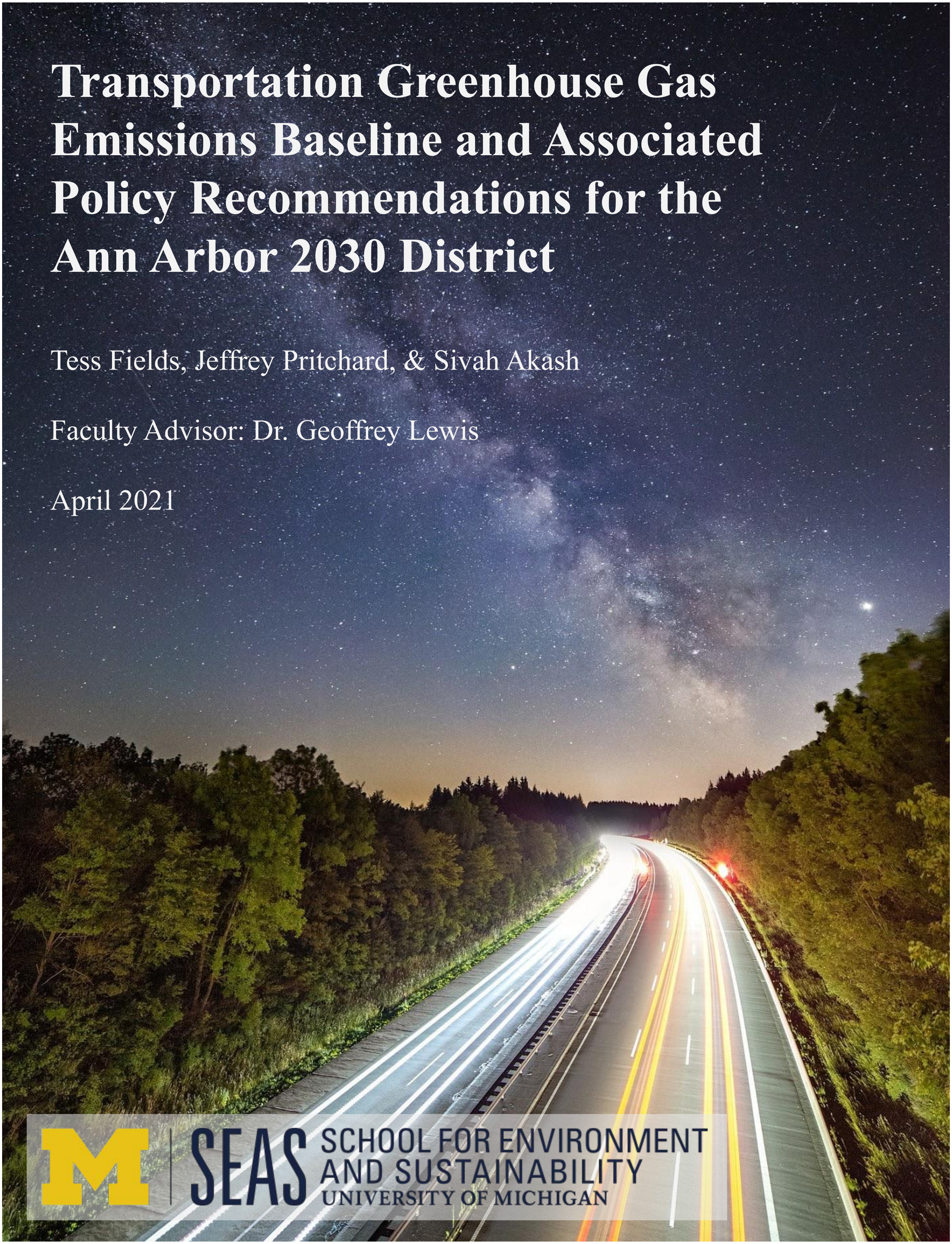
Tess Fields, Jeffrey Pritchard, & Sivah Akash

Faculty Advisor: Dr. Geoffrey Lewis

April 2021



SEAS SCHOOL FOR ENVIRONMENT AND SUSTAINABILITY
UNIVERSITY OF MICHIGAN

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Tess Fields, Jeffrey Pritchard, & Sivah Akash
Advisor: Dr. Geoffrey Lewis
Client: Ann Arbor 2030 District, Jan Culbertson

A project submitted in fulfillment of the requirements for the Master of Science degree at the University of Michigan School for Environment and Sustainability.

April 2021

Executive Summary

This report describes and presents estimation of the Ann Arbor 2030 District transportation greenhouse gas emissions baseline using a survey administered to District members. The survey methods and greenhouse gas inventory calculations included in this report focus on commuting emissions for individuals employed by Ann Arbor 2030 District building members. The transportation baseline is determined by assessing the greenhouse gas emissions based on the per-passenger fuel or electricity consumption of the vehicle used. Distance travelled, mode share, fuel type, and average fuel/electricity consumption are used to determine the emissions per commuter and these parameters were obtained from survey respondents or determined by the research team using local or national data. Policy recommendations from literature reviews and survey response data are provided based on the potential for emissions reductions. A survey was administered to employees regarding commuting patterns before and during the COVID-19 pandemic to establish a baseline in both periods and to study how the pandemic has affected commuting emissions in the District.

This baseline is determined to be 1,724 kilograms of CO_2e per commuter per year before the pandemic and 472 kilograms of CO_2e per commuter per year during the pandemic. These baseline values include emissions resulting from extraction and processing of fuels as well as combustion (i.e., well-to-wheels). Results also indicate that a shift in transportation modes from the high-intensity mode of driving alone in gasoline-powered vehicles to the lower-intensity mode of working-from-home is a valuable strategy for the Ann Arbor 2030 District to meet the goal of reducing transportation-related emissions at least 50% by the year 2030, based on a 2019 baseline. The report also provides other 2030 Districts with a toolkit for establishing and tracking emissions associated with commuting.

Acknowledgements

Many thanks to the tireless commitment of our research advisor, Dr. Geoffrey Lewis, and our client, Jan Culbertson. Thank you both for being such collaborative members of our team.

This research was also greatly aided and informed by Dave Low (2030 District Executive Director), Thea Yagerlener and Josh MacDonald (City of Ann Arbor), Isabella McKnight and Cindy Cicigoi (Cleveland 2030 District), Chris Cieslak and Paige Colao (Pittsburgh 2030 District), Larry Deck (Washtenaw Bicycling and Walking Coalition), Jarod Cory Kelly (Argonne National Laboratory), and Dr. Jonathan Levine (University of Michigan Taubman College of Architecture and Urban Planning).

We would also like to thank the building managers and employees of the following properties for helping us calculate the transportation baseline: 918-920 N Main, Ann Arbor Art Center, Ann Arbor Area Transportation Authority, Ann Arbor City Hall and Justice Center, Creative Windows, Fiat Building, First Congregational Church, First United Methodist Church, Genesis of Ann Arbor, Hobbs+Black Architects Offices, Jewish Family Services, Kerrytown Shops, Limestone Building, Meadowlark Builders, NEW Center, Quinn Evans Ann Arbor Office, Riverfront Building, South State Commons I, South State Commons II, South State Commons III, and St. Mary Student Parish.

Contents

Abbreviations

AAATA	Ann Arbor Area Transportation Authority
BEV	Battery Electric Vehicles
CH_4	Methane
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
EF	Emission Factor
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies
HEV	Hybrid Electric Vehicle
IPCC	Intergovernmental Panel on Climate Change
kWh	Kilowatt-hour
LCA	Life Cycle Assessment
MPG	Miles per Gallon
N_2O	Nitrous Oxide
PHEV	Plug-in Hybrid Electric Vehicle
US	United States
WTW	Well-to-wheels

Background

Client: the Ann Arbor 2030 District

The 2030 Districts Network is a greenhouse gas (GHG) emissions reduction initiative in 23 cities around the United States (US), where each District has committed to 50% reductions in energy-, water-, and transportation-related emissions by 2030 (2030 District Network 2020). Over 1,100 organizations have signed on to be District members, and the Network includes over 2,100 buildings and more than 506 million square feet of commercial space across the US (2030 District Network 2020).

The Ann Arbor 2030 District (hereafter referred to as "the District") is a private-public partnership made up of property owners, professional stakeholders, and community stakeholders (Ann Arbor 2030 District 2020). The District also serves as a partner in implementing the City of Ann Arbor's A2Zero Carbon Neutrality Plan for commercial and multi-family buildings (City of Ann Arbor 2020a). The District currently has over 90 commercial buildings as members, and contains a total floor area of 1,651,174 square feet (Ann Arbor 2030 District 2021). Eligible buildings include businesses, municipal buildings, places of worship, apartment associations, multi-family residences, and fraternities/sororities. University of Michigan-owned buildings, single family houses, or single family-attached houses are outside the scope of the District. Recommended emissions reductions strategies will focus on actionable steps building managers can take to influence the commuting behavior of their employees. Recommendations are based on the survey responses of employees in the District regarding their commuting patterns and their preferences towards selected transportation policies their employers could undertake. Baseline assessments in energy-, water-, and transportation-related emissions are required to measure the District's progress towards the 50% reduction goal in GHG emissions in the coming decade. The baselines for energy and water had already been calculated before the start of this project (Johnson-Lane 2020).

The energy baseline was the first assessment performed by the District and was established in 2019. Due to the varying size of buildings across the District, the baseline was measured using Energy Use Intensity (EUI). This considers the energy use per unit area of the building (in units of kBTU per square foot). The goal is to reduce energy use by 50% by 2030 for existing buildings and achieve carbon neutrality for new/renovated buildings by the same year. Each individual building tracks their energy use using the ENERGY STAR Portfolio Manager. The calculated EUI in 2019 was 5% lower than the 2019 baseline.

The water baseline was established in 2020 and was measured as Water Use Intensity (WUI) (in units of gallons per square foot). The District is working with the City of Ann Arbor to automate water data entry into the ENERGY STAR Portfolio Manager, after which most of the building owners will be tracking their own water use (Johnson-Lane 2020).

Scope and Expected Impact of this Project

The main goal of this project is to calculate the baseline commuting GHG emissions for the Ann Arbor 2030 District and offer emissions reduction recommendations to District members. More broadly, this project will be an important step in reducing Ann Arbor's GHG emissions, with the larger goal of mitigating global climate change. The transportation sector now accounts for the greatest proportion of US GHG emissions, having recently overtaken the electricity sector (US EPA 2020a). Transportation is a particularly complex system to target in terms of GHG reductions, as commuting-related emissions are largely dependent on the choices of individuals. This project seeks to capture the complexity of the District's commuting patterns in order to understand how best to design impactful emissions reduction policies. A toolkit has also been created for replication of this project's methods and analysis by other 2030 Districts as they establish their own transportation baselines.

There are various "scopes" of emissions, as detailed in the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (Fong et al. 2014). The "ownership" of these emissions can be considered from two perspectives. The first is from the purview of the commuter. For them, the Scope 1 emissions would be the emissions from fuel combustion for their personal fossil fuel powered vehicle or buses or ride-hailing vehicles; Scope 2 emissions would be the emissions created from electricity generation to power their electric vehicles; and the Scope 3 emissions would be upstream emissions generated by fuel processing and transportation. For this research, the ownership of emissions is instead considered from the purview of the employer. Here, Scope 1 emissions are those from fossil fuel combustion of fleet vehicles (for example, delivery and company-owned vehicles); Scope 2 emissions are those from electricity generation for electric powered fleet vehicles;[1] and Scope 3 emissions are both from employees' commuting and upstream emissions from fuel processing and transportation. Our project and the associated survey determine the Scope 3 emissions from the employer's purview.

COVID-19 Pandemic Considerations

The COVID-19 pandemic (hereafter referred to as "the pandemic") began shifting people to working from home in the US in March 2020. Because of the potentially large and long-lasting difference in commuting patterns due to the pandemic, the research team decided to collect information to calculate two baselines. The first baseline is for commuting emissions for the District before the pandemic and the second is for the commuting emissions for the District during the pandemic. (See **Future Commuting Surveys** section of the **Conclusion** for implications of choosing a pre- or post-pandemic baseline.)

[1] The research team also put together a secondary fleet survey to determine the emissions caused by building member fleets, but that survey will be conducted at a later date and is not within the scope of this project.

Research Methods

Other 2030 Districts' Commuting Baselines

Several other 2030 Districts have already established commuting baselines, utilizing various methods and levels of detail and complexity. A few of these Districts are discussed below. Similar to the Ann Arbor's 2030 District, these Districts only consider commuting in their baseline estimation. However, they do not consider emissions from non-CO_2 greenhouse gases or upstream emissions, both of which the Ann Arbor 2030 District baseline does include.

The Pittsburgh 2030 District is an initiative of the Green Building Alliance with 556 properties and 86.3 million square feet of floor area and is the largest 2030 District. For the creation of the baseline in 2015, the District used the Southwestern Pennsylvania Commission's Regional Travel Demand Model (Southwestern Pennsylvania Commission 2020), which is based on Citilabs Cube Voyager(Delaware Valley Regional Planning Commission 2019), a 4-step travel demand model (trip generation, trip distribution, mode choice, and trip assignment). This resulted in a commuting emissions baseline value of 1,794 kg CO_2 per commuter trip per year. The District conducted commuter surveys in 2015 and 2018, with the latter having more than 20,000 responses, for determining updated emissions per commuter. Emissions were found to be mostly impacted by proximity to work and access to alternate commuting options, such as public buses and carpooling. The District saved \$154 million as of 2019 by decreasing energy and water use, and from the social cost savings from commuting emissions reduction (Colao et al. 2019).

The Seattle 2030 District has 260 committed buildings covering 58.9 million square feet of floor area and was the first 2030 District to be established. The District used the Seattle Climate Partnership's carbon calculator to set the 128 kg CO_2 per commuter per year commuting baseline in 2010 (Wickwire and Combe 2017). Mode share was obtained from a 2010 survey administered by Commute Seattle, which is also a District member. One hundred sixty buildings reported for the commuting baseline, representing 39 million square feet. In 2019, there had been a 23.5% reduction compared to the 2010 baseline (Seattle 2030 District 2021).

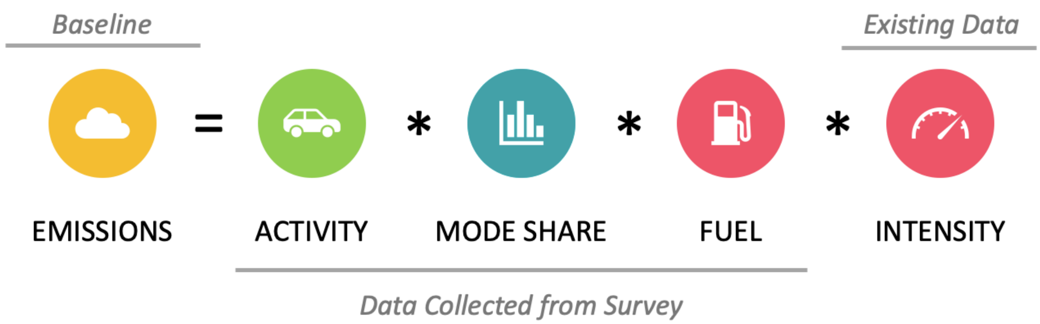
The Cleveland 2030 District has 257 buildings participating, with 60 million square feet of floor area. The baseline was determined using 2001 National Household Transportation data (Cleveland 2030 District 2019) and was determined to be 2901 kg CO_2 per commuter per year in 2016. A survey is sent out every other year, and the most recent (in 2020) showed a 49.1% decrease in commuting emissions from the baseline, which their report noted was largely due to the pandemic's impact on remote work (Cleveland 2030 District 2020).

The Ithaca 2030 District has 27 committed buildings that include 329,964 square feet of floor area. Their 2015 baseline was determined using the number of buildings, emission multipliers from the

Environmental Protection Agency (EPA), Commercial occupancy/number of workers per unit area from CBECS (national data), and a local city government survey and resulted in a baseline value of 1,501 kgCO_2e per commuter per year (Namnum 2017). An annual survey is sent to determine reductions in commuting emissions, with the 2019 survey showing a 7% increase in emissions compared to the baseline. Currently, even though 27 buildings have signed on to be District members, only the original 15 buildings considered in the baseline calculation track annual changes (Ithaca 2030 District 2019).

Literature Review

The literature review began by focusing on established methods for calculating transportation emissions baselines in cities. This work relies upon the ASIF framework to organize data collection for transportation emissions calculations (**Equation 1**). The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (Fong et al. 2014) is one of the primary sources for determining Scopes 1, 2, and 3 emissions and describes the ASIF framework. Data sources for estimating each component in **Equation 1** are listed in the **Emission Factors** section below (Fong et al. 2014).



Eq. 1

Activity reflects the number and length of trips (vehicle miles traveled, or "VMT"); Mode Share describes which mode of transportation or vehicle type was used in the trip; Fuel is the type of energy source used to complete the trip (Fong et al. 2014)*; and Intensity is the mass of emissions per mile of a trip.*

The research team also relied upon sources from the City of Ann Arbor and its A2Zero Carbon neutrality plan to provide information on policy change effectiveness and transportation improvements. Policy recommendations from the A2Zero plan are included in the survey to determine receptiveness of transportation policy adoption and aid in the District's transportation emissions reduction goal (City of Ann Arbor 2020a).

This project began before the pandemic arrived in North America. Additional research on the opportunities and challenges provided by a global pandemic was required to alter and expand our methods to collect data for past, present, and future emissions calculations (Shokouhyar, Shokoohyar, and

Sobhani 2021). As most workers throughout the US shifted to working remotely from home beginning in March 2020, the research team recognized a survey about commuting patterns would need to be altered. The team pivoted to include pre-pandemic and during-pandemic time frames in the survey, to capture the impact of the pandemic on transportation emissions in the District (as discussed further in the **Survey Design** section). A specific challenge acknowledged by the research team but not incorporated into this project involves the GHG emissions shift from the transportation sector to residences resulting from the pandemic and the requirement of millions of employees to work from home. While this project considers telecommuting to be a zero-emission mode (see **Emission Factors** section), telecommuting in actuality shifts the point of emissions from the workplace and the commute to the employee residence, at least in some proportion: "When employees shift from working at an office to working at home, the corporate emissions appear to have decreased even though they simply have shifted beyond the boundary of the reporting requirement" (Vandenbergh and Shewmake 2021). These telecommuting-associated emissions are smaller than that of commuting, but not truly zero.

Ann Arbor 2030 District Emission Factors

Data collected by the survey do not directly reveal an emissions baseline in annual kg CO_2e/person. Transportation modes and round-trip mileage need a conversion factor to calculate GHG emissions. We used local and national data sources to assign an emission factor to each transportation mode. Where national data were used but local level data can be applied, pending data availability, we explain what information needs to be collected to compute a local-scale emissions baseline. Conversely, if an emission factor calculation utilizes local/regional data, information on national data is provided. A conceptual model for our survey and analysis (including all emission factors) can be found below in **Figure 1**.

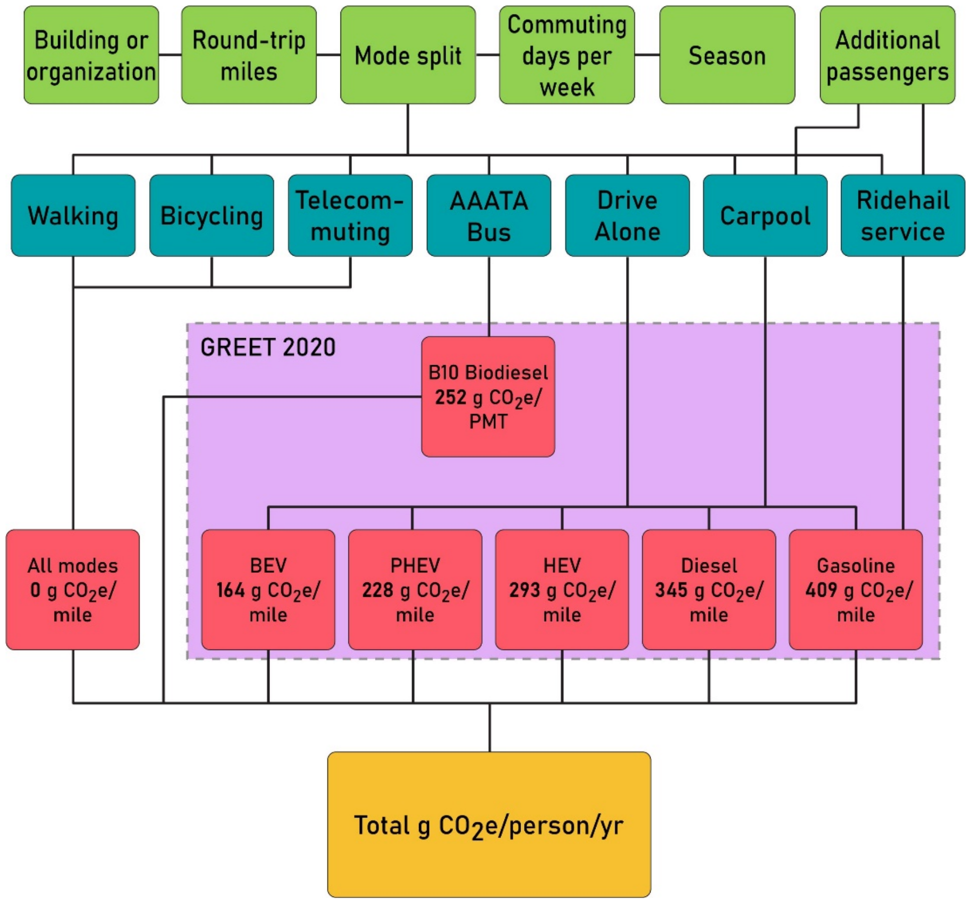


Figure 1: Representative Model for Commuting Emissions

Walking, Bicycling and Telecommuting

Shifting modes of transportation from high emission-intensity modes to low- and zero-intensity modes is crucial for achieving the District's goal of reducing GHG emissions by 50% by 2030. We assume zero GHG emissions from walking, bicycling and telecommuting modes, though, as discussed above, the emissions from telecommuting are not zero but are rather shifted (at least in some portion) to greater energy consumption in the home.

Driving Alone

Argonne National Laboratory manages the Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies Model (GREET) and is sponsored by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (Argonne National Laboratory 2020). The GREET model, updated annually, is used in Life Cycle Assessments (LCA) to estimate GHG emissions and other life cycle impacts across a variety of vehicles and fuel types in the US. The emission factors used in our analysis include CO_2, CH_4, and N_2O and use the well-to-wheels (WTW) values provided in GREET. WTW values include emissions from extraction, processing, and combustion of fuels.

For vehicles connecting to an electricity grid, such as plug-in hybrid electric vehicles and battery electric vehicles (PHEV and BEV), the ReliabilityFirst (RFC mix) regional grid is used in GREET to calculate emission factors. The RFC mix includes electricity generation sources for multiple states in the Midwest, including Michigan. DTE shared data on the regional electrical grid mix for the Ann Arbor Region (**Table 1)**. The fossil fuel and renewable electricity generation percentages provided by DTE can be manually entered into GREET to create a localized emission factor (City of Ann Arbor 2020b). Electricity mix comparisons for DTE, DTE sourced regional mix, and RFC mix can be found in **Table 1**. The research team chose to use a regional energy mix for ease of replicability for future calculations and comparability with other 2030 Districts. The 2019 RFC mix is less carbon intensive than the 2019 DTE energy mix. Emission factors for fossil-fuel-based personal vehicles—i.e., gasoline, diesel, or hybrid-electric vehicles (HEV)[2]—are taken directly from GREET 2020. Values for all emission sources included in this model can be found in **Figure 1**. Exact GREET cell locations for emission factors can be found in **Table 2**. Reported fuel efficiency from survey responses was not used in this analysis, as the research team decided the GREET emission factors (which rely on a national average of fuel efficiency) were more consistent and did not result in a substantial difference for most respondents.

[2] HEVs are defined as self-charging, non-grid-connected hybrid-electric vehicles (e.g., a conventional Toyota Prius), whereas PHEVs are defined as plugging into an electricity source and require consideration of the electric grid when calculating an emission factor.

Table 1: Energy Mix Comparison			
Electricity Source	DTE Energy's Fuel Mix	Regional Average Fuel Mix (DTE Reported)	RFC Mix (GREET)
Coal	58.6%	41.8%	25.2%
Nuclear	23.7%	26.6%	33.9%
Gas	8.7%	23.6%	35.2%
Oil	0.2%	0.4%	0.2%
Hydroelectric	0.1%	0.8%	1.4%
Biofuel	0.1%	0.8%	NA
Biomass	1.0%	0.5%	0.2%
Solar	0.2%	0.1%	0.5%
Wind	7.3%	5.0%	2.8%
Wood	0.1%	4.4%	NA
Solid Waste Incineration	0.1%	0.0%	NA
Other	NA	NA	0.6%
DTE Purchased Electricity from Region*	-	16.3%	-
Renewable Fuels Total	8.7%	6.8%	5.3%
Fossil Fuels Total	67.5%	65.8%	60.6%

** DTE purchased 16.28% of its electricity in 2019 from regional sources in MI, IL, IN, OH, and WI.*

<u>Ride Hailing</u>

We assume all vehicles operating for ride-hailing services are gasoline-powered. According to Henao and Marshall, the average vehicle occupancy for ride-hailing services is 1.4 passengers per ride (Henao and Marshall 2019). The emission factor for ride-hailing is therefore the emission factor for gasoline vehicles divided by 1.4 (see **Table 2**). This parameter can be updated for future surveys if new information regarding ride-hailing ridership is released. It is expected that this mode would play a more significant role in larger cities.

<u>Bus Transit</u>

GREET allows the user to change cell values to create non-default emission factors. The research team altered the default B20-Biodiesel fuel value in GREET to reflect the B10-Biodiesel used by transit buses of the Ann Arbor Area Transportation Authority (AAATA). We calculate emissions on a per-passenger basis in our analysis and GREET provides a bus emission factor based on passenger miles.

Districts can create a more locally specific calculation if total passenger-mile data are available from transit authorities. The AAATA tracks fuel consumption per passenger trip and total fuel consumption per year by fuel type. This research team could not accurately calculate, to the level of individual trips, an emission factor for bus transit based on local-level data. To calculate an emission factor for a local/region bus transit system one would need to obtain data for total fuel consumption and total passenger-miles traveled in each period.

Table 2: GREET 2020 Emission Factors

Num.	Description	Value	Unit	GREET Cell Location
1	Gasoline	409	gCO_2e/mile	Results tab, E55
2	Diesel	345	gCO_2e/mile	Results tab E835
3	HEV	293	gCO_2e/mile	Results tab E1075
4	PHEV*	228	gCO_2e/mile	Results tab, E1405
5	BEV*	164	gCO_2e/mile	Results tab, E2095
6	Ridehail	292	gCO_2e/mile	*calculated*
7	Transit Buses**	252	gCO_2e/mile	HDV_WTW tab, E3387

** GREET default is US mix for electrical grid generation sources; the research team selected the regional grid ReliabilityFirst (RFC Mix), which includes the state of Michigan.*

*** GREET default for biodiesel is B20 – Biodiesel. The research team changed the percentage of biodiesel to a 10% (B10 – Biodiesel) mixture used by AAATA transit buses.*

Survey Design

The research team considered both a bottom-up method (where the baseline would be aggregated from data collected from District members) and a top-down method (where the baseline would disaggregate existing data from general Ann Arbor commuting trends). We chose the bottom-up survey method to capture not only the specific commuting patterns of employees in the District but also to capture specific policy preferences that would be relevant to District members. The research team used the example of the Cleveland 2030 District's survey and spreadsheet model as a starting point.

The survey was designed and implemented in Google Forms due to its zero cost, simple interface, and replicability (i.e., open to any potential future user who may not be affiliated with University of Michigan). The survey questions, included in **Appendix 3**, capture building affiliation, number of commuting days, round trip commute length, mode share of an average commute by percentage, number of passengers, vehicle and fuel type, fuel efficiency, and potential policy preferences. Questions regarding mode share are formatted as percentages that add up to 100% to accommodate multi-modal commutes and include walking, biking, driving alone, carpooling, public buses, ride hailing services (e.g., Uber or Lyft), and telecommuting. The survey accounts for respondents who work some days from home by asking about commuting days. The last option of "I only ever telecommute" in the mode share question is to account for people who never commute into work. The mode share question is further broken out into four categories: pre-pandemic fair weather; pre-pandemic cold weather; during-pandemic fair weather; and during-pandemic cold weather. The decision to differentiate between fair and cold weather was made to accommodate survey respondents who used different modes throughout the year (e.g., biking in the summer and driving in the winter). As discussed above, the decision to differentiate between pre-pandemic and during-pandemic was made to capture the impact of the pandemic on commuting patterns in the District. The research team acknowledges that asking survey respondents to respond to questions regarding transportation decisions from months prior potentially introduces error (as discussed in the **Sources of Error and Bias** section in the **Results**). There was not an alternative research solution, as the survey was being administered after the pandemic had already begun. Moreover, as commuting was regularly a daily task for most people pre-pandemic, the research team believes that any potential errors introduced by respondents' misremembering are not likely to be substantial and there was no reason to believe that any error would skew to over- or underestimating commuting patterns across respondents.

Eight policy options were included in the survey:

1. Increased secure bike rack parking / storage at my workplace;
2. Closer bus stops to work;
3. Free or subsidized public transportation pass;
4. Expanded work from home policies (outside of pandemic);
5. On-site childcare;
6. Installed EV charging at my workplace;
7. Financial incentives to carpool;
8. Access to shared company vehicle (e.g., ride home or shuttle programs).

For each policy, preferences were asked as a qualitative scale:

- "Will not change my commuting behavior"
- "Not likely to change my commuting behavior"
- "Undecided"
- "Likely to change my commuting behavior"
- "Will change my commuting behavior"
- "I already have access to this service"

A pilot survey was administered from October 2020 to November 2020 to a subset of the District's buildings' occupants. No substantial changes were made to the survey based on this pilot, and the final survey was administered from December 2020 to February 2021.

Incentives

All survey respondents, including those who took the pilot survey, were told they would be entered into a gift card raffle. Two respondents were selected at the end of the project (April 2021) to each receive a $50 gift card to an Ann Arbor establishment.

IRB Approval

The survey was reviewed by The University of Michigan's Health Sciences and Behavioral Sciences Institutional Review Board (IRB-HSBS). Upon IRB-HSBS review, the survey was given IRB exemption status per the federal exemption category EXEMPTION 2(i) and/or 2(ii) at 45 CFR 46.104(d).

Quantitative Analysis

This project's quantitative analysis was performed in different ways by two research team members, one using Excel and the other using Python. The two methods are described in **Appendix 2: Spreadsheet Model** and **Appendix 3: Python Model**. Both methods follow the same ASIF framework (**Equation 1**). This section describes this framework and how it was used in both methods.

Survey responses were collected in Google Sheets, where each respondent was an individual row, and each question was an individual column. These data (with personally identifying information removed for privacy) were then analyzed using Microsoft Excel and Python. Some data cleaning had to be performed (e.g., removing text from non-numeric responses and adding appropriate building addresses where "Other" had been selected). The calculation methods were identical for the four categories (pre-pandemic fair weather, pre-pandemic cold weather, during-pandemic fair weather, and during-pandemic cold weather) and began with calculating GHG emissions for each respondent. Fair weather and cold weather categories were each half a year in length. For each mode, the mode percentage was multiplied by the number of commuting days per week, round trip distance, and associated emission factor (see **Emission Factors** section for more detail), resulting in weekly emissions per mode per passenger, which were multiplied by average number of working weeks to calculate seasonal emissions (23 weeks) (OECD 2020; 2021). Pre-pandemic fair weather and pre-pandemic cold weather were summed to achieve annual pre-pandemic emissions per person, and during-pandemic fair weather and during-pandemic cold weather were summed to achieve annual during-pandemic emissions per person. Total change and percent change in annual emissions per person were then calculated between pre-pandemic and during-pandemic. The individual emissions per person were then aggregated by building.

One hundred ninety people completed the survey. Google forms, the platform used to administer this survey, does not require percentage selections to add up to 100% (see Question 5 in **Appendix 3**) and a few respondents answered the mode question incorrectly**.** The research team contacted individuals who did not correctly fill out the mode question but were not able to correct all errors. Remaining incorrect responses to this question resulted in data for 16 respondents being removed from the final data set, which is 8.4% of respondents, leaving 174 responses in the analysis. The research team did not remove responses that were less than or equal to 10% away from 100% total (in either direction) for any of the four categories.

Assumptions for Quantitative Analysis

The research team made assumptions throughout the quantitative analysis that are sources of potential error. These assumptions should be noted when replicating this analysis, as some assumptions may need to be updated or altered, given the specific District's needs.

1. The survey asks about pre-pandemic and during-pandemic commuting patterns and seasonal patterns to gain a fairly detailed look at annual commuting patterns, but the survey assumes that a respondent's commuting patterns are seasonally constant. In other words, the survey does not explicitly account for a person who might only have to come to work a handful of times per month, or a person who might have to travel to various locations for work.
2. For respondents who skipped the fuel type question, "Gasoline" was used as the assumed fuel, since we assumed most people driving their own vehicles are driving conventional gas-powered cars. If respondents skipped this question because they do not drive, "Drive alone" will still result in zero emissions because of the mode share multiplication formula (i.e., the reported mode share for "Drive alone" would be 0%).
3. Average mode share across the District (see **Results** section) was not weighted by trip distance but rather considered all respondents equally in calculating the average.
4. For those responses that were value buckets, the midpoint was used in calculations (e.g., 15.5 miles for the 11-to-20-mile bucket) (see **Potential Improvements** section).
5. Reported fuel efficiency was not used in this analysis, as the research team decided the GREET emission factors (which rely on a national average of fuel efficiency) were preferable for ease of use and replicability across the country.

6. This project uses a 100-year global warming potential (GWP) for converting methane (CH_4) and nitrous oxide (N_2O) fossil fuel emissions into carbon dioxide equivalents (CO_2e) (US EPA 2020b). This is the assumption used in GREET.
7. The research team assumed that telecommuting is a zero-emission mode.
8. The research team assumed “Ride hailing” involves 1.4 passengers per trip (Henao and Marshall 2019).
9. The research team assumed people work 46 weeks per year (OECD 2020; 2021).

Results

Baseline Emissions

Using survey responses from 174 individuals across 21 buildings, we calculated the District's pre-pandemic (2019) annual commuting-related GHG emissions baseline to be 1,724 kg CO_2e per commuter per year and during-pandemic (2020) annual commuting-related GHG emissions baseline to be 472 kg CO_2e per commuter per year (**Figure 2**). This is a 73% decrease in commuting emissions between the two years, which we confidently assert is a direct result of the pandemic and associated shift to remote work (see **Impact of Pandemic** section in the **Conclusion**). This is reflected in the change in mode share from the survey responses (see **Mode Share** section below). The difference between fair and cold weather commuting emissions was negligible both pre- and during-pandemic (**Table 3**), likely because of the dominance of driving alone as a commuting mode throughout the year. However, this will be an interesting metric to track in future surveys to see if seasonal mode share is something that buildings can influence with policies such as summer biking or walking incentives.

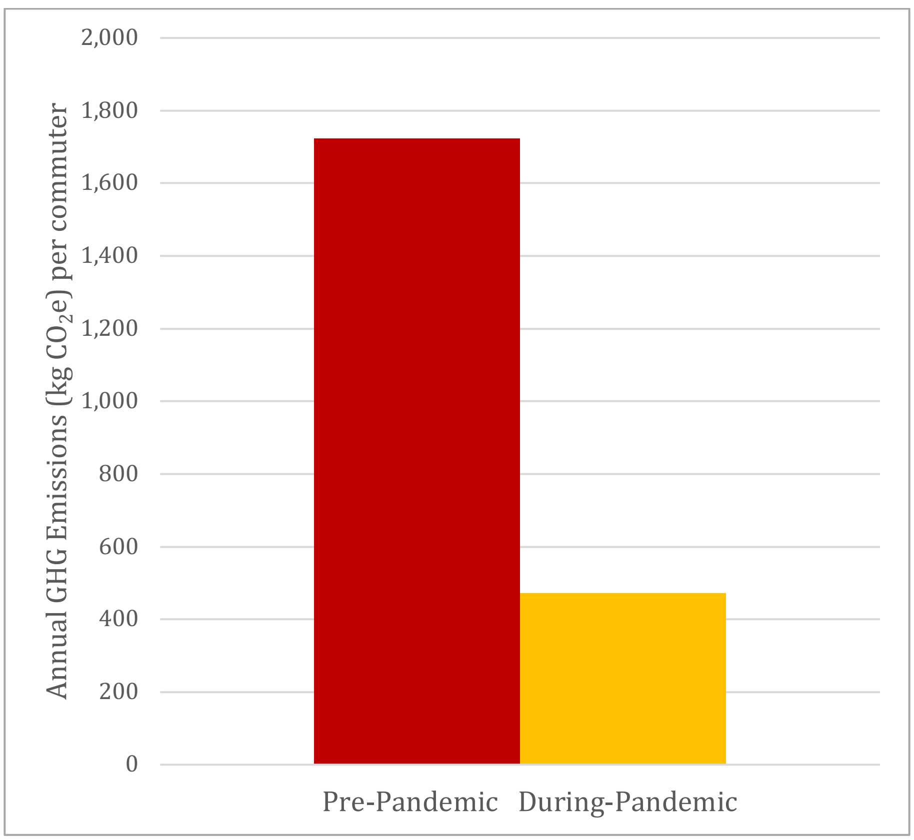


Figure 2: Ann Arbor 2030 District's Pre- and During-Pandemic Commuting Baselines

Table 3: Commuting GHG Emissions for Reporting Buildings in the Ann Arbor 2030 District					
	Pre-pandemic (2019) (kg CO_2e per commuter)	During-pandemic (2020) (kg CO_2e per commuter)	Pre-pandemic (2019) (kg CO_2e per commuter)	During-pandemic (2020) (kg CO_2e per commuter)	Percent Change
Fair Weather	151,531	40,920	871	235	-73%
Cold Weather	148,424	41,143	853	236	-72%
Annual	299,955	82,064	1,724	472	-73%

Figure 3 illustrates the spread in per commuter emissions across the 21 buildings and 174 respondents included in the analysis. The red line shows the pre-pandemic average, and the yellow line shows the during-pandemic average. Nearly every building experienced a precipitous drop in emissions due to the shift to working from home during the pandemic.

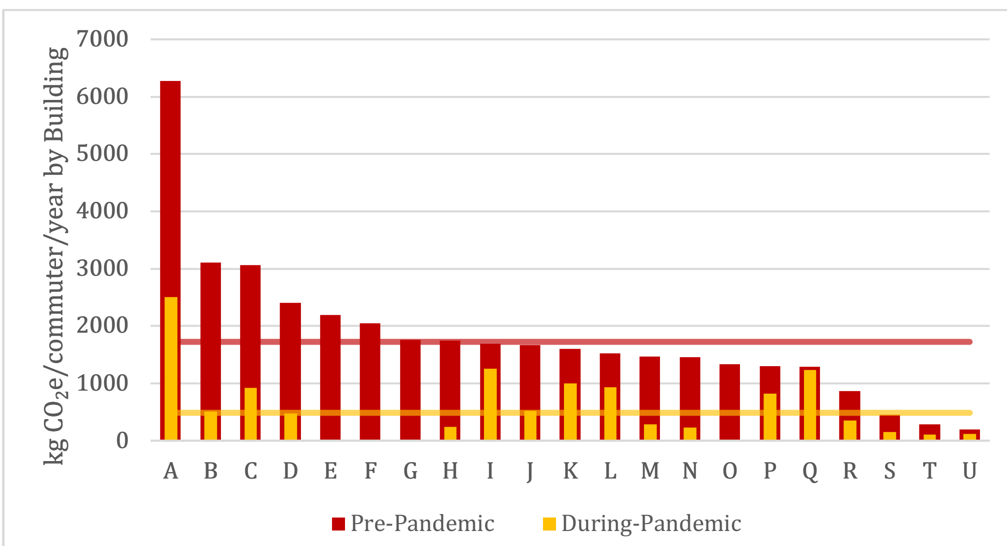


Figure 3: Ann Arbor 2030 District's Commuting Emissions Per Building

Mode Share

According to our survey results, driving alone was the most used commuting mode (81%) in the District before the pandemic. But during the pandemic, nearly 50% of commuting was avoided by working remotely, with only 44.7% of the commuting being respondents driving alone. The use of bus and ride hailing transportation modes dropped to zero, and the use of carpooling reduced by nearly 70% during the pandemic. It should be noted that the mode shares do not exactly add up to 1, due to minor errors in mode share input by some respondents.

The mode share obtained via the survey is compared with the Bureau of Transportation Statistics' 2019 Michigan data in **Figure 4**. The pre-pandemic mode share is very comparable to the statewide mode share, with 82% of Michiganders driving alone to work. Use of public transportation, walking, and biking were slightly higher in the District compared to the state. Ride hailing is omitted from this graph because the Bureau of Transportation Statistics does not consider it separately, but it was very small pre-pandemic and dropped to zero during the pandemic (U.S. Bureau of Transportation Statistics 2020).

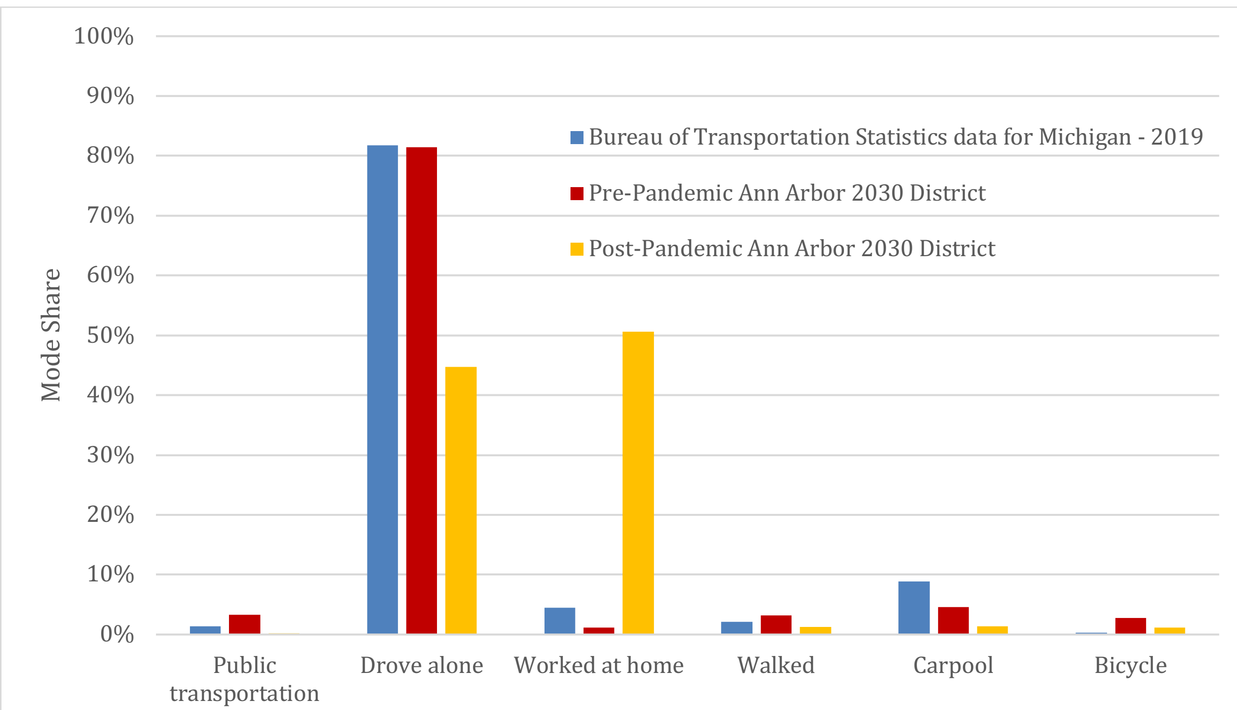


Figure 4: Mode Share Comparison for the Ann Arbor 2030 District

Vehicle Type Breakdown

Of the close to 90% of respondents that drive some type of car (either alone or carpooling), 87% drive a gasoline powered vehicle, 7% drive a hybrid electric, 4% drive a plug-in hybrid electric, and 2% drive a battery electric vehicle (**Figure 5**). This is also comparable to the statewide vehicle breakdown for

Michigan (U.S. Bureau of Transportation Statistics 2020). BEVs are expected to grow in proportion across the country in coming years, so this will be an interesting metric to track for future surveys.

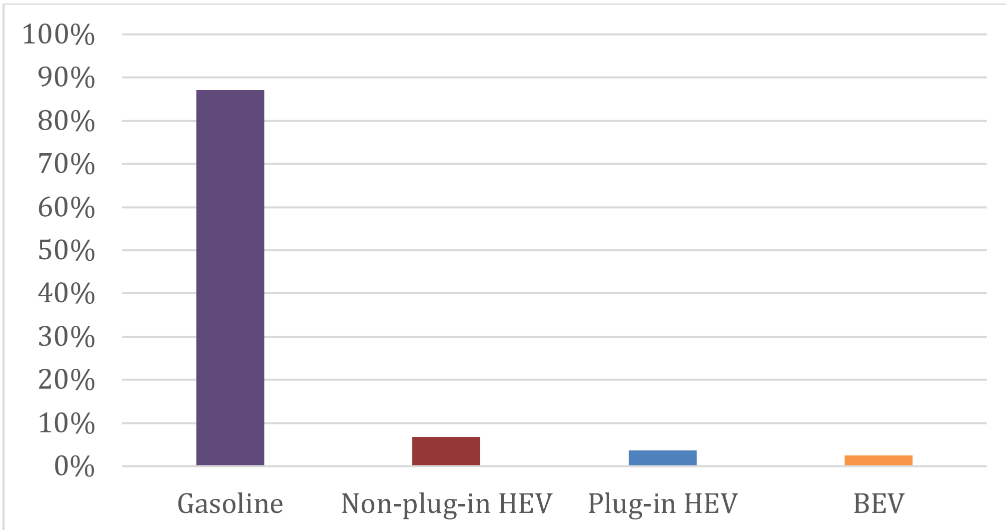


Figure 5: Vehicle Type Breakdown for the Ann Arbor 2030 District

Since driving alone is the primary mode of transportation in the District and most vehicles are gasoline-powered, driving alone was also the primary contributor to GHG emissions in the District (**Figure 6**). Emissions from driving alone dropped nearly 74% during the pandemic, explaining most of the emissions drop apparent in **Table 3**.

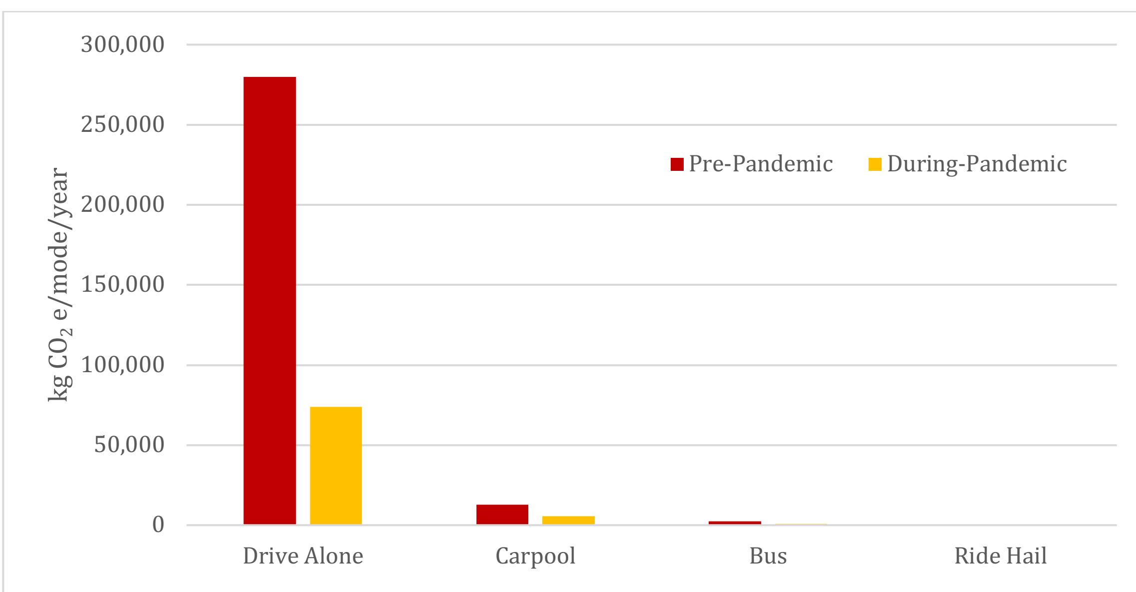


Figure 6: Total GHG Emissions per Mode per Year for the Ann Arbor 2030 District

Policy Preferences

Survey responses to potential transportation policies were aggregated by building and across the entire District. **Table 4** and **Figure 7** depict these findings.

Table 4: Policy Preferences of Ann Arbor 2030 District Survey Respondents

	"Will not change my commuting behavior"	"Not likely to change my commuting behavior"	"Undecided"	"Likely to change my commuting behavior"	"Will change my commuting behavior"	"I already have access to this service"
Bike Storage	79.3%	8.0%	4.0%	4.0%	1.7%	2.9%
Bus Stops	73.0%	7.5%	5.7%	5.7%	3.4%	4.6%
Public Transit Subsidy	68.4%	12.1%	5.7%	5.2%	3.4%	5.2%
Work from Home	18.4%	5.2%	6.3%	24.7%	36.2%	9.2%
Childcare	88.5%	1.7%	2.9%	1.7%	4.6%	0.6%
EV Charging	78.7%	4.6%	4.6%	6.3%	2.9%	2.9%
Carpooling Incentives	72.4%	6.3%	10.3%	8.6%	2.3%	0.0%
Company Vehicle	70.1%	7.5%	12.1%	8.6%	1.7%	0.0%

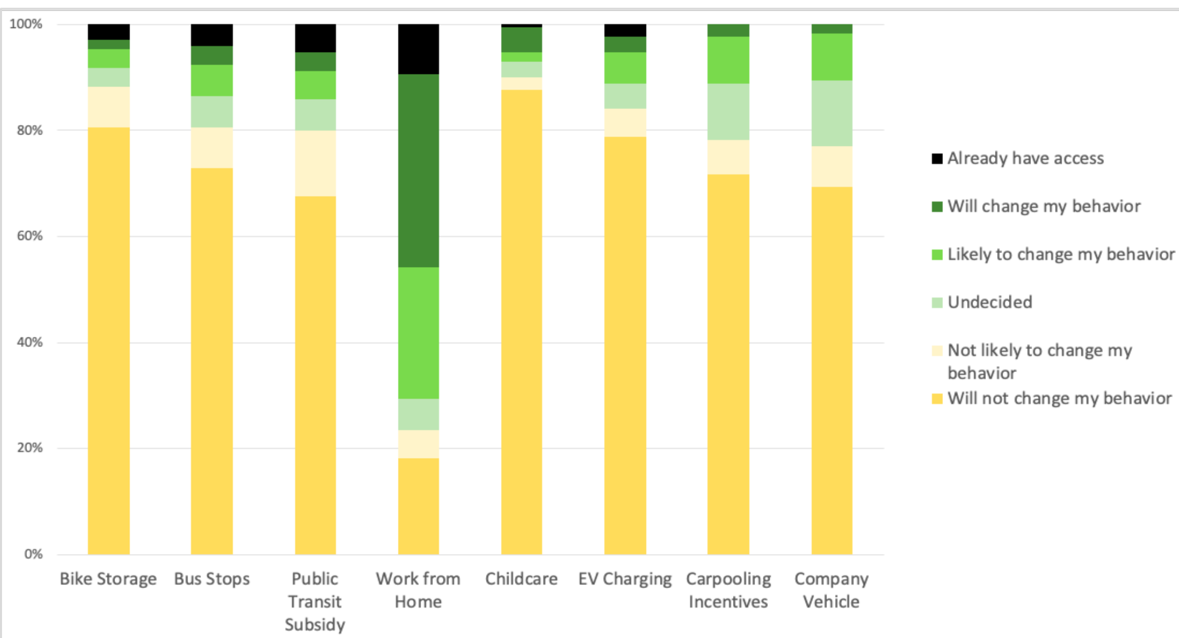


Figure 7: Policy Preferences of Ann Arbor 2030 District Survey Respondents

Increased ability to work from home (outside of the pandemic) was the policy that had the highest reported potential to change commuting behavior. A majority (60.9%) of respondents reported that it either would change their behavior or likely would change their behavior, while 23.6% of respondents reported that it either would not change their behavior or likely would not change their behavior. It should be noted that there is likely a large degree of confirmation bias associated with this question—because the pandemic had (at the time of this survey) forced many people to work from home for nearly an entire year, those who responded favorably to increased work from home policies had likely already acclimated to working from home and were confident that this was a feasible option. Conversely, the other seven policy options likely remain untested or seemingly irrelevant to many survey respondents, perhaps even outside their experience. The research team suspects that prior to the pandemic, increased ability to work from home may not have had such a substantial favorability over the other policy options.

The next most popular policy was carpooling incentives, with 10.9% reporting that it either would change their behavior or likely would change their behavior. However, 78.7% reported that it either would not change their behavior or likely would not change their behavior. Other than increased ability to work from home, no policy had a majority of respondents reporting that the policy was at least somewhat likely to change their behavior.

See **Policy Proposals** in the **Conclusion** for a discussion of GHG emissions-reducing policy proposals by the research team.

Sources of Error and Bias

The survey was completed by commuters in the District individually and voluntarily. Instructions were intentionally written so as not to prime the respondents in a particular way; for instance, descriptions and instructions specifically refrained from mentioning climate change or GHG reductions with the intention that respondents would not try to make their emissions larger or smaller. While the survey was emailed to employees by building managers, it was made clear that individual survey responses would not be shared with their employers and an individual building's aggregate emissions would not be judged in any way. However, it is possible that some respondents either intentionally or unintentionally misrepresented their own commuting patterns. This could result in respondents understating their own transportation patterns so as to not be negatively judged for perceived "high" GHG emissions or overstating their own transportation patterns so as to set a higher building GHG emissions baseline to ease meeting a 50% reduction goal. We ultimately decided there was no reason to believe this bias would skew overwhelmingly in either direction. There is also the possibility that respondents misunderstood questions (such as the mode share adding up to greater than 100%, as discussed in the **Quantitative**

Analysis section above). The research team attempted to remove any responses with egregious errors from the analysis.

The survey questions regarding round-trip commute length and fuel efficiency[3] were asked in a "bucketing" format (e.g., "Less than 5 miles," "6 to 10 miles," etc.). Midpoint estimates were used in calculations referring to these questions, which introduces error. For instance, a response of "11 to 20 miles" would have 15.5 miles used in the relevant formulas. The research team has decided to dispense with this technique for future iterations of the survey. The bucketing technique was originally intended to make taking the survey easier, but the research team prefers that the survey respondents make the estimates themselves (see **Potential Improvements** section).

Finally, there is the issue of sample size and representativeness of this baseline sample population. The District continues to grow—now including over 90 buildings—but only 21 buildings were surveyed for this analysis. It should be noted that a wide variety of building types are captured in this analysis, including municipal buildings, places of worship, and businesses. However, restaurants are particularly lacking from this analysis. Only including 21 buildings is due to a combination of timing (buildings that have joined since the survey implementation were not considered in this analysis) and the impact of the pandemic. Many buildings that would have otherwise participated in the survey did not feel equipped to administer the survey while so many other pressures were at play throughout 2020 (which is especially true of restaurants). Within the 21 buildings surveyed, 174 respondents were included in the analysis, which the research team estimates as a survey response rate of 41% based on the number of employees building managers reported sending the survey to. This baseline therefore represents emissions per commuter *of reporting buildings*. See **Future Commuting Surveys** section for how new buildings will be considered.

[3] The survey initially asked about vehicle fuel efficiency, but the research team ultimately decided to use a national average from GREET. See **Emission Factors** section for more information.

Conclusion & Recommendations

Impact of the Pandemic

As mentioned in the **Sources of Error and Bias** section, difficulties created by the pandemic on several building owners led to a reduced participation in the final survey. Only 21 buildings were able to participate in the survey out of more than 90 buildings in the District.

Though there was not a large difference in seasonal transportation patterns (between cold and fair weather months), there was a significant change when comparing the effects of the pandemic on commuting (-73%). Though a large number of survey respondents (39.4%) expected to go back to their pre-pandemic commuting patterns for work, a similarly large number (38.2%) expect to at least see some change in their pre-pandemic commuting to work after the pandemic ends (**Figure 8**).

When asked about which policy would possibly affect their commuting in the future, most expect that expanded work from home policies would change their commuting behavior the most, likely because they have worked from home successfully during the pandemic. Pew Research Center has found similar results, with more than half of US workers preferring to work from home when given a choice, and when McKinsey surveyed executives during the pandemic, 15% of executives said more than a tenth of their employees can work remotely at least two or more days per week, compared to 8% of executives before the pandemic (Parker, Horowitz, and Minkin 2020; Lund et al. 2020).

It is important to note that telecommuting is not zero-carbon, with the shift of energy use from office to home and the commuting energy use being replaced by device and internet energy use. Data are currently inadequate to analyze this problem and future research should therefore focus on this aspect of emissions (O'Brien and Yazdani Aliabadi 2020).

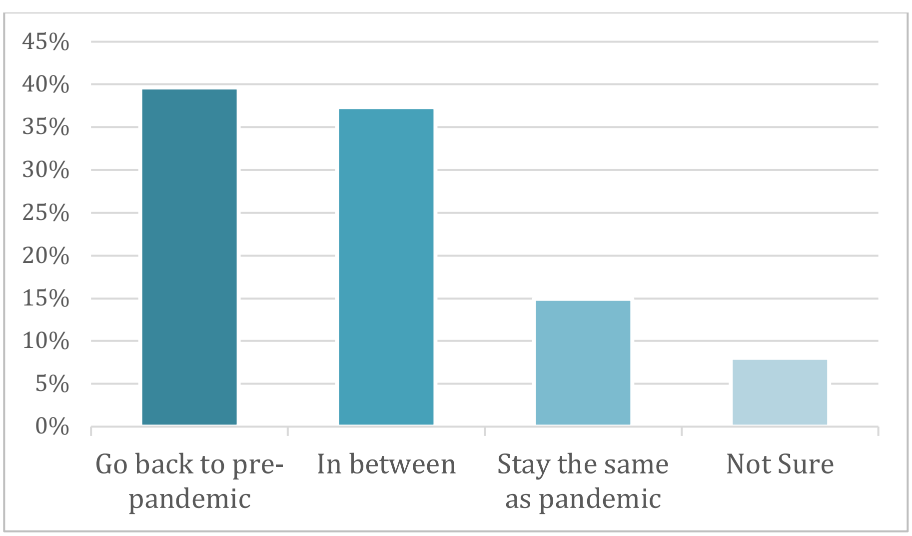


Figure 8: Survey Respondents' Expected Permanence of the Pandemic's Impact on Transportation

Policy proposals

In light of the observed change in commuting emissions due to the pandemic (-73%) and the reported favorability of increased ability to work from home in the policy preference section of the survey, the research team strongly recommends that District members consider expanded work from home policies post-pandemic. While there are many non-GHG factors for building occupants to consider—workplace communication and social interactions, work-life balance, necessary in-person business operations, etc.—expanded work from home policies seem to have the greatest opportunity to quickly and durably reduce GHG emissions, especially given the dominance of single-passenger, gasoline-powered vehicles as a transportation mode in the District. Furthermore, work from home policies do not need to be 100%, as they were largely under the pandemic; allowing all employees (who would not have otherwise worked from home) to work remotely two days per week could potentially decrease commuting emissions by 40% (assuming a five-day work week).

The research team further encourages buildings to pursue other creative ways of shifting commuting modes away from high-intensity to low- or zero-intensity options. As noted in the **Policy Preferences** discussion of the **Results** section, there is likely a substantial degree of confirmation bias in respondents' favorability towards the working from home policy option, as the majority of workers were required to work from home for most of 2020 due to the pandemic. Many commuters may not know that a new commuting policy could be viable for them until they are able to try it out, and District members should still try to enact other incentive policies on a trial basis. Maintaining open communication with employees is also important to understand building-specific commuting options and needs, and future iterations of this survey can help inform these discussions. Detailed breakdowns of building-specific emissions, mode shares, and policy preferences were shared with each District member building.

Finally, the District should take the more substantial steps of prioritizing the development of affordable housing in centralized locations and disincentivizing parking for personal vehicle commuting with the goal of reducing driving alone as the primary form of commuting. Details on these suggestions can be found in more detail in the President's Commission on Carbon Neutrality from the University of Michigan (University of Michigan 2021).

Future Commuting Surveys

This Ann Arbor 2030 baseline presents emissions per commuter *of reporting buildings*. The 50% emissions reduction goal will be based on this 2019 (pre-pandemic) emissions per commuter metric. The research team has created an updated survey for the District to administer every two years to track emissions reductions. A 50% reduction from 1,724 kg CO_2e per commuter per year represents an ultimate goal of 862 kg CO_2e per commuter per year. As other buildings in the District decide to track their commuting emissions, they should fill out the survey to be included in the average emissions per commuter for the District as a whole, meaning this metric may go up or down as new members are included. This is similar to how the energy baseline is tracked in the Ann Arbor 2030 District (i.e., some buildings that join are above the average baseline and some are below, but all have the same goal of reaching an average energy consumption that is 50% below the initial baseline by 2030).

The research team has also compiled a toolkit of resources for other 2030 Districts to replicate this commuting emissions baseline (see **Appendix 4: Toolkit**). The quantitative analysis has been integrated into an online Google Sheets (see **Appendix 1: Spreadsheet Model** for details on the calculations), which is linked to the toolkit version of the Google Forms survey so that calculations will update automatically once respondents fill out the survey. Other 2030 Districts can create copies of these resources to administer their own surveys. 2030 Districts will be able to implement this survey with few updates—particularly in the "Parameters" portion of the spreadsheet analysis—or more extensively shape the survey to their own needs. However, more extensive editing of the survey will necessitate updating to the associated spreadsheet model as well.

The main consideration for other 2030 Districts planning to calculate a transportation emissions baseline is to understand the implications of establishing a pre- or post-pandemic baseline. Undoubtedly, transportation patterns across the US will be irrevocably altered by the pandemic, with many workplaces planning to keep at least some degree of expanded work from home policies. If a District only collects data on post- pandemic commuting patterns, such a baseline is likely to be far smaller than a pre-pandemic baseline, making the 50% reduction by 2030 more difficult to achieve. The research team therefore recommends that Districts collect data on pre-pandemic commuting patterns as a baseline. However, as we get farther away from the pandemic, greater error will be introduced into pre-pandemic estimates; there will be employees who did not work for building members pre-pandemic and recalling estimates of commuting patterns from pre-2020 will likely become less and less accurate. As such, the research team recommends that Districts implement their transportation surveys as soon as possible to mitigate this source of error.

Potential Improvements to the Research Methods

Throughout this project, the research team has collected areas of improvement for future iterations of this transportation survey and analysis, in Ann Arbor as well as in other Districts. It should be noted that there is always a tradeoff between greater detail and simplicity of completing the survey for respondents, so this balance should be considered in future iterations of the survey.

1. Once it became apparent that the primary mode of transportation in the District was "Drive alone," questions arose about the correlation between parking availability and the choice to drive.

For the future survey, the research team has added the question, “Do you have access to parking at work?” with the answer options: “Yes, it’s free or reimbursed in a lot/garage,” “Yes, I have to pay for a lot/garage,” “Yes, I park on the street,” and “No” in order to capture this relationship.

2. Districts should decide whether it is worthwhile to split out seasonal mode changes. While it is potentially more accurate for certain respondents, most respondents did not report any change across the season (see **Results** section) and this added detail might be confusing or overly burdensome to some respondents.
3. The survey asked for the number of commuting days per week before and after the pandemic and assumed this does not change seasonally, but some respondents likely had a different number of commuting days in the cold and warm weather in these two periods as well. If seasons are considered, seasonality should be applied to commuting days as well as modes.
4. Bucketing should not be used; the trade-off between ease of use for the respondent and compromising accuracy with the midpoint method does not seem worthwhile. Respondents should simply be asked to enter a value.
5. For questions where a respondent needs to provide a value, greater emphasis should be put on asking the respondents to enter numeric values only (i.e., without words, like miles or ranges), so that post-processing and analysis is more straightforward.
6. When asking for commuting distance, it should be made clear that it is the total distance from residence to workplace, including regular detours to schools, etc.
7. There should be a clearer focus on the comments/feedback question for determining policy recommendations, especially in the pilot survey, as geographically specific policy recommendations may need to be incorporated into the final survey.
8. An added policy option of more affordable housing closer to work has been added to the future survey. It is noted in the question that respondents should interpret “affordable” as whatever that means to them personally.
9. The survey could help collect information on the potential and challenges of less energy-intensive transportation modes by asking specific questions to specific target groups within the overall population. For example, asking respondents why they do or do not choose public transportation to get to their workplace.
10. Emissions associated with telecommuting should be considered, though data are currently inadequate to fully characterize these emissions (O’Brien and Yazdani Aliabadi 2020).
11. The pilot survey could be performed on an individual basis to understand the survey issues better (i.e., understanding where people tend to enter wrong values or get confused). This could mean either asking some respondents questions in real time (in person or over the phone/web) and

noting answers or asking some respondents to fill out the survey in front of the researchers and provide feedback in real time.

Final Takeaways

Our goal was to calculate a commuting GHG baseline for the Ann Arbor 2030 District, and we did that for both pre-pandemic and during the pandemic, as can be seen in **Figure 2**, which illustrates the 73% decrease in commuting emissions that we observed during the pandemic.

In terms of recommendations for buildings, we recommend that employers keep at least some work from home flexibility. A demonstrated way to reduce commuting emissions is to let people not commute, at least some of the time. However, we also think buildings should still trial other mode-shifting incentive policies. People now know they can work from home because of the pandemic, but there are probably other commuting policies that will work for people if they can try them. The uptake of these policies can be something that future surveys ask about to track effectiveness.

By 2030, the District aims to reduce its average commuting emissions to 862 kg CO_2e per commuter per year, to meet the 2030 District's goal of 50% reduction by 2030. Due to the expected permanence (at least in some part) of the shift to working from home, a 50% reduction by 2030 should be easily achievable. While choosing a pre-pandemic baseline is the easier jumping off point, properties with the capability to exceed this goal should continue to push for reductions, given the severity and gravity of global climate change. The District should therefore look towards taking direct action in both reducing commuting miles by prioritizing the development of affordable housing in centralized locations and in shifting to less emissions-intensive commuting modes by, for example, disincentivizing parking for personal vehicle commuting. Details on these and other emission reduction strategies can be found in the final report from the University of Michigan’s President's Commission on Carbon Neutrality (University of Michigan 2021).

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Appendix 1: Spreadsheet Model

Raw Data Tab

Data from the Google Sheets survey responses were copied and pasted into a Microsoft Excel spreadsheet (tab named "Data_Raw"). Each entry was assigned a numeric ID starting at 1 and increasing in the order entered from the Google Sheet, which together with the "Timestamp" and "Building Name" could be used to identify the survey respondent if necessary. Names and email addresses were deleted for privacy reasons.

Some data cleaning had to be performed; for instance, numeric responses that included words such as "mpg" or "miles" were edited to only include the number in the cell. Additionally, some respondents' mode shares added up to more than 100%; the research team reached out to those respondents for clarification, and the responses were then edited. Most respondents chose a building address from the drop-down list provided in the survey. For those respondents that chose "Other" and typed in their own building address, the survey team had to manually sort through those addresses to match and/or clean them up for aggregation purposes.

Parameters

The "Parameters" tab includes assumptions and inputs to the analysis tabs. The emission factors are the most important part of this tab and the table includes the transportation mode, emission factor, relevant units (which were all g CO_2e/mile, except for "Bus" which was g CO_2e/passenger mile), sources, and assumptions. There is a table that includes miscellaneous parameters for reference, such as number of working weeks, BEV kWh/mile, Ann Arbor electricity-associated emission factor, etc. There is also a table used in formulas converting policy responses to number codes.

The survey questions regarding round-trip commute length and fuel efficiency[4] were asked in a "bucketing" format (e.g., "Less than 5 miles," "6 to 10 miles," etc.). Midpoint estimates were used in calculations referring to these questions, which introduces error. For instance, a response of "11 to 20 miles" would have 15.5 miles used in the relevant formulas. The research team has decided to dispense with this technique for future iterations of the survey. The bucketing technique was originally intended to make taking the survey easier, but the research team prefers that the survey respondents make the estimates themselves.

[4] The survey initially asked about vehicle fuel efficiency, but the research team ultimately decided to use a national average from GREET. See **Emission Factors** section for more information.

Individual Analysis Tab

Most analysis was performed in a tab named "Analysis_Individual." The spreadsheet is organized with rows for individual respondents and columns for logical steps of analysis. The first five rows of the analysis provide descriptions of each column ("Short name," "Description," "Formula explanation," "Question," and "Units"). Each cell of the analysis refers to relevant cells in the "Parameters" and "Data_Raw" tabs. The spreadsheet breaks out the analysis into the four categories of the survey: pre-pandemic fair weather, pre-pandemic cold weather, pandemic fair weather, and pandemic cold weather. The analysis is identical for all four categories except for which cells they refer to in the "Data_Raw" tab.

The first 27 columns ("C" through "AC") of the analysis refer to data inputs or respondent identifiers. There are IF statement formulas that serve to fill in assumptions (e.g., if the respondent chose one of the buckets for round trip commute length, the formula fills in the midpoint number from the "Parameters" tab and if the respondent entered a number, the formula fills in that number). Columns "J" and "K" serve as a check that the mode share for both fair and cold weather sum to 100% and highlight the cells in red if not. The mode share columns pull the reported percentage from "Data_Raw" and fill in 0% for "No use" responses. Column "AB" refers to number of passengers in the vehicle; if the respondent chose "I did not select 'carpool' as a transportation option," then the formula fills in 1; if the respondent entered a number of carpool passengers, then the formula adds 1 to the number of reported carpool passengers to account for "owned" emissions (i.e., carpool emissions are divided by the number of people in the car). Column "AC" refers to vehicle fuel type. These reported fuel types are used to pull in the associated emission factor from the "Parameters" tab. An important assumption was made here: if the respondent skipped this question or chose "I did not choose drive alone," the formula defaults to "Gasoline." This decision was made because the research team assumed most people driving their own vehicles are driving conventional gas-powered cars. If respondents skipped this question because they do not drive, "Drive alone" emissions will still result in 0 because of the mode share multiplication formula.

The next 8 columns ("AD" through "AK") perform the calculations for g CO_2e associated with each mode in fair weather. The basic formula for each mode per respondent is:

$$(\#\ commuting\ days) * (round\ trip\ miles) * (\%\ mode) * (g\ CO_2e\ per\ mi\ emission\ factor) \quad \text{Eq. 2}$$

The "Drive Alone" and "Carpool" columns use IF statements to refer to vehicle fuel type. The "Carpool" column divides by the number of people in the vehicle. The "Ride Hail" column divides by 1.4 people. Column "AL" sums all 8 of the mode-associated emission columns to get weekly emissions for that season, and Column "AM" multiplies the weekly emissions by the average number of working weeks in that season (23 weeks). The next 10 columns ("AN" through "AW") repeat this analysis for cold weather.

The last column in the section ("AX") sums the fair weather and cold weather emissions to get annual emissions. The next columns of this analysis ("BA" through "CV") repeat this analysis for the during-pandemic timeframe. The next section is just two columns ("CX" and "CY") that calculate the gross and percent change in emissions from pre-pandemic to pandemic.

The last section (Columns "DB" through "DK") turns policy responses into 1-5 numerical representations. This section is used to aggregate policy preferences in the "Building Policies" tab.

Building Analysis and Policies Tabs

The Building Analysis tab breaks out each building in the District into different rows and simply sums each category of emissions using IF statements referring to building identifiers in the "Analysis_Individual" tab and reports the gross and percentage change at the building level from pre-pandemic to during-pandemic.

The Building Policies tab breaks out each building in the District into different rows and counts the number of responses per policy category using IF statements referring to building identifiers in the "Analysis_Individual" tab and reports the total and percent policy preferences at the building level.

Dashboard

The Dashboard populates based on the dropdown menu with a list of the buildings in the District and an option of the District as a whole. The various aggregate metrics use IF statements that refer to the dropdown menu option, and include metrics such as pre-pandemic fair weather emissions, pre-pandemic cold weather emissions, during-pandemic fair weather emissions, during-pandemic cold weather emissions, average emissions per commuter pre- and during-pandemic, percent change, and policy preferences. The graphs included in the Dashboard refer to these aggregate metrics and therefore auto-populate when a new option is chosen. This Dashboard is meant to be an easy access point for summary metrics about District members and the District as a whole and will be integrated into the toolkit as well.

Appendix 2: Python Model

The Python programming language has been in development for nearly 30 years and over this time it has grown to be very versatile and popular, finding application in everything from robotics to data analysis. Due to its simplicity and availability of several libraries to manage large volume of data, the team chose Python as one of the analysis tools for this project. Python is also free and open source, making it a good fit for a non-profit organization like the 2030 District. Compared to traditional applications like MS Excel, Python has a learning curve at the beginning, but both Python and Excel have the ability to automate the analysis for our Project. Depending on the comfort and experience of the analyst, they can use either tool to get the same result. Some prior tasks are required before the responses are input into either Excel or Python, like manually editing respondent entered values for distance commuted, since they do not follow a standard format.

Jupyter Notebook was used as an editor for creating and running the program since it is also an open-source IDE and shows both the code and the results at the same time. This makes it easier for the user to understand the program and helps with debugging during program creation due to the ability to run the program “cell-by-cell.” There are good alternate open-source IDEs like PyCharm, but for the purpose of the project and its replicability, Jupyter Notebook documents are better. Support for Markdown also helps with documentation.

Various packages (libraries) have been used in the Python program for quicker analysis, data import and export, and reducing redundancy. Namely, they are “pandas”, “math”, “csv”, “Pathlib”, “NumPy” and “os.” As mentioned previously, the input data are first cleared of inconsistent values manually using an application like Excel (Ex: Changing a respondent input value of “25.2” miles to “25.2”). Then the file name is entered in the Python code file. Then the various emission factors and mileages are input. As long as the column (each individual question) remains the same, the program should provide the desired output. The emissions per year per commuter are determined using the formula:

$$\frac{\text{Emissions}}{\text{commuter}} = \text{Distance} * \left(\frac{\text{Emissions}}{\text{Distance}}\right) = (\text{Days} * \text{Miles}) * \Sigma(\text{Mode Split} * \text{Emission Factor}) \quad \text{Eq. 3}$$

This output the weekly emissions value since the questions (and thus input values) were asked on a weekly basis. This is then converted to yearly emissions.

The Jupyter Notebook is a part of the toolkit and you can get access to it by contacting the Ann Arbor 2030 District at annarbor@2030districts.org. The flowchart displaying the various steps in the program is illustrated in **Figure 10** below.

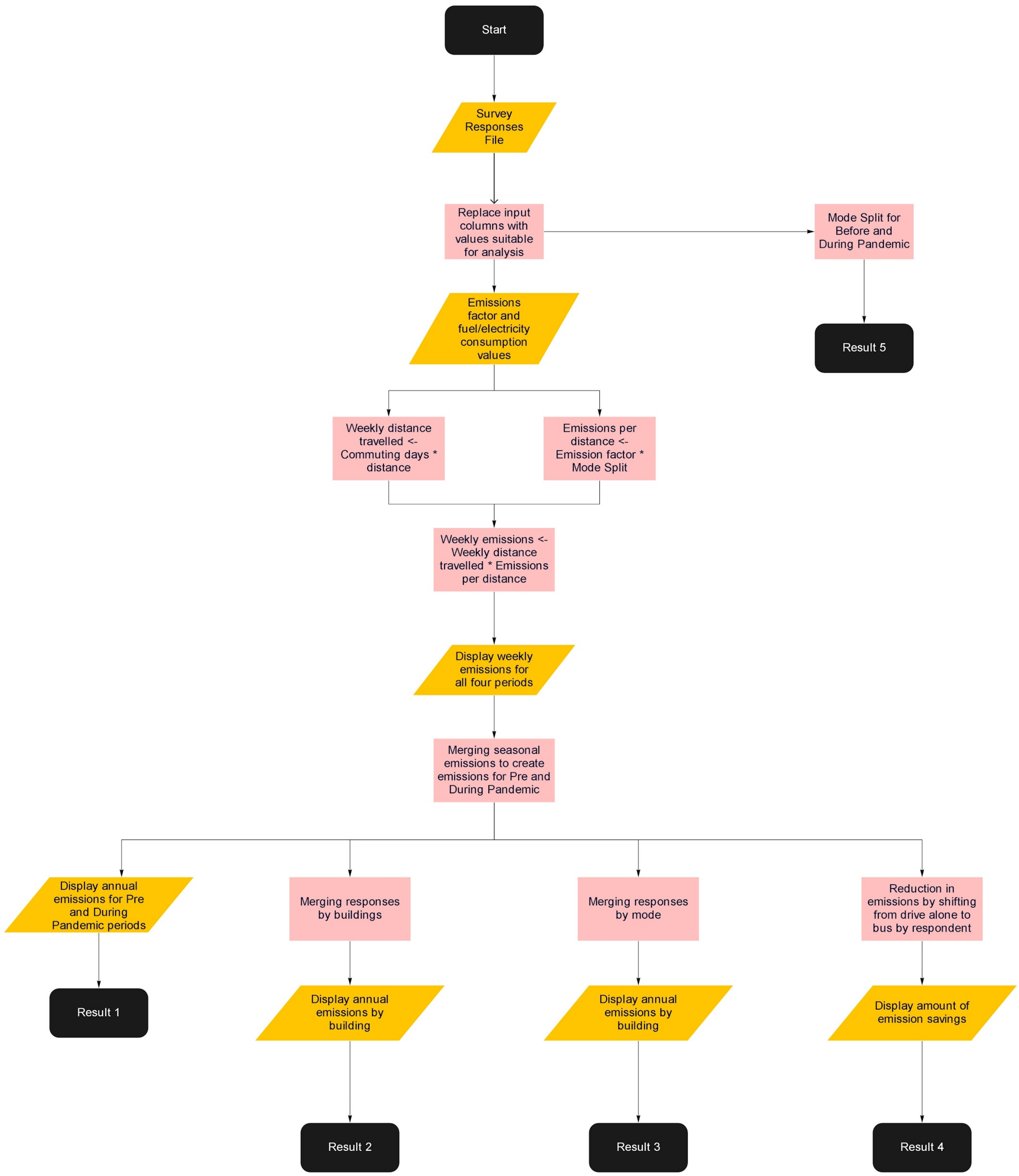

Figure 10: Flowchart of Python Program

Appendix 3: Ann Arbor 2030 District Survey

The survey that was sent to members of the Ann Arbor 2030 District is below.

Commuting Survey

Thank you for taking part in this survey to calculate the transportation greenhouse gas emissions baseline for the Ann Arbor 2030 District. Your building is a member of the 2030 District.

Your responses will have no bearing on you or your company -- we are simply trying to calculate an aggregate estimate of the District's transportation related emissions. While we may follow up with you if we have clarifying questions regarding your answers, your responses will be kept anonymous and will only be used for the purposes of calculating this aggregate baseline.

If you have any questions regarding this survey, please email Project2030District@umich.edu.

For more information about the Ann Arbor 2030 District, visit their website: https://annarbor2030district.wildapricot.org/

* Required

Email address *

Your email

Please enter your name. Information provided will only be used for follow-up correspondence, if needed.

Your answer

Question 1: Please select which building/organization about which you are answering these questions. *

Select one: (Member list updated - 25-sep-2020)

Choose

If you selected "Other" please list your building's address here.

Your answer

Question 2a: How many days per week did you typically commute to work **before COVID**? *

- ◯ 0
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7

Question 2b: How many days per week do you typically commute to work **during COVID**? *

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7

Question 3a: How many days per week did you typically telecommute (i.e., worked from home) to work **before COVID**? *

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7

Question 3b: How many days per week do you typically telecommute (i.e., worked from home) to work **during COVID**? *

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7

Question 4: How many miles is your ***round trip*** commute for work? If you know your exact miles, type them in the "Other" box. *

- Less than 5
- 6 to 10
- 11 to 20
- 21 to 30
- 31 to 40
- 41 to 50
- 51 to 60
- 61 to 70
- 71 to 80
- 81 to 90
- 91 to 100
- Over 100
- Other:

Explanation for question 5:

We are hoping to capture any changes in employee commuting patterns both (1) pre-COVID vs. during COVID and (2) seasonally. Please answer the below four-part question by selecting all applicable modes of transportation and the corresponding percentage of mileage for that mode. For example, if a person's one way commute is 10 miles and she drives 2 miles to the bus terminal and takes the bus the rest of the way, she would enter 20% for "drive alone" and 80% for "Ann Arbor Area Transit Authority Buses." Please note that drive alone includes cars and motorcycles too.

Example for question 5:

	20%	30%	40%	50%	60%	70%	80%
Walk	◉	○	○	○	○	○	○
Bicycle	○	○	○	○	○	○	◉

Question 5a: Which form of transportation did you typically use to get to work **before** COVID in **fair weather months** (approx. April -- September)? *

Choose an estimated percentage, **based on round trip mileage**, for each transportation option as shown below. **Please make sure all options add to 100%**. (Drive alone includes cars and motorcycles.)

	No use	10%	20%	30%	40%	50%	6
Walk	○	○	○	○	○	○	○
Bicycle	○	○	○	○	○	○	○
Drive alone (automobile/motorcycle/moped)	○	○	○	○	○	○	○
Carpool	○	○	○	○	○	○	○
Ann Arbor Area Transit Authority Buses	○	○	○	○	○	○	○
Ride hailing services (Uber/Lyft)	○	○	○	○	○	○	○
I only ever telecommuted	○	○	○	○	○	○	○
I did not work for the employer/organization at this time	○	○	○	○	○	○	○

Question 5b: Which form of transportation did you typically use to get to work **before** COVID in **cold weather months** (approx. October -- March)? *

Choose an estimated percentage, **based on round trip mileage**, for each transportation option. **Please make sure all options add to 100%**. (Drive alone includes cars and motorcycles)

	No use	10%	20%	30%	40%	50%	6
Walk							
Bicycle							
Drive alone (automobile/motorcycle/moped)							
Carpool							
Ann Arbor Area Transit Authority Buses							
Ride hailing services (Uber/Lyft)							
I only ever telecommuted							
I did not work for the employer/organization at this time							

Question 5c: Which form of transportation do you use to get to work **during** COVID in **fair weather months** (approx. April -- September)? *

Choose an estimated percentage, **based on round trip mileage**, for each transportation option. **Please make sure all options add to 100%**. (Drive alone includes cars and motorcycles)

	No use	10%	20%	30%	40%	50%	6
Walk							
Bicycle							
Drive alone (automobile/motorcycle/moped)							
Carpool							
Ann Arbor Area Transit Authority Buses							
Ride hailing services (Uber/Lyft)							
I only ever telecommute							
I did not work for the employer/organization at this time							

Question 5d: Which form of transportation do you use (or expect to use) to get to work **during** COVID in **cold weather months** (approx. October -- March)? *

Choose an estimated percentage, **based on round trip mileage**, for each transportation option. **Please make sure all options add to 100%**. (Drive alone includes cars and motorcycles)

	No use	10%	20%	30%	40%	50%	6
Walk	◯	◯	◯	◯	◯	◯	(
Bicycle	◯	◯	◯	◯	◯	◯	(
Drive alone (automobile/motorcycle/moped)	◯	◯	◯	◯	◯	◯	(
Carpool	◯	◯	◯	◯	◯	◯	(
Ann Arbor Area Transit Authority Buses	◯	◯	◯	◯	◯	◯	(
Ride hailing services (Uber/Lyft)	◯	◯	◯	◯	◯	◯	(
I only ever telecommute	◯	◯	◯	◯	◯	◯	(
I did not work for the employer/organization at this time	◯	◯	◯	◯	◯	◯	(

Question 6a: If you selected “Carpool” for question 5a/b, how many people did you typically commute with pre-COVID? *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ I did not select "carpool" as a transportation option.

Question 6b: If you selected “Carpool” for question 5c/d, how many people do you typically commute with during COVID? *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ I did not select "carpool" as a transportation option.

Question 7: If you responded “drive alone” or “carpool” to question 4, what is the fuel type for your vehicle? *

- Gasoline
- Diesel
- Plug-in gas-electric
- Non-plug-in hybrid gas-electric
- Fully battery electric vehicle primarily charged at my home
- Fully battery electric vehicle primarily charged at my work
- Fully battery electric vehicle primarily charged at a public charging station
- I did not select "drive alone" or "carpool"

Question 8a: If you responded “drive alone” or “carpool” to question 4 and drive a non-electric vehicle, what is the approximate fuel efficiency of your vehicle?(If you know your exact fuel efficiency, enter it in the "Other" field) *

- 10 to 20 mpg
- 21 to 30 mpg
- 31 to 40 mpg
- I did not select "drive alone" or "carpool"
- I drive an electric vehicle
- Other:

Question 8b: If you drive an electric vehicle, how many kilowatt-hours does your vehicle consume during your commute?

Your answer

Question 9: If your commuting patterns changed because of COVID-19, how do you anticipate they will change post COVID-19? *

- I think my commuting patterns will go back to the way they were pre-COVID
- I think my commuting patterns will stay the same as they are during COVID
- I think my commuting patterns will be somewhere in between
- I'm not sure

Question 10: Assuming non-COVID conditions, consider the following policy proposals and respond with how you think each would impact your commuting decisions if implemented. *

How likely would the following policies change your commuting behavior?

	Will not change my commuting behavior	Not likely change to my commuting behavior	Undecided	Likely to change my commuting behavior	Will change my commuting behavior	I already have access to this service
Increased secure bike rack parking / storage at my workplace	○	○	○	○	○	○
Closer bus stops to work	○	○	○	○	○	○
Free or subsidized public transportation pass	○	○	○	○	○	○
Expanded work from home policies (outside of COVID)	○	○	○	○	○	○
On-site childcare	○	○	○	○	○	○
Installed EV charging at my workplace	○	○	○	○	○	○
Financial incentives to carpool	○	○	○	○	○	○
Access to shared company vehicle (like ride home programs)	○	○	○	○	○	○

Question 11: Please provide feedback on this survey (e.g., any questions you found confusing; questions regarding our assumptions/methods; etc.)

Your answer

Question 12: Do you have any other comments you want to share with us about the contents of this survey (e.g., other effects COVID-19 has had on your transportation habits)?

Your answer

Would you like to have a personalized report sent to the email address provided in this form? *

- ○ Yes
- ○ No

Send me a copy of my responses.

Submit

Appendix 4: Toolkit

The toolkit is in the form of a Google folder, to be "owned" and distributed as needed by Jan Culbertson of the Ann Arbor 2030 District. It includes:

1. Detailed instructions for how to administer the survey and perform the analysis;
2. A concise checklist of necessary steps for how to administer the survey and perform the analysis;
3. An instructional video (recorded by this research team) walking through the necessary steps in the checklist;
4. A template Google Forms survey;
5. An associated template Google Sheets spreadsheet model;
6. A folder with the two Analysis Models used in the Ann Arbor 2030 District's baseline research;
7. The final presentation of this research team, recorded on Friday, April 23, 2021;
8. And this final report.

If you would like to access the toolkit, please reach out to the Ann Arbor 2030 District at annarbor@2030districts.org.