An Internal Carbon Price for the City of Ann Arbor

by

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Executive Summary

Carbon pricing is frequently cited as an effective and economically viable policy solution. However, few examples of carbon pricing programs, like a carbon tax or fee, currently exist at the local scale. Where entities might lack jurisdiction to implement a carbon tax or are otherwise constrained by budget, politics, or other resources, **internal carbon pricing** offers a solution. An internal carbon price allows an organization to put a price on carbon for its own energy consumption or production to reduce harmful emissions and demonstrate a commitment to sustainability goals. For this report, a **carbon price** refers to any program that applies a price to carbon emissions. **Carbon fee** is used interchangeably with **carbon tax**, both of which are used to refer to carbon pricing programs that levy a specific charge on a unit of emissions (e.g. one metric ton).

The City of Ann Arbor's Office of Sustainability and Innovations ("the Client") recruited our team of four University of Michigan ("the University") master's students from the School for Environment and Sustainability (SEAS) to explore the impacts of and design an internal carbon fee program. The program would place a price solely on Ann Arbor's municipal carbon emissions and is proposed to start in the upcoming 2021 fiscal year. This is a major step in achieving the city's carbon neutrality goals, consistent with its landmark A2Zero plan.

Over approximately 14 months, our team researched how to create an operable internal carbon fee program for the City of Ann Arbor. Using skills in economic modeling and data analysis, we modeled the energy, cost, and emissions impacts of a $5/metric ton fee on the City of Ann Arbor's buildings and fleet emissions. We also put together a detailed program design and supporting materials to help kickstart the process in its first year.

Researching this project required in-depth understanding of the economics of carbon pricing, the City of Ann Arbor's internal operating structure, budgeting mechanism, and utility billing process. We began the process with a review of professional and academic evidence, and municipal data provided by the Client. We coupled the literature review with interviews with professional and academic experts in public policy, urban planning, and environmental economics. Following this initial research phase and through meetings with members of Ann Arbor's city government, we created an economic model and a detailed process for the program. The economic model determines the fee owed by each department based on energy, natural gas, gasoline, and diesel consumption. The model also projects program revenue and expected emissions reductions as a result of the program through 2030. The program is designed to fit into existing city financial and operating structures to collect carbon fee revenue and allocate the funds back to departments to support energy efficiency investments.

Under the $5/metric ton carbon fee scenario, we estimated that energy and fuel costs would increase by between 1.5 to 4.4 percent in 2020. The internal carbon fee would yield a 0.1 percent emissions reduction and generate $173,200 in revenue by the end of the first program year. With an annual incremental $5/metric ton increase in fee, the program would impose a $55/metric ton cost on emissions that results in a 7.4 percent emissions reduction and bring $1.2 million in gross revenue in 2030.

We recommend for the Client to use the economic model to calculate each department's carbon fee (i.e. program revenues). Finance and Administrative Services ("Finance") would collect program revenues into an internal service fund called the Carbon Fund. The Client would oversee the Carbon Fund and determine the prioritization and use of funds.

As a result of our work, we provide the following short-term recommendations to the Client:

- Pilot an internal carbon fee with a $5/metric ton starting price, beginning in FY2021.
- Work with the Finance department to create an internal service fund to collect fees from departments operating under the City's General Fund.
- Calculate and apply each department's internal carbon fee based on energy consumption and fleet fuel usage.
- Communicate internal carbon fee structure and fee impacts to each affected department using informational materials such as frequently asked questions (FAQ) documents or an energy report.
- Allocate program revenue to prioritize building energy audits, followed by the most relevant and important energy efficiency upgrades as determined by the audits and city needs at the time of investment.
- Following effective program implementation, explore potential expansion of the program to departments outside of the City's General Fund.

Our experience has also provided us with general takeaways and best practices for internal carbon pricing program design and implementation:

- Perform extensive background research into similar carbon pricing schemes before designing a final program.
- Accurately track and inventory all emissions within the project scope to support accurate price calculations and forecasting.
- Create a user-friendly model that allows employees to easily track the impacts of a fee on the system.
- Garner support from key stakeholders, establish clear rules for participation in the program, and integrate its functions into existing operating structures.

Table of Contents

Introduction

Global climate change, caused by greenhouse gas (GHG) emissions from the burning of fossil fuels, poses potentially the single most significant threat to human health and the environment. The burning of coal, petroleum products, and natural gas emit GHGs that are trapped in the Earth's atmosphere, causing global temperatures to increase, which leads to sea-level rise, changing precipitation patterns, increases in the frequency and severity of droughts, and other dangerous impacts (Romm, 2015). As a result, there is a pressing need for large-scale economic and social restructuring to reduce reliance on fossil fuels as an energy source. While the United States federal government has yet to implement policies that aggressively address greenhouse gas emissions on a nationwide scale, states and municipalities are taking the initiative to reduce fossil fuel use at the local level.

Ann Arbor is a city of over 120,000 residents in Washtenaw County, Michigan. Like many U.S. cities, it has begun to examine strategies and enact programs to mitigate its emissions and adapt to the long-term impacts of climate change. The Office of Sustainability and Innovations (OSI) plans and executes the City of Ann Arbor's (the "City") sustainability and energy-related activities.

In November 2019, Ann Arbor's City Council passed a climate emergency declaration and committed to achieving carbon neutrality by 2030. Carbon neutrality means net-zero emissions—that the city will capture as many emissions as it produces. Achieving carbon neutrality would require significant coordination between the City and the University, businesses, and households across Ann Arbor. It would be a monumental effort that would transform the way the city operates. In April 2020, OSI presented its plan—titled "A2Zero"—for achieving these reductions. A2Zero is built on the foundations of being equitable, sustainable, and transformative. The proposal outlines seven main strategies aimed at reforming electricity, waste, and transportation practices in Ann Arbor. The plan details long-term sustainability goals like renewable energy expansion, energy efficiency improvements, and increased use of electric vehicles, as well as waste reduction, improved land use and transportation access, and responsible resource management (City of Ann Arbor, 2020). DTE Energy ("DTE), the electricity and natural gas utility that serves all of Ann Arbor, uses coal and oil to generate about 65 percent of the electricity it provides to Michigan customers (DTE Energy, 2018). As a result, Ann Arbor would significantly reduce its carbon footprint by reducing energy consumption and replacing fossil fuel-based electricity generating sources with renewable energy sources like solar and wind power.

To help the City meet its municipal carbon neutrality goal, OSI has been interested in the prospect of adopting an internal carbon fee. As of 2018, municipal emissions comprise two percent of the City's total of 2.2 million metric tons of emissions (City of Ann Arbor, 2019a). An internal carbon fee places a price on carbon emitted from selected municipal activities that use energy. The increased cost of consuming electricity, natural gas, and petroleum (i.e., vehicle fuels) incentivizes energy conservation behaviors among employees, thereby reducing Ann Arbor's municipal carbon footprint. In addition, energy efficient or renewable energy alternatives become more financially competitive with incumbent energy sources. This helps OSI present a business case to Ann Arbor's City Council for switching to renewable energy sources. A carbon fee program that collects fees from departments also creates a sustained revenue stream to fund municipal energy efficiency infrastructure improvements.

A carbon tax, while widely discussed in economic circles, has few existing examples in the United States. There is even less precedent to follow for city governments. Instituting such a program sends a message that Ann Arbor is serious about climate change and is willing to lead by example. It further sets Ann Arbor apart as an innovator among local governments, as the City would be one of the first in the U.S. to use an internal carbon price.

For this report, a **carbon price** refers to any program that applies a price to carbon emissions. **Carbon fee** is used interchangeably with **carbon tax**, both of which are used to refer to carbon pricing programs that levy a specific charge to a specified quantity of emissions (e.g. one metric ton).

Research Question & Objectives

This project has two primary research objectives:

1. Model the economic and environmental impacts of an internal carbon fee.
2. Determine the appropriate program design to integrate an internal carbon fee into the City of Ann Arbor's municipal operations.

In our research, we considered several design elements, including the fee's starting price and its scaling level over its lifetime. Another important decision was the fee's scope of coverage in terms of emissions sources and taxable parties included in the program. Finally, we determined how funds collected from the fee would be used or distributed.

Our team also considered the equity impact of a fee on different city departments. How much does each department pay and how much benefit do they receive? Is this equitable or just based on the department's size or budget? These considerations are important because equity is one of the foundational principles for sustainability and carbon neutrality initiatives in Ann Arbor. It is crucial that no department is so adversely affected that it cannot complete its primary functions and provide public services.

Lastly, we researched potential barriers to overcome in getting the carbon pricing program enacted, and how employees might respond to the price. We anticipate that there will be some resistance to this fee, especially because it impacts department budgets, which are already stretched thin. Therefore, it is important to investigate reasons for that opposition and consider ways to overcome them. There may also be other financial, political, or logistical obstacles, and it is prudent to identify those as well.

Background

The Economics of Carbon Pricing

The idea of putting a price on carbon emerges from the economic concept of a Pigouvian tax, or a tax that is placed on activities that create negative externalities. A **negative externality** is an unintentional damage associated with a transaction that is not captured in its explicit price. Implementing a tax raises prices and reduces the quantity consumed of the harmful goods. In the context of climate change, carbon emissions are generally unaccounted for in the price of energy-intensive goods or activities; these emissions constitute a negative externality on the environment and society. Market failures arise when consumers lack sufficient incentive to reduce emissions-generating activities. Pricing negative externalities is a way to prevent market failure and account for its social damages (Rabe, 2018).

Governments have previously levied taxes or fees to address externalities like cigarette smoking on public health, and ozone depletion due to aerosol usage; both of these programs were effective in reducing the harmful impacts associated with the usage of cigarettes and aerosols (Larsen et al., 2018). These successful programs have served as templates in advocating for a carbon tax.

We explored two main carbon pricing mechanisms. While other methods of pricing carbon exist, for this project, the two relevant types of carbon pricing programs are a carbon fee and a shadow price:

1. A **carbon tax or fee** places a price on carbon emissions on a per-unit basis. Under this scheme, every unit (e.g., metric ton) of carbon that an entity emits has a corresponding cost that the entity is required to pay to the body overseeing the program. Carbon emissions are defined as carbon dioxide emitted into the atmosphere (usually accounted on a per ton basis) as a result of burning fossil fuels primarily for producing electricity, heating, transportation, as well as many industrial processes. Carbon taxes usually generate revenue for the governing body instituting the tax.

2. A **shadow price** or **price on paper** attaches a hypothetical ("shadow") cost to each unit of carbon emitted to represent the externalities not included in traditional financial analyses. The purpose of such a pricing scheme is to explicitly account for the externality in financial decision making without requiring actual payment for this external cost. Shadow prices are typically applied to capital investments to raise the perceived cost of carbon-intensive activities when compared to low-carbon alternatives (Carbon Pricing Leadership Coalition, 2019). For city governments, a shadow price on carbon emissions could affect budgeting decisions for new infrastructure and construction, vehicle purchases, and procurement.

There are several benefits to carbon pricing. First, it creates a price signal to which users can see and respond. By raising the price of emissions-intensive goods, the target audience is incentivized to reduce the consumption of such goods. Because the price of fossil fuels increases, low-carbon energy sources become more cost-competitive by comparison; this encourages investments in clean energy. Over the long term, the reduced consumption drives down emissions compared to a business-as-usual case. Due to such benefits, many economists believe that pricing carbon is an effective method of addressing climate change (Kaufman & Gordon, 2018).

In addition to influencing consumption levels and encouraging energy conservation, carbon pricing provides institutions with the opportunity to expand on sustainability and equity goals. Carbon taxes can be designed to generate revenue that can be spent or redistributed to meet clean energy, equity, or other goals (Boyce, 2018). Tax revenue may be used to invest in energy efficiency or climate mitigation projects, redistributed to communities affected by the tax, or reduce government debt. It may also be revenue-neutral by returning the revenue to consumers or offsetting taxes in another spending area (Bordoff & Larsen, 2018)

An entity that places a carbon price on its emissions, essentially "taxing themselves," enacts an **internal carbon price**. Organizations add a carbon price on their operations' building and transportation emissions when paying for utilities or making upfront capital investments. This may be done because an internal carbon price is the most politically feasible option, or because the organization lacks the jurisdictional authority to tax entities besides itself. It can involve the physical collection of funds (like a more traditional carbon tax), or it can simply be used to influence long-term investment decisions (like a shadow price) (Second Nature, 2018). Internal carbon pricing has multiple benefits for organizations. It creates incentives for the organization to reduce operating costs, supports internal sustainability goals, and presents an opportunity to educate employees about energy conservation to reduce emissions.

Carbon pricing has been implemented all over the world, primarily as a carbon tax. The first country to adopt a tax on carbon emissions was Finland in 1990, which was followed by several other northern European countries like the Netherlands, Norway, and Sweden (Sumner, Bird, & Dobos, 2011). Currently, no federal regulation of carbon exists in the United States. At the city and state levels, the City of Boulder, Colorado, and the State of Washington have proposed legislation to enact carbon fees (Boulder's passed, while Washington's failed). As climate change becomes more urgent and more states and organizations begin to commit to sustainability goals and action plans, a carbon tax is developing greater appeal (Nadel & Kubes, 2019).

Economists and researchers have attempted to calculate the **social cost of carbon** (SCC), which quantifies the cost of emitting one metric ton of carbon in dollars, based on long-term environmental damage and economic loss (Nordhaus, 2017). The SCC is applied to benefit-cost analyses to explicitly account for the value of climate impacts associated with a policy or project (Resources for the Future, 2019). The true magnitude of the SCC is widely debated. In peer-reviewed studies, estimates for the SCC range from -$50 to $8,752 per ton, depending on the discount rate, scope, and modeling assumptions (Wang, et al, 2019). A commonly cited figure is the SCC used by the Obama administration, which is $42/ton. In practice, prices range widely, from $2/ton to $120/ton. Some carbon tax proposals are based on the $42/ton SCC, while other prices are molded by alternative models or political feasibility (Interagency Working Group, 2010).

As of 2019, 96 private companies had instituted an internal carbon fee or shadow price in the United States, and 142 additional companies had plans to implement a program by the end of the year (Carbon Pricing Leadership Coalition, 2019). For example, Microsoft has a well-known internal carbon fee program, and Disney and Wells Fargo both use internal shadow pricing (CDP, 2015). Higher education institutions like Yale University and Swarthmore College have also instituted internal carbon fees (Second Nature, 2019).

The City of Ann Arbor

This section describes aspects of Ann Arbor's city government operations that are key to this project.

Sustainability in Ann Arbor

Ann Arbor established the Office of Sustainability and Innovations in 2018, but climate action was taking place in the city long before that. The first Climate Action Plan was adopted in 2012 and the subsequent Master Plan update in 2013 incorporated a Sustainability Framework. Following the United States' withdrawal from the Paris Agreement, Ann Arbor signed on to the *We Are Still In* campaign to pledge emissions reductions despite the lack of federal climate policy (City of Ann Arbor, 2019a).

Ann Arbor's 2016 Climate Action Plan called for a 25 percent reduction of the entire city's carbon emissions by 2025, and a 90 percent reduction in emissions by 2050 (City of Ann Arbor, 2016). In 2017, the City of Ann Arbor passed a resolution to power its municipal operations with 100 percent clean and renewable energy by the year 2035 (City of Ann Arbor, 2017). The City updated its plan in 2019 to be even more ambitious with the adoption of the carbon neutrality by 2030 goal.

The City's most recent greenhouse gas inventory reported 2.2 million metric tons of emissions in 2018, which denotes a 12 percent decline since the year 2000. Of that total, 2 percent (approximately 44,000 metric tons) is associated with municipal sources, including city-owned buildings and vehicles (City of Ann Arbor, 2020). Emissions in Ann Arbor mainly come from the burning of fossil fuels for electricity generation; DTE's grid mix is approximately 65 percent fossil fuel based (DTE Energy, 2018).

OSI is responsible for planning and executing the City's sustainability and emissions reduction policies. This involves coordinating with the University, the Ann Arbor Area Transportation Authority, and other community partners. Other stakeholders in the city government include City Council, the City Administrator's office, and citizen commissions like the Environmental Commission, Energy Commission, and Transportation Commission.

The carbon neutrality planning process, or A2Zero, kicked off in November 2019 and concluded in March 2020. To engage the public and solicit feedback, OSI held public events, conducted online surveys, and launched a website. The department gathered input from residents, technical experts, and academics. The planning process was supported by the University, community groups, and other partner organizations. A2Zero builds concepts of sustainability, equity, and transformation into all program goals. The draft plan, presented in March 2020, includes seven overarching strategies and 44 initiatives to meet 2.2 million metric tons of GHG reduction potential (City of Ann Arbor, 2020).

Operating Structure

Ann Arbor has a council-manager form of government, meaning that the City Council has legislative duties while the City Administrator oversees the administration of policy. The City Council adopts policies and approves the annual budget (City of Ann Arbor, 2018a).

The City departments relevant to implementing an internal carbon fee are highlighted below:

- **Finance and Administrative Services ("Finance")** oversees the City's budget. The office is responsible for managing funds and authorizing spending. For utility services, Finance sends invoices to individual departments for their monthly utility consumption and fuel use, then pays the bills to DTE.
- **The Office of Sustainability and Innovations ("OSI" or "the Client")** develops and implements sustainability programs, both internally and citywide, following the city's sustainability goals. This includes energy efficiency, waste reduction, transportation electrification, and more. OSI oversees Ann Arbor's "A2Zero" carbon neutrality plan.
- **Fleet and Facilities ("Facilities")** is responsible for maintenance, procurement, and investment of city-owned infrastructure, such as city buildings, vehicles fleet, and the airport. This department includes building managers who are the decision-makers that decide how to upgrade buildings, and the transportation team that oversees the city fleet.
- **The City Administrator's Office** oversees city operations across Ann Arbor, while also working on long-term strategic and financial planning. Departmental units report to the City Manager.

Budget and Financing Structure

Ann Arbor's fiscal year begins on July 1 (City of Ann Arbor, 2019b). Budget-setting for the fiscal year takes place from February through May. Individual departments propose their budgets to City Council in Council Work Sessions in February and March. The City Administrator presents the full recommended budget proposal in April. Council votes on the budget in May, which is finalized by at least seven (out of nine total) affirmative votes. State of Michigan law requires that the City's budget be balanced, meaning that revenues must equal estimated expenditures (i.e., the city cannot run a surplus or deficit) (City of Ann Arbor, 2019b).

The City's budget is stored in several types of funds, which are distinguished by their use or purpose. Their main distinctions are described below:

- **The general fund** is the primary operating fund for the City. Many costs are covered by the general fund, including employee payroll and office equipment.

- **Special revenue funds** contain money directed towards specific uses and are therefore restricted in their spending. Funding collected from tax millages, federal or state grants, are all structured as specific revenue funds.

- **Enterprise funds** are used for operations that provide goods or services to the general public. Their funding comes from user charges. Water and wastewater are examples of enterprise funds.

- **Internal service funds** represent funding for one department to provide internal goods and services to other departments, which that department is charged for. Information Technology and Fleet Services are internal service funds.

- Other funds include funds for capital projects or paying off debts. Because they do not support the emissions-generating operating expenses of any city department, they are not considered within this project.

The allocation of city budget into different funds complicates the implementation of an internal carbon fee. The City cannot simply extract a fee from any fund without first understanding the restrictions placed upon that fund by city and state laws. Because special revenue funds are earmarked for specific uses, fees that are withdrawn from those funds must be returned to those same funds or used to serve the specific purpose that the fund was created for. For example, a fee collected from Water Treatment Services must return or reinvest that *exact* amount towards water treatment services. Enterprise funds represent another challenge because they are sourced from user charges to provide critical public services. Because of this, a fee on enterprise funds may resemble a tax on the public, which is expressly forbidden by state law. This means that the program design must exempt certain funds from fee collection or design specifications on spending to overcome this (T. Crawford, Personal Communication, October 30, 2019).

Because one of the main sources of municipal emissions comes from the consumption of electricity and natural gas in buildings, it is important to understand how each City department pays for these utility services. Finance receives bills from DTE and sends an invoice to each department. Each department views the invoice and enters the amount to be paid in the City's internal billing system, from which Finance withdraws the funds to pay the bill. For units that work in shared buildings like Larcom City Hall, there is an extra step: utility services are billed to each department through a municipal service charge, by the percentage of floor space that each department occupies. A total of nearly 150 bills is processed each month.

Utility billing represents one of the City's municipal service charges. A **municipal service charge** recovers administrative costs that are paid for by the general fund, directing the charge to the service unit that incurs them (City of Ann Arbor, 2018b).

Transportation also represents a source of municipal emissions for the City, namely from gasoline and diesel fuels. The City has a personal vehicle fleet and a fueling station that is used for its operations. Fleet Services, a division of the Fleet and Facilities department, keeps track of the vehicles checked out by each department, including the mileage driven and fuel costs. The City has its own fuel pumps, so they can easily bill departments for this usage. Specialized vehicles, such as police cars or fire trucks, are owned and procured by their respective departments.

Implementing a Carbon Fee

Hypothetically, Ann Arbor could implement a citywide carbon tax, which would result in emissions reductions across the city that exceed what could be achieved in the municipal sector alone. However, there are legal restrictions that prevent the city from levying a citywide tax without voter approval, as articulated in the Headlee Amendment to the Michigan Constitution (Mich. Const. art. IX, § 25). The Michigan Supreme Court in *Bolt v. Lansing* (1998) further established criteria that distinguished between a city fee and a tax in the State of Michigan:

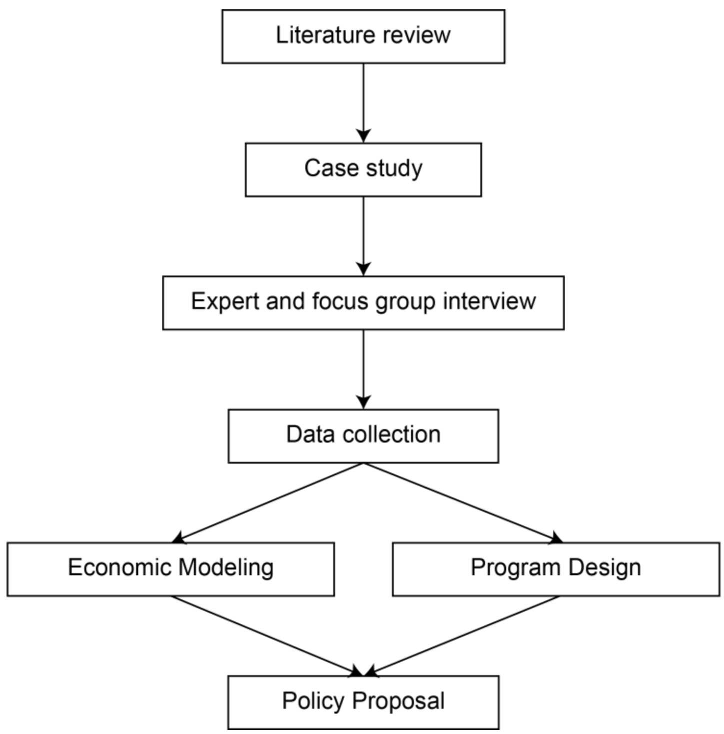
1. A fee serves a regulatory purpose to provide a service that benefits its payers.
2. A fee must be proportionate to the necessary costs of service.
3. A fee must be voluntary.

Based on this definition, it is more appropriate to consider the carbon price as a fee—one that city departments pay into for reduced emissions. Because a citywide charge requires voter approval, the City can only enact an internal fee that acts as a transfer from one fund to another. Because of this, our team focused only on researching internal carbon pricing methods.

Methods

The following section is split into two parts: **Phase I: Research** describes the research process used to inform the project scope and feasibility, while **Phase II: Modeling and Design** describes our methods for creating the economic model and designing a detailed carbon pricing program. All referenced resources and supporting documents are provided in the Appendices, located at the end of this document. A process flow diagram outlining our research process is provided below (Figure 1).

Figure 1. Research Flow Diagram



Phase I: Research

Literature and Case Study Review

We began the research process with a review of relevant literature to understand the theory and objectives behind internal carbon pricing. The goal of this research step was to discover best practices that would inform the next phase of economic analysis and program design.

Our team reviewed the scope of internal carbon pricing in the public and private sectors to identify several organizations that have implemented or are in the process of implementing an internal carbon price. Reviewed documents included technical reports, case studies, academic literature, and policy documents. Following discussions with the Client, we investigated both carbon fee programs and carbon shadow price programs. After reviewing 15 different carbon pricing programs, we compiled the research findings into a set of matrices to summarize the attributes of different programs. The matrices allowed us to identify the advantages and disadvantages of each program with respect to the needs of the City of Ann Arbor. The matrices are provided in Appendix D: Example Carbon Price Matrices.

In addition to published papers and professional reports, our team utilized resources at the University of Michigan, including faculty expertise and library research. Examples include Microsoft's guide to designing an internal carbon fee (Nikolova & Phung, 2017) and Dr. Barry Rabe's (2018) book *Can We Price Carbon?* We met with Dr. Rabe for advice on our project during the research and program design processes. In addition to Dr. Rabe, we consulted University of Michigan professors Dr. Samuel Stolper (project team advisor) and Dr. Jonathan Levine.

Our team also interviewed members of external entities that had designed or worked closely with carbon pricing programs. Subjects of these interviews included the sustainability manager for Boulder, CO, which currently has a citywide tax on electricity consumption. In addition, we spoke with members of the team of master's students from Duke University who worked on a master's project to propose a redesign of Boulder's climate tax program. We also spoke with city planners in Vancouver, British Columbia, and remotely attended a carbon pricing workshop hosted by the city of Tempe, Arizona.

A complete list of sources used during this literature review phase, including a list of interviews conducted, is provided in Appendix F: Complete List of References.

Data Audit and Analysis

To effectively design and model the program, we had to understand the City's budgetary and finance processes, municipal energy consumption data, and municipal emissions data. To accomplish this, we completed a review of the following documents and processes:

- The City's Energy Coordinator provided a **greenhouse gas inventory** that details municipal building energy consumption and municipal fleet fuel usage, including the factors used to account for energy transmission and distribution losses. We also received **municipal energy consumption data** from all metered buildings. We used this information to establish emissions and price projections for each department in the economic model.
- Finance provided the City's **Comprehensive Annual Financial Report**. Our team used this information to determine each department's source of funding, budgetary allowances, and relevant financial constraints. We used this report to identify an appropriate carbon price that would not prohibit the provision of vital public services.

- Our team met with Finance several times during the project. In these meetings, the Finance detailed the **utility billing process** that each department is subject to. We used this information to develop the fee collection and revenue distribution processes.
- Finance provided a **municipal service charge report** and **municipal fleet fuel data**. The municipal service charge report details the square footage breakdown of each department in shared building spaces. This information helped us identify how to appropriately designate fees on shared utility energy bills. Municipal fleet fuel data includes the make and model of each vehicle, the department under which each vehicle operates, each vehicle's fuel type (unleaded, diesel, or compressed natural gas), and the total number of units of fuel consumed by each vehicle.

Phase II: Modeling and Design

Following the research phase, we split our efforts to simultaneously create the economic model and fee calculator and develop program administrative and financial processes.

Economic Model

We developed a model using Microsoft Excel to quantify the fiscal and emissions impacts of an internal carbon fee. The model covers emissions from electricity and natural gas consumption from municipal buildings, and gasoline and diesel combustions from city fleets. It is adapted from the Washington Carbon Tax Assessment Model (CTAM) and adjusted to use Ann Arbor's emissions and consumption data (Washington State Department of Commerce, 2019).

The model forecasts emissions and carbon revenue associated with different levels of carbon prices. The projection relies heavily on accurate data and emissions-related parameters, which are explained in the model assumptions. The model projects future building energy and fleet fuel consumption given that the carbon fee increases total energy and fuel prices. We used elasticities of demand to estimate the trajectory of consumption reductions in response to the price increases. In addition, we applied emissions factors and future regional energy mix forecasts to predict emissions reductions. Finally, the model accounts for electricity and natural gas distribution and transmissions losses.

Data Collection

Consumption Data

We reviewed City emissions inventories and analyzed municipal building emissions data from 2015 to 2018. We set the 2015 emissions level as the baseline for future estimations. We also collected fleet fuel consumption for the entire year of 2018 to project future consumption levels based on the estimated growth rate. We then categorized buildings and fleets under departments that are responsible for paying the energy costs. The classification by departments provides a breakdown of the carbon fee's dollar impact on each service unit.

Elasticities of Demand

The price elasticity of demand is a value that indicates how much consumption may be reduced by an increase in price. Our team used the long-term elasticities of demand from the CTAM. These values are the product of extensive literature reviews on fuel and sector-specific elasticities of consumption. We collected the elasticities of building electricity and natural gas consumptions from the CTAM's provided data for the commercial sector. We gathered demand elasticities of gasoline and diesel from the CTAM's provided data for the transportation sector. Additionally, our model includes a stickiness parameter to estimate the length of time required for the price elasticity to be fully rolled out. This accounts for the tendency of energy consumption to adjust slowly despite changes in its costs. The values are shown below in Table 1.

Table 1. Energy Source Elasticities of Demand and Stickiness.

Energy Source	Elasticity	Stickiness (year)
Electricity	-0.48	15
Natural Gas	-0.35	20
Gasoline	-0.61	10
Diesel	-0.44	10

Emissions Factors

An emissions factor measures the emissions released by some output of energy or fuel. We collected most of the emissions factors used in this model from the Environmental Protection Agency Emissions Factor for Greenhouse Gas Inventories (EPA 2018a). However, we estimated the emissions factors for electricity based on the electricity provider's (DTE Energy) projected future energy mix. We estimated an emissions factor trajectory consistent with DTE's publicly committed timeline of renewable energy deployment and coal power plant retirements. The emissions factors for electricity decreases over time as DTE plans to increase renewable energy generation twofold by 2024 (DTE, 2019). To account for power losses along electricity transmission and distribution lines, we added a 5 percent loss factor to the calculation (Equation 1) (EPA, 2018b). We also added 27 percent to the emissions factor for natural gas to account for methane leakage (Equation 2) (Forrest et al., 2019). Table 2 lists the emissions factors included in the model.

$$\text{(1) Electricity Emissions Factor} = \frac{Baseline\ Emissions\ Factor}{1 - Line\ loss\ \%}$$

$$\text{(2) Natural Gas Emissions Factor} = (1 + \text{Methane Leakage } \%) * \text{Baseline Emissions Factor}$$

Table 2. Energy Source Emissions Factors

Energy Source	Unit	2020 Parameter
Electricity	lbs/kWh	1.53
Natural Gas	lbs/ccf	14.87
Gasoline	lbs/gallon	19.60
Diesel	lbs/gallon	22.43

Energy Price and Estimated Growth

We collected regional energy price scenarios and future consumption forecasts from the Energy Information Administration's Annual Energy Outlook (EIA, 2018). Our team used the energy price forecasts from the East North Central Region Reference Case to analyze the impacts of different levels of a carbon fee on the existing energy price. In addition, we used the EIA's projections to forecast future growth in energy consumption (Table 3).

Table 3. EIA Projected Consumption Growth Rate by Sector

Sector	Annual Growth Rate
Electricity	0.012%
Natural Gas	0.003%
Gasoline	-0.031%
Diesel	-0.013%

Model Assumptions

Emission and Consumption Projections

We based emission and consumption projections on the future regional energy mix that combines DTE Energy's energy mix with EIA's projected consumption growth. We assumed that the DTE will deploy renewable energy as planned. In addition, we assumed Ann Arbor's consumption growth will align with the EIA projected regional growth rate. However, any discrepancy between the timeline and actual modification of the energy mix will impact the emissions factor trajectory and the accuracy of the estimated emissions. The model user may consider updating the projections once new energy mix and consumption data become available.

Price Impact

We assume that the price of energy is the same across the City's 150 billing accounts and aligns with EIA's regional price case. However, carbon price impacts on energy prices might differ between departments based on their energy agreements with DTE because of different baseline prices. For example, prices for special uses such as water or wastewater treatment infrastructures have different energy contracts and rate structures. The model uses EIA's regional price case, which may not reflect the true energy costs in the municipality.

Department Budget Impact

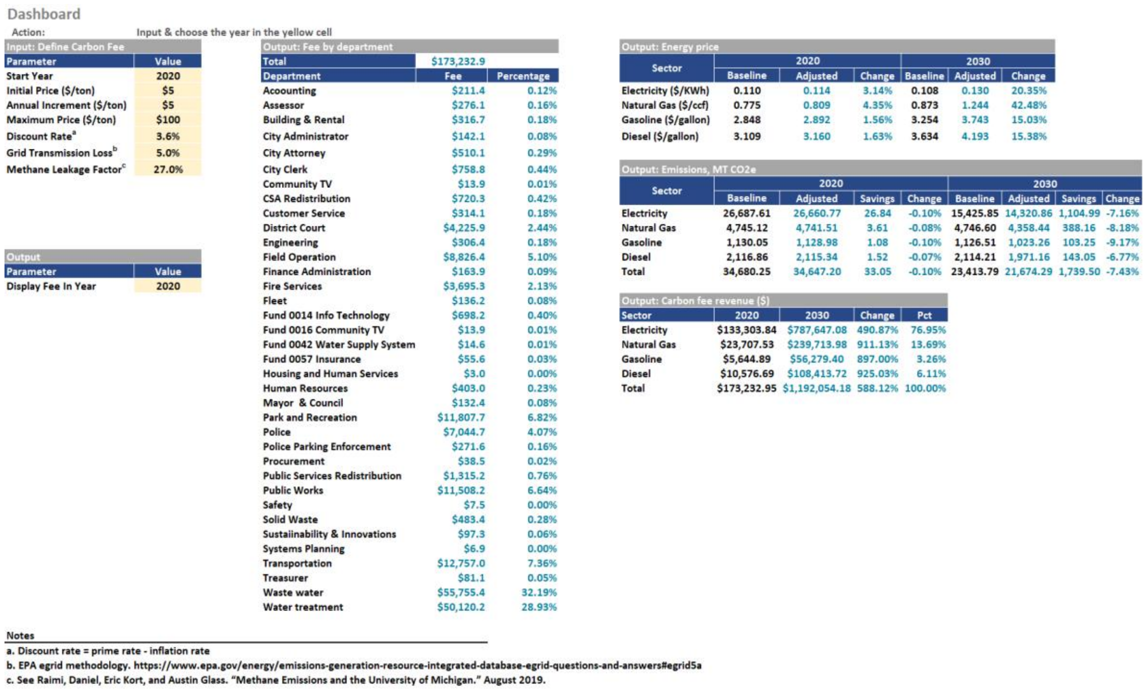
Our model assumes that all building and fleet fuel emissions are subject to the fee. The model also assumes building classification under departments are accurate. However, the scope of the fee may not ultimately include all municipal departments. Additionally, there are some facilities that city departments use but do not manage. For example, some parking structures are included in the City's building inventory but are operated by external entities. These facilities are excluded from the scope of the carbon fee program.

Methodology

Figure 2 shows the dashboard of the model, designed for ease of usability. On this sheet, the user can enter model inputs and view results like departmental annual fee, energy price, emissions, and carbon fee revenue by year. The model provides annual projections of the program's impacts from 2020 to 2050. On the dashboard, users may adjust the following inputs:

- The starting carbon price
- The program start year
- Annual price increment
- Maximum carbon price
- Discount rate
- Percentage of grid transmission loss
- Percentage of methane leakage

Figure 2. Dashboard of the economic model



Dashboard

Action: Input & choose the year in the yellow cell

Input: Define Carbon Fee	
Parameter	Value
Start Year	2020
Initial Price ($/ton)	$5
Annual Increment ($/ton)	$5
Maximum Price ($/ton)	$100
Discount Rate[a]	3.6%
Grid Transmission Loss[b]	5.0%
Methane Leakage Factor[c]	27.0%

Output	
Parameter	Value
Display Fee In Year	2020

Output: Fee by department		
Total	$173,232.9	
Department	Fee	Percentage
Acoounting	$211.4	0.12%
Assessor	$276.1	0.16%
Building & Rental	$316.7	0.18%
City Administrator	$142.1	0.08%
City Attorney	$510.1	0.29%
City Clerk	$758.8	0.44%
Community TV	$13.9	0.01%
CSA Redistribution	$720.3	0.42%
Customer Service	$314.1	0.18%
District Court	$4,225.9	2.44%
Engineering	$306.4	0.18%
Field Operation	$8,826.4	5.10%
Finance Administration	$163.9	0.09%
Fire Services	$3,695.3	2.13%
Fleet	$136.2	0.08%
Fund 0014 Info Technology	$698.2	0.40%
Fund 0016 Community TV	$13.9	0.01%
Fund 0042 Water Supply System	$14.6	0.01%
Fund 0057 Insurance	$55.6	0.03%
Housing and Human Services	$3.0	0.00%
Human Resources	$403.0	0.23%
Mayor & Council	$132.4	0.08%
Park and Recreation	$11,807.7	6.82%
Police	$7,044.7	4.07%
Police Parking Enforcement	$271.6	0.16%
Procurement	$38.5	0.02%
Public Services Redistribution	$1,315.2	0.76%
Public Works	$11,508.2	6.64%
Safety	$7.5	0.00%
Solid Waste	$483.4	0.28%
Sustaiinability & Innovations	$97.3	0.06%
Systems Planning	$6.9	0.00%
Transportation	$12,757.0	7.36%
Treasurer	$81.1	0.05%
Waste water	$55,755.4	32.19%
Water treatment	$50,120.2	28.93%

Output: Energy price

Sector	2020			2030		
	Baseline	Adjusted	Change	Baseline	Adjusted	Change
Electricity ($/KWh)	0.110	0.114	3.14%	0.108	0.130	20.35%
Natural Gas ($/ccf)	0.775	0.809	4.35%	0.873	1.244	42.48%
Gasoline ($/gallon)	2.848	2.892	1.56%	3.254	3.743	15.03%
Diesel ($/gallon)	3.109	3.160	1.63%	3.634	4.193	15.38%

Output: Emissions, MT CO2e

Sector	2020				2030			
	Baseline	Adjusted	Savings	Change	Baseline	Adjusted	Savings	Change
Electricity	26,687.61	26,660.77	26.84	-0.10%	15,425.85	14,320.86	1,104.99	-7.16%
Natural Gas	4,745.12	4,741.51	3.61	-0.08%	4,746.60	4,358.44	388.16	-8.18%
Gasoline	1,130.05	1,128.98	1.08	-0.10%	1,126.51	1,023.26	103.25	-9.17%
Diesel	2,116.86	2,115.34	1.52	-0.07%	2,114.21	1,971.16	143.05	-6.77%
Total	34,680.25	34,647.20	33.05	-0.10%	23,413.79	21,674.29	1,739.50	-7.43%

Output: Carbon fee revenue ($)

Sector	2020	2030	Change	Pct
Electricity	$133,303.84	$787,647.08	490.87%	76.95%
Natural Gas	$23,707.53	$239,713.98	911.13%	13.69%
Gasoline	$5,644.89	$56,279.40	897.00%	3.26%
Diesel	$10,576.69	$108,413.72	925.03%	6.11%
Total	$173,232.95	$1,192,054.18	588.12%	100.00%

Notes

a. Discount rate = prime rate - inflation rate

b. EPA egrid methodology. https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid-questions-and-answers#egrid5a

c. See Raimi, Daniel, Eric Kort, and Austin Glass. "Methane Emissions and the University of Michigan." August 2019.

The carbon price is converted from a $/metric ton carbon dioxide equivalent to the "effective carbon price" that the departments owe based on units of consumption (Table 4). Carbon dioxide equivalent, or CO_2e, is used to incorporate GHGs like methane into one universal unit.

Table 4. Effective vs. Original Carbon Price Units

Sector	Effective Carbon Price	Original Carbon Price
Electricity	$/kWh	$/metric ton CO_2 equivalent
Natural Gas	$/ccf	
Gasoline	$/gallon	
Diesel	$/gallon	

The change in prices and the elasticities of demand adjust according to equations (3) and (4). Because elasticity is a negative value, the adjusted consumption will always be less than the baseline. We calculated after-price emissions by multiplying the after-price consumption by the emissions factors (Equation 5). We then calculated revenue by multiplying after-price consumption by the effective carbon price (Equation 6):

$$(3)\ \text{Price Change (\%)} = \frac{\text{Effective Carbon Price}}{\text{Baseline Price}} * 100\%$$

$$(4)\ \text{Adjusted Consumption} = \text{Baseline Consumption} * (1 + \%\ \text{Price Change} * \text{Elasticity})$$

$$(5)\ \text{Emissions} = \text{Adjusted Consumption} * \text{Emissions Factor}$$

$$(6)\ \text{Revenue (\$)} = \text{Adjusted Consumption} * \text{Effective Carbon Price}$$

Program Design

Meetings with City staff during the research phase heavily informed the program design phase. The goal of this phase was to design an effective and efficient carbon pricing program that created minimal overhaul to existing city operations.

To ensure a detailed understanding of existing city processes, we reviewed city budget and policy documents, as well as conducting in-person and virtual meetings with the City's Chief Financial Officer and other members of the Finance department. We evaluated potential methods of fee collection, fund creation, and revenue redistribution. Our team also conducted a meeting with OSI and various department heads to gauge reactions to the proposed carbon fee program and determine possible roadblocks to implementation.

The Client submitted a request to the City's legal team to review the legality of an internal carbon price. This step was critical to ensure that the program would not violate any laws or face funding restrictions. We simultaneously explored the option of implementing a carbon shadow price rather than a traditional carbon fee. A shadow price does not collect revenue, but rather applies a price for emissions as a line item for future investment and development decisions. This circumvents the potential issue of departmental exemptions from participation but would result in no actual revenue generated by the program.

We worked closely with OSI to design solutions to roadblocks and map out a detailed final set of processes. Our team created flow charts to depict our understanding of pre-carbon price program budget structures and show how the carbon pricing program would fit into these systems. In collaboration with OSI and Finance, we provided interim deliverables detailing the proposed program design, responded to multiple rounds of comments and updates, and finalized the internal carbon fee program structure.

Results and Discussion

Economic Model Outputs

We investigated three starting carbon price levels: \$5, \$10, and \$42/metric ton CO_2e. The Columbian government uses the \$5/MT CO_2e for a carbon tax on fossil fuels (World Resources

Institute, 2018). Large private entities like Microsoft and Disney employ the $10/metric ton CO_2e price for their carbon pricing programs. The $42/MT CO_2e is the Environmental Protection Agency's suggested social cost of carbon for the year 2020, given a 3 percent discount rate (EPA, 2016). The model shows projections of the effective carbon price, amount of emissions savings, and allocable carbon revenue under the three price scenarios in 2020 and 2030 (Tables 5 and 6). In addition, to evaluate fiscal impacts on each department, we broke down the percentage of each department's contribution compared to the total carbon revenue (Table 7).

Table 5. Effective Carbon Price and Percent Change from Baseline in 2020 and 2030

Sector	Unit	$5/MT (% change)	$10/MT (% change)	$42/MT (% change)
2020 Rates				
Electricity	$/kWh	$0.003 (3.14%)	$0.007 (6.29%)	$0.029 (26.40%)
Natural Gas	$/CCF	$0.034 (4.35%)	$0.067 (8.70%)	$0.283 (36.54%)
Gasoline	$/gallon	$0.044 (1.56%)	$0.089 (3.12%)	$0.373 (13.11%)
Diesel	$/gallon	$0.051 (1.63%)	$0.102 (3.27%)	$0.427 (13.72%)
2030 Rates				
Electricity	$/kWh	$0.022 (20.35%)	$0.023 (22.20%)	$0.037 (34.04%)
Natural Gas	$/CCF	$0.371 (42.48%)	$0.405 (46.34%)	$0.621 (71.06%)
Gasoline	$/gallon	$0.489 (15.03%)	$0.533 (16.39%)	$0.818 (25.13%)
Diesel	$/gallon	$0.550 (15.38%)	$0.610 (16.78%)	$0.935 (25.72%)

In 2020, a $5/MT CO_2e starting carbon price is equivalent to an additional 0.3 cents per kilowatt-hour (kWh) of electricity consumption, or a 3.14 percent increase in electricity price. In the same year, the cost of natural gas would increase by 3.4 cents per centum cubic feet (CCF), which is equivalent to a 4.35 percent increase. We estimate the prices of gasoline and diesel to increase by 4.4 and 5.1 cents per gallon, respectively, representing 1.56 and 1.63 percent cost increases. Our modeled carbon price increases by $5/MT annually, which would yield a 2030 carbon price of $55/metric ton. We expect the costs per unit of consumption to grow by between 15 to 20 percent across energy sectors in 2030.

Table 6. Estimated Emissions Reductions and Carbon Revenue in 2020 and 2030

	2020		2030	
Starting Price	**Emissions Reductions (Metric Tons)**	**Revenue ($1000's)**	**Emissions Reductions (Metric Tons)**	**Revenue ($1000's)**
$5/MT CO_2e	33.1 (-0.1%)	173.2	1,739.5 (-7.4%)	1,192.1
$10/MT CO_2e	66.1 (-0.2%)	346.1	1,897.6 (-8.1%)	1,290.9
$42/MT CO_2e	277.6 (-0.8%)	1,444.9	2,909.7 (-12.4%)	1,886.3

We estimate a $5/MT starting carbon price would induce an emissions reduction of 0.1 percent in 2020. This would bring in $173,000 of carbon fee revenue that year. Our team estimates that with a $55/MT price in 2030, the city could reduce 7.4 percent of municipal emissions from the business-as-usual case (i.e., no carbon pricing program) and generate about $1.2 million in fees (Figure 3).

Figure 3. Estimated Emissions Under Three Price Scenarios in 2015 through 2030

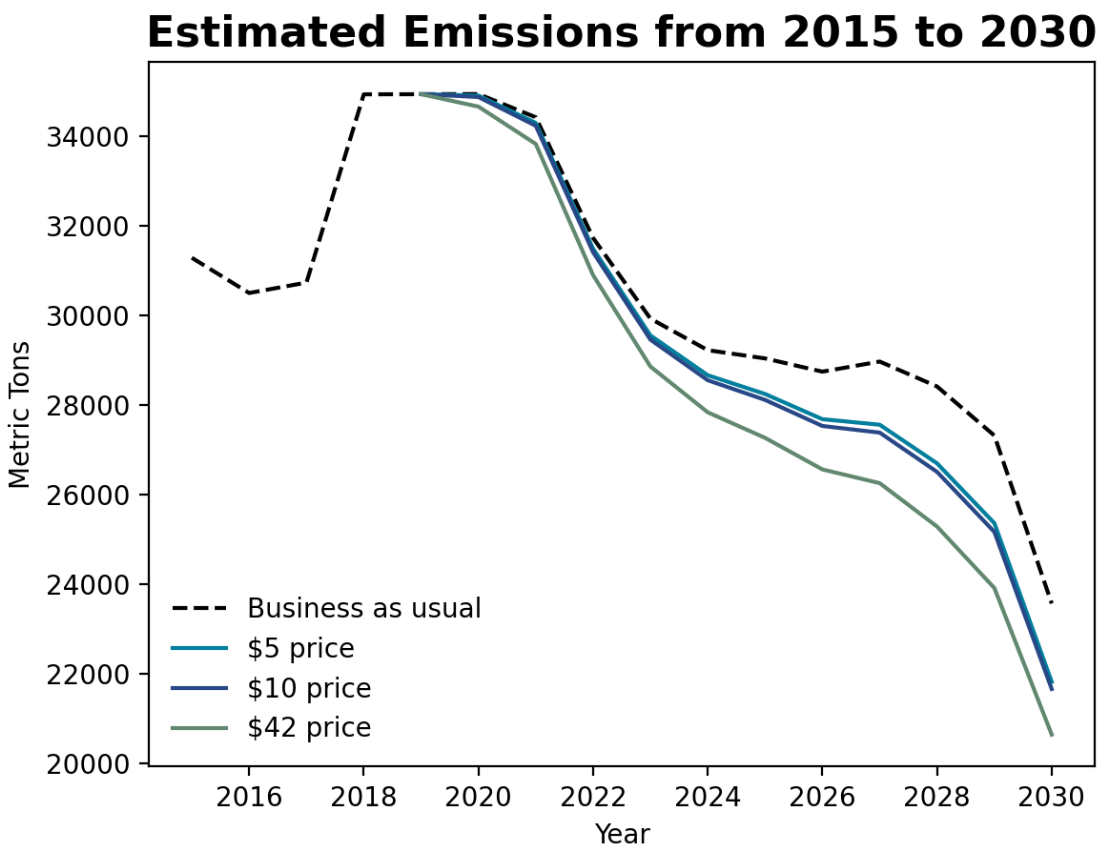


Table 7. Fiscal Impact on Top-Emitting Departments

Starting Price	$5/MT	$10/MT	$42/MT	Percentage of Total Contribution
Wastewater Treatment	$55,755	$111,401	$464,948	32.2%
Water Treatment	$50,120	$100,142	$417,981	28.9%
Parks and Recreation	$11,807	$23,593	$98,501	6.8%
Public Works	$11,508	$22,999	$96,131	6.6%
Field Operation	$8,826	$17,635	$76,613	5.1%
Police	$7,044	$14,076	$58,762	4.1%

Wastewater treatment and water treatment units contribute about 60 percent of total carbon revenue based on their emissions profiles. Other top-emitting departments are Parks and Recreation, Public Works, Field Operations, and Police. These six departments consisted of about 83 percent of carbon revenue sources.

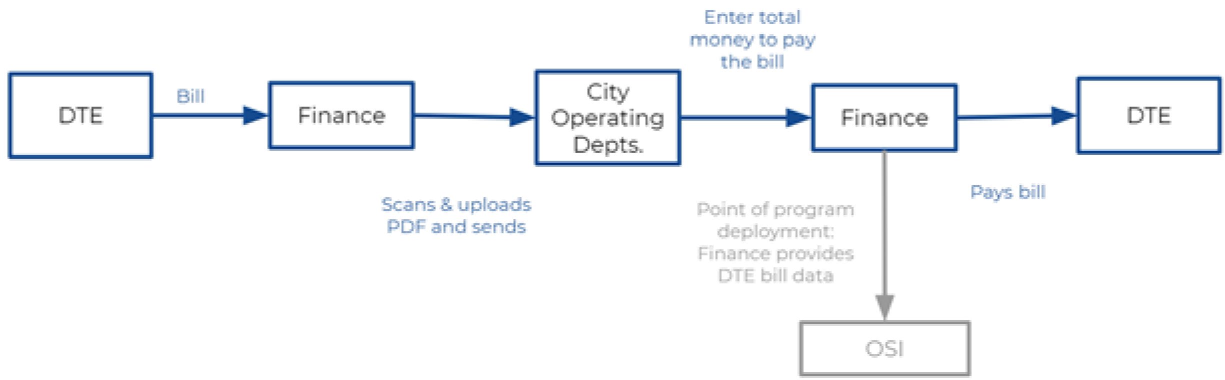
Program Design Parameters

The overall goal of the program design phase was to cause the least possible overhaul to existing city financial and administrative systems in Ann Arbor. The more change that a carbon fee program causes on existing systems, it will be more difficult to be adopted. Our team designed the program so that any city employee or member of an external entity interested in replicating this project can easily understand the process.

Gas and Electric Billing

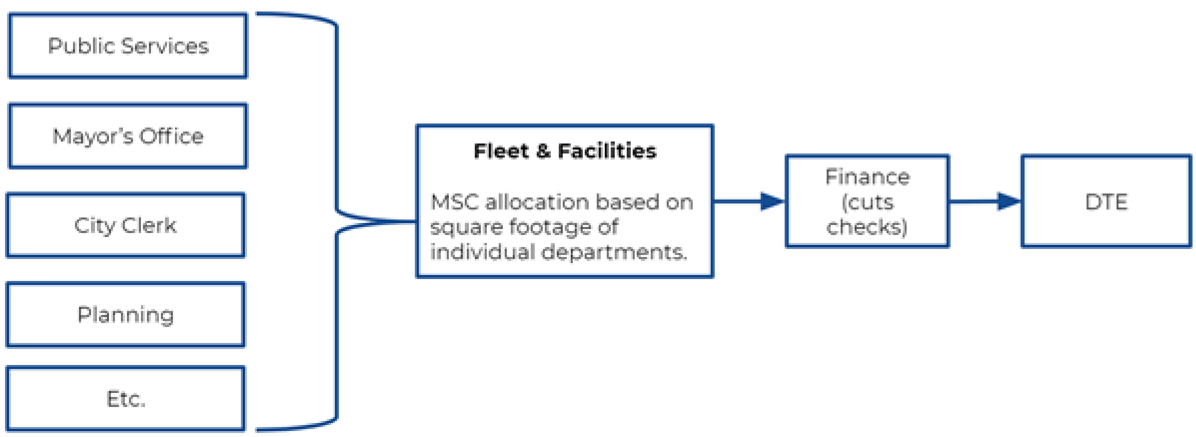
Before establishing systems for carbon fee revenue collection and redistribution, we gained a detailed understanding of municipal mechanisms for natural gas and electric utility bill allocations, collections, and payment. We then determined the ideal step at which to deploy the carbon pricing program. The pre-carbon pricing program process (shown in blue) and step of program deployment (shown in gray) are depicted in Figure 4. The gray text shows the step where Finance can provide OSI with a copy of the monthly utility bill data, and presents the point at which an internal carbon fee may be deployed.

Figure 4. Pre-Carbon Pricing Program Utility Bill Collection Process



For buildings containing multiple city departments (e.g., Larcom City Hall), the City allocates utility fees based on department square footage. For example, if the Mayor's office occupies 10 percent of City Hall's total square footage, that office is responsible for 10 percent of the building's total utility fees. In this case, Facilities (which manages city buildings) and Finance collect utility fees through a municipal service charge. This process is shown in Figure 5.

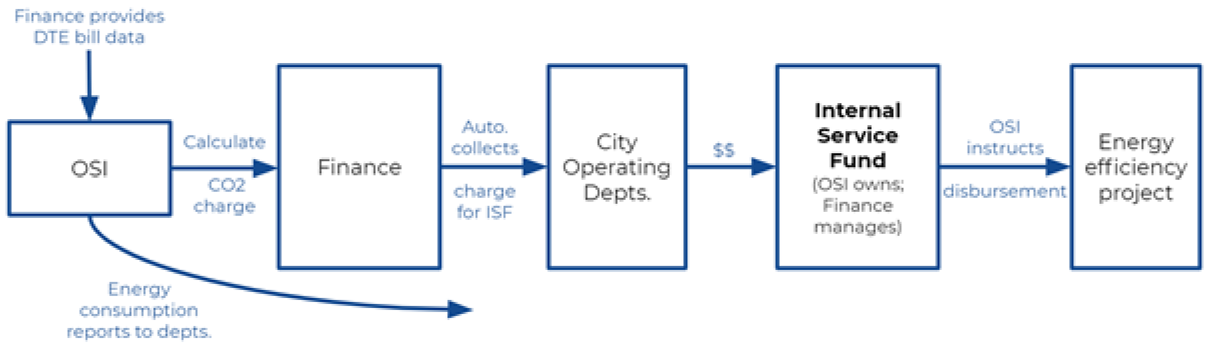
Figure 5. City Hall Utility Bill Collection Process



Understanding this process helped us decide that because departments are billed for utilities on a monthly basis, the carbon fee should also be levied on a monthly basis. Staff at the Finance also recommended setting up an internal service fund to collect fees from each department. Because many departments already pay into IT services with an internal service fund, this is a process that they have already encountered. Therefore, this minimizes obstacles to implementation and understanding among city employees.

Starting from the point of deployment shown in grey in Figure 3, the final carbon fee collection process is depicted and described below (Figure 5). The carbon pricing program utilizes the same system for allocating carbon fees to departments in shared buildings.

Figure 5. Carbon Fee Collection Process



The process for carbon fee revenue collection for natural gas and electricity consumption is described as follows:

1. DTE sends all city building electricity and gas bills to Finance.
2. Finance scans all bills and sends them to each city department responsible for paying their utility bills, while also making a copy of each bill available to OSI. For shared units, bills are sent to Fleet and Facilities.
3. OSI inputs electricity consumption units in kilowatt-hours (kWh) and natural gas consumption (ccf) into the economic model.
4. The model calculates emissions produced by each department's consumption and outputs the corresponding carbon fee. OSI sends these results to Finance.
5. Finance applies carbon fees every month to each department using an internal service fund called the Carbon Fund.
    a. Some departments have restrictions concerning revenue collection and redistribution. Fees collected from departments with these restrictions must be earmarked for redistribution into the same department from which the charge was applied.

Gasoline and Diesel Fee Collection

The process for applying the carbon fee to gasoline and diesel consumption is even simpler than for electricity and natural gas. The city's Fleet and Facilities department, as well as the Police and Fire Departments, already collect mileage data for departmental use of city-owned vehicles. These departments will simply provide this data to OSI to be inputted into the economic model. The model calculates the associated emissions and corresponding fees, which will then be passed along to Finance for application to the appropriate departments. The internal carbon fee applies to city-owned vehicles only and would not be used for any personal vehicle usage.

Final Revenue Usage

We describe the process for redistributing revenue accumulated into the Carbon Fund below. It is up to the discretion of OSI to prioritize buildings and departments with the greatest need for Carbon Fund revenues. This allows the fund to be dynamic and responsive to the City's most immediate needs at the time of revenue allocation:

1. On a rolling basis, OSI will utilize revenue in the Carbon Fund to reduce the city government's carbon footprint and increase energy efficiency
2. We recommend that funds will be prioritized for energy audits in city buildings. Energy auditors inspect and measure the energy use in buildings to recommend opportunities for energy reduction. OSI will prioritize buildings that exhibit the greatest need for an audit. Because commercial energy audits can be costly, the fees collected through the internal carbon price program may only subsidize a portion of the total cost of an audit in its initial years.
3. OSI will allocate Carbon Fund revenues for energy efficiency upgrades if there are no higher priority building energy audits required.
    a. Building and department managers may apply for funds for energy efficiency improvements using the Carbon Fund Application, provided in Appendix C: Carbon Fund Application. This provides an opportunity for employee engagement and education on energy conservation.
    b. OSI and building managers should consider the results and recommendations from building energy audits when making energy efficiency upgrade investment decisions
    c. Ultimately, OSI has the authority to prioritize energy efficiency improvements it deems most important.
4. We recommend that funds earmarked for specific departments follow the same path: energy audits maintain the highest priority, followed by energy efficiency upgrades

Discussion, Roadblocks, and Solutions

Roadblock #1: Data Scrubbing

Through discussions with the Finance department, we learned that DTE's process of providing bills to the city operates on a fairly antiquated system. DTE sends monthly paper bills to the city, which forces Finance to scan approximately 150 separate utility bills into their system for allocation to each department. Finance then prints and mails 150 paper checks to DTE each month. Moreover, DTE was unable to meet requests to synchronize billing cycles across city departments. Currently, municipal utility bills are not sent on the same day of each month.

This system posed a significant threat to the viability of the carbon pricing program. We were concerned that adding the carbon pricing program to this already cumbersome and inefficient system would require more resources than OSI and Finance would be able to provide. We recognized that those managing the program require a straightforward carbon fee calculation process, so manually entering 150 bills' worth of consumption data into the economic model each month was not a realistic option. We held a meeting with the Client and IT department to discuss the viability of developing software to digitize the bills and automatically populate the model with consumption data. The IT representative informed us that while this is possible, creating such a software would be difficult and time-consuming. As a workaround, we also considered basing the carbon charge on the utility bill dollar amounts, rather than on consumption data. However, we determined that this solution would be too complicated and inefficient. Any changes to DTE's rate structures would require OSI to regularly update the model from the back end every time DTE implemented a rate change.

This roadblock led to a few takeaways and decisions. First, a carbon pricing program can be significantly impacted by the decisions and processes of the local utility. A more technologically streamlined process (e.g., providing synchronized electronic bills) would reduce complexity for the implementation of a carbon pricing program. This issue contributed to the decision to start the program with only departments that fall under the City's General Fund. Doing so allows OSI to show that the program is functional and effective with fewer departments before expanding to all city departments. It also buys time for OSI and IT to develop data-scrubbing software, or for DTE to switch to an electronic billing system that could bypass the need for such a software. For now, OSI must manually enter consumption data into the economic model to produce corresponding carbon fees.

Roadblock #2: Departments with Fund Restrictions

In our conversations with Finance staff, we learned that there are state-level limitations on the application of fees to city departments that offered public services (e.g., the Water Department). This posed an issue because one of the main goals of the project is to generate revenue that can be placed in a fund to be used to further OSI's sustainability efforts. If the program could not legally apply a fee to any department that provides public services, this would significantly limit the project's scope.

Upon learning this, the Client submitted a request to the legal team to determine if an internal carbon fee was feasible for the city. Our team investigated shifting project scope to a carbon shadow price to solve this problem. A carbon shadow price would not apply an actual fee to emissions, but rather a "shadow" cost of carbon emissions to all major future business decisions. While this initially seemed like a possible workaround, we concluded that this was not a one-for-one swap.

Our team and the Client ultimately decided not to employ a shadow price for the following reasons:

1. A shadow price does not generate actual revenue. An important goal of the project was to generate a source of funding for OSI to work towards ambitious carbon neutrality goals in Ann Arbor, including in its municipal operations. While a carbon shadow price can reduce overall emissions in the long-term, it would not provide more immediate resources for OSI.

2. Accurately calculating the emissions impact of future investments is usually project-specific and highly detailed. For example, a shadow price can be very useful when deciding between different schematic designs for new construction. However, our team lacked the data to calculate the carbon intensity of all potential materials in a new construction process. As a result, OSI would have to calculate the shadow price for every major future investment decision, which would be time-consuming. Furthermore, capital projects in a mid-sized city like Ann Arbor are infrequent. A shadow price would not only be time-intensive to research, but also see much lower utilization than an internal carbon fee would.

3. Very few cities had implemented a successful internal municipal carbon pricing program. It was important to make this project as reliable as possible to meet an ancillary goal of spurring the adoption of internal carbon pricing by other cities in the future. A shadow price is more dependent upon local conditions, and therefore is less easily replicable than a carbon fee.

Given these critiques of a shadow price, we worked closely with OSI and Finance to find an alternate solution that allowed the carbon fee program to remain intact. Because of *Bolt v. Lansing*, no city in Michigan can apply a fee that would cause departments that provide public services to ratepayers to increase their rates. Therefore, the internal carbon fee could not create severe cost burdens for departments like Water, as this would run the risk of forcing these departments to increase rates. We recommend earmarking all applicable carbon fee charges to be redistributed back into those same departments. As a result, there is no possible net change to the total budget of these departments, but rather funds are simply shifted within the budget. Still, potential issues arise with prioritization: even though carbon fee revenue would be redistributed for energy efficiency upgrades, departments providing essential services may still have a greater need for these funds. For example, budget constraints might the Water Department to decide between paying into the carbon fee or investing in new water filters to address recently discovered contaminants that pose risk to residents in Ann Arbor.

We recommended initiating an internal carbon fee with only departments that fall under the City's General Fund. This decision provides the Client the opportunity to prove the program's effectiveness while also discussing these potential conflicts with applicable department heads to determine long-term solutions. Some service-providing departments may be exempt from the program altogether, or with more time to build the fee into their budget, departments like Water would become more able to absorb the impact of the carbon fee on their budget.

Challenges and Limitations

Several factors presented limitations for this project. These challenges included a lack of existing cases for reference, lack of publicly available data, lack of time and team capacity, and unforeseen global health and economic conditions.

Currently, most local governments do not have external or internal carbon fee programs. OSI is attempting to use something innovative and new for the City. While this is exciting in many ways, the program's success is also uncertain. Programs that do exist have been implemented in private companies or government entities at the state and national levels. However, program obstacles and technical particulars vary by organization type and their scale of operations. This makes the data and details of such programs difficult to obtain and translate to our project.

To determine emissions projections, we needed to establish the emissions intensity of the electricity delivered by DTE. However, DTE does not publish its emissions data. We used information gleaned from DTE public statements and our literature review to inform the estimates. Without verified data from DTE, the model's emissions projections may be inaccurate.

OSI operates within a local government, bound by competing priorities and limited resources. In addition to managing existing programs, OSI has been working to develop a city-wide carbon neutrality plan. The internal carbon fee program is only one component of the city's larger carbon neutrality goal, and this broader goal required a full-time commitment from the Client. Staff turnover can also create obstacles in communication and transitioning knowledge among employees. We needed to revise our planned scope of work in response to the tight schedule and limited resources.

Finally, the rise of the COVID-19 pandemic in early 2020 presented unexpected interruptions to the project's timeline and reduced our capacity to fully complete our planned scope of work. Due to the unprecedented changes to academic and municipal operations, we were forced to cancel several meetings both internally and with the Client. These cancellations prevented important opportunities to discuss final expectations and conclude project activities. Ultimately, we needed to trim several project tasks to accommodate these circumstances.

Changes in Scope

Due to shifting client needs, time constraints, and unforeseen circumstances relating to the rise of COVID-19 in the final months of the project, we had to change portions of the original scope of work defined in our project proposal. While these actions were not completed, we recommend exploring the following as next steps to refine the program and expand it beyond the pilot phase:

- Our team had initially planned to oversee a pilot simulation of the carbon fee which would assess the program's impact on various city departments. Though these charges would not have been collected, the simulation would have served to identify potential program obstacles. The pilot would have been initiated during the City's annual budget process. However, we needed to forgo the pilot due to limited time and resources.

- We had proposed working with focus groups to identify city employee concerns and inform the design of communication and education materials. The Client decided to pursue more informal avenues of communication with city employees to raise their concerns, comments, or questions.
- We originally intended to produce an energy report template that could be easily tailored and distributed to each department in the program, consistent with output from the economic model. The energy report would detail each department's energy usage, monthly carbon fee payment, and recommend opportunities for carbon fee. However, due to limited time at the end of the project and the disruption created by the pandemic, we decided to remove this from our project scope.

Recommendations and Best Practices

Recommendations

Our short-term recommendations to the Client are as follows:

- Pilot an internal carbon fee with a $5/MT starting price, beginning in FY2021.
- Working with Finance to create an internal carbon service fund to collect fees from departments operating under City's General Fund.
- Calculate and apply each department's internal carbon fee based on energy consumption and fleet fuel usage.
- Allocate program revenue to prioritize building energy audits, followed by the most relevant and important energy efficiency upgrades as determined by the audits and city needs at the time of investment.
- Communicate internal carbon fee structure and fee impacts to each affected department using information materials such as frequently asked questions (FAQ) documents or an energy report

We also issue the following medium and long-term recommendations to the Client:

- Increase the carbon price by $5/MT annually, to reach $55/MT by FY2030.
- Expand the coverage of the fee to more funds and departments, if legally acceptable and operationally feasible.
- Establish a partnership with DTE to automate and synchronize energy bills and allow for more accurate carbon fee calculation.

Best Practices

We relied on several factors and processes to ensure that the impacts of a proposed carbon fee could be accurately analyzed. These insights provide broader lessons for any local government unit or entity interested in developing an internal carbon pricing program.

Because emissions data are key for forecasting impacts of the fee, an internal carbon price requires **complete and accurate data**. For our model, one of the most crucial data sources was Ann Arbor's GHG inventory update, which was completed in November 2019. Other important inputs in the model included the source of funds for each department and shared building breakdown by department. This information allowed us to build a model that accurately forecasts how city operations might be affected by varying fee levels. Therefore, it is critical that such inputs are accurate, up-to-date, and reliably tracked within the City.

The early stages of our project involved **research on existing cases and examples** to help demonstrate the feasibility of a fee and lessen the uncertainty of the program. In this step, we explored options and selected the best fits for Ann Arbor's local context, considering the constraints on legality, staffing, and budget. Through a literature review and interviews with academic experts and city sustainability managers, we were able to identify best practices that contributed directly to the program's design in Ann Arbor. Furthermore, it allowed us to foresee potential barriers and devise solutions to overcome them.

With a carbon fee program, employees at every level must be involved. However, the details of carbon pricing are still very complicated for many people, including city employees and planning professionals. We created a **user-friendly model and process** to forecast long-term fee impacts and roll-out of the program. While completing our research and refining the deliverables, we considered the operability of the carbon fee model and how our work would be used by city employees once we were no longer involved in the program. This allowed us to create materials that OSI, Finance, and all departments can rely on as they work to get the carbon fee program off the ground. Supporting materials, like the model instructions and a list of FAQs, help answer questions and provide guidance.

Through interviews and case studies, we have also determined several best practices that are key to the successful adoption of a carbon fee program. These heavily shaped our program design. Without such elements, it increases the risk that an internal carbon fee would struggle to be implemented or succeed in achieving the estimated savings.

First, **political support is paramount**. Support from key decision-makers within the city help overcome potential pushbacks from employees. In Ann Arbor, the fee had early support or interest from crucial actors such as the City Administrator and Finance. They participated in meetings and provided feedback on our research, and they became influential advocates for the internal carbon fee. Because of this, the FY2021 budget proposal from OSI included a proposal for an internal carbon fee. When it comes to implementing a carbon pricing program in the public realm, it is crucial to have support from major decision-makers or stakeholders. It also helps to **establish partnerships and cultivate support** for the policy. Our case studies and interviews further highlight the importance of having stakeholder buy-in. Washington State's two carbon tax initiatives provide examples of policies that failed in part because they could not galvanize enough support among the primary stakeholders. For example, it would be beneficial to work with the local utility to determine the optimal price and streamline revenue collection. This is how the electricity tax was implemented in the City of Boulder.

A second component that enables success is to provide **clear information for everyone**. The mechanics of a carbon fee and optimal consumer responses should be easily comprehensible. Employees should understand the overall concept of a carbon fee, how it works, and why the city is implementing the policy. One concern that emerged in our research is perceived helplessness; employees may feel like they are unable to reduce the fee they are being charged because they do not know how they can change their energy-consuming behavior. This emphasizes the importance of a communications and education campaign that is coordinated and wide-reaching. Because of this, we recommended circulating energy usage reports to all employees that motivate users to reduce consumption, provide tips and methods of consumption reduction, and draw connections between energy conservation and fee reductions. Moreover, employees should be encouraged to participate in the program revenue allocation process, including the use of a carbon fund application. A carbon fee program must be easy to understand, and stakeholders must perceive the rules to be clear and fair. A transparent process and a consensus among participants help implementation and long-term effectiveness of the program.

Finally, an internal carbon fee should be **easy to implement** for those who are responsible for managing the program. The fee should be integrated into existing billing or financing systems, rather than require a larger overhaul or transformation of city operations to establish the fee. Our discussions with Finance and OSI revealed opportunities to collect the fee through the City's existing billing process and to contain revenue in an internal service fund administered by OSI. Such a process design is key to ensuring minimal overhaul to existing systems and reducing effort and resistance towards program implementation.

Conclusion

Our research demonstrates that an internal carbon fee is a feasible policy option at the city level and has the potential to reduce emissions and change employee behavior. However, its design must be thoughtful and catered to the needs and operations of the city. While this is challenging, our model shows that even a \$5/MT CO_2e fee can drive meaningful change in terms of both carbon reductions and behavioral and institutional change.

The City is currently undergoing its FY2021 budget process, which includes OSI proposing a full plan to attain carbon neutrality by 2030. An internal carbon fee is among the many strategies included, and for which OSI projects that such program would raise \$30,000 in its first year of operating on the general fund. The internal carbon fee is one of the first initiatives of the City's plan, which shows Ann Arbor's serious commitment towards carbon neutrality.

We recommended immediate next steps to research, design, and deploy a communications and education campaign, which did not end up in this project's final scope of work. A thoughtful and prepared education campaign is crucial to ensure that employees view the program in a positive light and do not view the fee as burdensome or confusing. This contributes to the long-term viability and seamless integration of the carbon fee into the City's operations and maintenance.

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Appendices

Appendix A: Client Deliverables

Our team produced the following client deliverables:

- An **economic model** developed in Microsoft Excel. The emissions included in the model include those from electricity and natural gas consumption in municipal buildings and fuel consumption from municipal fleet vehicles. The tool models emissions projections and revenue generation under a given pricing scenario. It is adapted from the Washington Carbon Tax Assessment Model by using Ann Arbor emissions and consumption data (Washington State Department of Commerce, 2019). External entities may request a copy of the model from the Office of Sustainability and Innovations.
- **Carbon Model Instructions** provides detailed descriptions of the information in each tab of the economic model. External entities may request a copy of the model instructions from OSI.
- A **Carbon Fee and Fund FAQ** that provides an overview of the broader elements, implications, and processes associated with the carbon fee and carbon fund program. This overview is intended as a resource for municipal employees seeking clarification and guidance on the program. The FAQ document can be found in Appendix B: Carbon Fee and Fund FAQ.
- A **Carbon Fund Application** serves as the primary funding request form for any department requesting financial assistance for energy audits and energy efficiency projects. The application requires a description of the project, an estimated timeline, the amount of funding requested, estimated energy savings, and any additional potential benefits as a result of the project. The Carbon Fund Application can be found in Appendix C: Carbon Fund Application.
- A **Final Report** provides a comprehensive explanation of the processes, methods, and technical systems associated with the development of the program.

CARBON FEE & FUND FAQ

CITY OF ANN ARBOR, MICHIGAN

Office of Sustainability and Innovations

Phone (734) 794-6430 ext. 43724 (Josh) or ext. 43725 (Missy)

jmacdonald@a2gov.org or mstults@a2gov.org

What is an internal carbon fee?

An internal carbon fee is a fee that places a monetary value on the emissions associated with the organization's energy consumption.

Why is the city implementing an internal carbon fee?

The City of Ann Arbor has committed to a 2030 carbon neutrality goal. To successfully meet this goal, the Office of Sustainability and Innovations is working hard to help city operations reduce energy consumption. The internal carbon fee will facilitate this reduction behavioral change, and funds for updated equipment and technology.

How does the internal carbon fee work?

The internal carbon fee is applied to each metric ton of CO_2 equivalent emissions produced from municipal building energy consumption and municipal fleet fuel consumption. The fee is collected into the city's carbon fund and redistributed to provide financial assistance to city departments seeking to perform energy audits or implement energy efficiency projects. Departments interested in pursuing funding can apply through the Carbon Fund Application.

What is the price per ton?

The starting price per ton is five dollars per metric ton of carbon dioxide equivalent emissions ($5/metric ton CO_2e).

Will the price change over time?

Yes, the price will gradually increase to 55 dollars per metric ton by 2030. However, this price is subject to change depending on current economic, social, and environmental conditions or as seen fit by the Office of Sustainability and Innovations (OSI).

How is the fee calculated?

There are four sources of energy and fuel that fall under the carbon fee. These sources include electricity, natural gas, gasoline, and diesel. Electricity is measured in kilowatt-hours (kWh), natural gas is measured in hundred cubic feet (CCF), and gasoline and diesel are measured in gallons. Each energy source emits a specific amount of CO_2 equivalent emissions per measured energy unit consumed. The emissions per energy unit account for a fraction of a metric ton. The fee is applied proportionally to the measured emissions per energy unit. This equates to 0.003 cents per kWh, 0.034 cents per CCF, 0.044 cents per gallon of gasoline, and 0.051 cents per gallon of diesel.

How is the fee collected?

The fee is collected on a monthly basis from each city department subject to the carbon fee. Using the energy consumption data from each department's monthly energy (electricity and natural gas) bill and the logged travel information associated with municipal vehicle use, OSI determines the total carbon fee assessed to each department. For departments with shared building spaces, the carbon fee is applied to the building's energy bill and apportioned by the square footage of office space occupied by each department. The fee is then included with the department's monthly energy bill and collected by the Finance Department.

What happens to the revenue collected from the program?

The revenue is collected in the Carbon Fund. Each department that is subject to the carbon fee will have access to this capital to fund energy audits and energy efficiency projects with prior approval from the OSI. Monies from certain departments will be earmarked for that department's use (please contact OSI for more information if you feel that this applies to your department).

How long will the program run?

Current modeling for the carbon fee ends in 2030. However, there is no set deadline established for the retirement of the fee. OSI will continually assess the need for the fee as the city works to meet its climate goals.

Will the fee be applied to my department?

As of the program's launch in 2021, the fee is only applied to municipal emissions generated by departments within the city's General Fund. It is anticipated that the program will be expanded to include emissions from departments that fall under other municipal funds.

How do I know how much my department will have to pay each month?

Ask the Office of Sustainability and Innovations.

How does OSI decide which projects will be funded?

Departments interested in performing energy audits and/or implementing energy efficiency projects will apply for funding. OSI will prioritize energy audits to better understand the needs of each department and provide recommendations for energy efficiency opportunities. OSI will approve funding for the energy efficiency projects that exhibit significant cost-effective energy reduction strategies.

CARBON FUND APPLICATION

CITY OF ANN ARBOR, MICHIGAN

Office of Sustainability and Innovations

Phone (734) 794-6430 ext. 43724 (Josh) or ext. 43725 (Missy)

jmacdonald@a2gov.org or mstults@a2gov.org

Applicants interested in applying for project funding should fill out each of the yellow highlighted sections below. Staff in the Office of Sustainability and Innovations are available to help answer any questions you may have. Completed applications should be submitted electronically to jmacdonald@a2gov.org with the subject "Carbon Fund Grant Application". Carbon funds will be prioritized for energy audits for all buildings that have not been audited recently. You may apply for carbon funds for energy efficiency or other carbon emission/energy reduction related upgrades if your department's building has had a recent audit. Note that your department/building manager may be approached by the Office of Sustainability and Innovations regarding an energy audit regardless of the completion of this application.

Title of Project: Insert a short title for your project.

Location of Project: Identify where the project will take place.

Service Area Applying for Funds: Enter the name of the Service Area applying for carbon funds.

Contact Details: Enter the name and contact details for the individual coordinating the application.

Description of Project: Insert a description of your energy project. Be sure to include: a) existing conditions (what equipment is currently installed, what is the proposed project intended to replace, what quantities of equipment are involved); b) new conditions (what equipment will be installed or removed, and in what quantity); c) estimated energy savings associated with the project (if available); d) why the project is important; and e) if available, any technical documentation demonstrating project's potential impact on energy use, cost, greenhouse gas emissions, and other applicable environmental indicators (may include, but is not limited to: product or equipment spec sheets, contractor estimates, lighting plans, facility or equipment usage schedules, energy bills).

Estimated Project Start Date: Insert your desired start date.

Estimated Project Completion Date: Insert your estimated project completion date.

Amount Requested: Insert amount requested from the Carbon Fund.

Other Sources of Funding: Identify if any other sources of funding exist to support this project. This isn't required but if matching funds are being used, please outline those here.

Estimated Energy Savings: If known, enter the estimated energy savings associated with your project. If unknown, please enter your energy usage and the amount you paid in energy bills the previous year at the site where your energy project is being proposed.

Project Co-Benefits: Identify any benefits, other than energy use reduction, that your proposed project might have (e.g., community education, staff training, improved employee comfort).

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Estimated Energy Savings: Enter the estimated energy savings from the proposed project.

Estimated Greenhouse Gas Reduction: Enter the estimated greenhouse gas reduction potential of the proposed project.

Estimated Annual Cost Savings: Enter the estimated cost savings associated with the energy project.

Estimated $/ton of GHG

Additional funding sources: Enter the name, amount ($), and percent (%) of the total project cost of any additional sources of funding for your energy project. Write "N/A" if 100% of the project cost is to be covered by the carbon fund.

Example Carbon Fee Program Matrix

ORGANIZATION	ORG TYPE	PROGRAM	YEAR STARTED	CARBON / CLIMATE GOALS	CARBON PRICE PER TON	IMPLEMENTATION	REVENUE USE	BENEFITS	CHALLENGES	RESULTS/IMPACTS	OTHER NOTES/ INSIGHTS	SOURCE 1	SOURCE 2
Yale University	University	Yale Carbon Charge program	2015	Carbon neutrality by 2050	$40/ton	Buildings emitting more than their average compared to Yale's overall performance are taxed at $40/ton, with that money redistributed to buildings emitting less than their average.	Returned to buildings emitting less, historically, than Yale as a whole does historically	Participating buildings received a monthly report informing them of their energy consumption and charge; selected price reflects the current social cost of carbon. Since the tax was applied at the building level, the scope covered electricity, gas, steam, and chilled water energy sources.	Building managers were the only ones receiving information about the charge and held the responsibility for making changes based on that decision	In the pilot study, buildings subject to a carbon charge reduced emissions more than those without	Multiple schemes tested in pilot phase; this one ultimately selected for financial feasibility	Source 1	Source 2
State of Washington	Government	Washington Initiative 1631, Carbon Emissions Fee Measure	Proposed 2018	Reach 1990 baseline by 2020; 25% below by 2035; 50% below by 2050	$15/ton, ramping by $2 annually	Major polluters like fossil-fuel companies and industries must pay the fee, although a select few (like Boeing and Centralia, a coal-fired power plant) were exempted	Fund statewide environmental programs, including air and water quality, and equity (investing in disadvantaged communities)	Around 80-85% of state emissions would have been taxed. All revenue would have been reinvested in climate and energy	The companies subject to the tax (and therefore opposed it) had major political and lobbying power, funneling tons of money into defeating it. Overall a very partisan issue.	None as it did not pass, though it was estimated to have generated $2.2B in the first 5 years.	Because this was a statewide tax, it had to pass as a ballot measure. This is Washington state's second attempt at a carbon tax - this first one largely failed due to a lack of political support	Source 1	Source 2
Mahindra & Mahindra	Private Company	Internal Carbon Price	2016	25% reduction by 2020; carbon neutral by 2040	$10/ton	Collects tax on Scope 1 and 2 emissions company-wide	Revenue invested in projects to reduce company emissions	Covers company-wide emissions; they have used the revenue to invest in several large-scale conservation and efficiency upgrades.	Large corporation with many units subject to taxation; challenged by investors as M&M is a manufacturing company with significant pressure to keep costs as low as possible	M&M estimates that its carbon footprint has reduced 44% since implementing the program. This positive outcome has led the company to set even more ambitious targets. Sustainability is one of the company's leading principles, unique for a company in an emerging economy.	Mahindra & Mahindra is part of The Mahindra Group, which is one of the largest Indian companies in the world. The vertically-integrated auto manufacturer employs over 2 million people.	Source 1	
Boulder, CO	Government	Climate Action Plan (CAP) Tax	2006	80% emissions reduction by 2050	$0.0003-0.005/kWh; varies by sector	Taxes electricity consumption only; partnership with local utility to include tax in customer billing statement	Contributed to municipal fund to finance implementation of city's climate action plan	Tax displayed in customer billing statements provides a price signal to reduce electric consumption; rate that varies by sector has some equitable balance; climate programs for low-income households offset the regressive tax	Only covers a single source of emissions (electricity is only 50% of emissions source); the tax rate is not tied to grid emissions intensity	Generates ~$1.8M annually for a suite of climate action projects, primarily in energy efficiency	expire in 2023, so Boulder is looking at expanding the scope of its tax to include more emissions sources. In 2018, they worked with a master's project team from the Duke MEM program to explore several options and their feasibility.	Source 1	Source 2
British Columbia, CAN	Government	Carbon Tax	2008	40% reduction by 2030	Started at $10 CAD/ton; increases $5 annually until $50 in 2021. Currently, the tax is $35 CAD/ton	Taxes at the point of sale for gasoline, diesel, natural gas, heating fuel, propane and coal; applies to both individuals and businesses/industry	The revenue primarily funds programs that assist industry and businesses with emissions reductions. A Climate Action Tax Credit is available to low-income households to offset the burden of paying the tax.	Revenue neutral - taxpayers received rebates and income taxes were lowered	Some energy-intensive sectors struggled; government froze the tax rate for five years due to concerns that it hurt economic competition - the tax began to rise again after a new majority party was elected	Covers 70% of GHG emissions. Net emissions declined 5%, even as GDP increased 17%, demonstrating no harm to local economy.	heralded as an exemplary implementation of a carbon pricing program that has reduced emissions, generated revenue for sustainability initiatives, and positively impact customer behavior. Its successful led to Canada's PM	Source 1	Source 2

Shadow Price Example Matrix

ORGANIZATION	ORG TYPE	PROGRAM	YEAR STARTED	CARBON / CLIMATE GOALS	SHADOW PRICE PER TON	DISCOUNT RATE	IMPLEMENTATION	BENEFITS	RESULTS/IMPACTS	OTHER NOTES	SOURCE 1	SOURCE 2	SOURCE 3	SOURCE 4
European Bank for Reconstruction and Development (EBRD)	Bank	Carbon pricing methodology	2019	None stated	2020;$50-100 by 2030; $78-156 by 2050.	6%	projects that increase emission by 25,000 metric tonnes of CO2e per year	Paris Agreement. Identify and mitigate climate externality in invested	None published	conduct sensitivity analysis and identify switching value, which is a	Source 1	Source 2		
City of Vancouver, BC	Government	Vancouver Internal Carbon Price	2018	55% renewable energy by 2030, 50% carbon reduction by 2030, 80% reduction by 2050	$150/tonne (USD $112/ton). Add $5 per year from 2020. Multiply previous year's price by 1.06 from 2022 and beyond	None applied	LCA analysis for procurement of vehicles, mobile equipment, and fuels; acquisition and upgrade of energy efficiency of City building; methane emissions from Vancouver landfill	Factor into decision making and moves the city away from carbon-intensive projects	None published	Carbon price schedule will be reviewed every 5 years. Lack of education and change management are the main reasons that the city chose to align with Metro Vancouver's carbon price ($150) instead of SCC ($200-300) as the starting price	Source 1	Source 2	Source 3	Source 4
Minnesota Public Utilities Commission	State Agency	Commission order of updating environmental values	2018	None stated	$9.05-43.06 per ton starting from 2020	3% for high end of price range and 5% for the low end	Use the value to evaluate infrastructure projects and energy resource acquisition	Quantify harm from carbon emission	One of the first state agency to incorporate SCC in state-level decision-making	Political and industrial push back that industrial groups filed petition for reconsideration	Source 1	Source 2	Source 3	
Novartis	Private Company	Environmental Sustainability Vision	2016	30% by 2020	$100/tonne	None applied	Select major GHG reduction project based on cost savings determined by the internal carbon price.	Demonstrate leadership by proactively addressing climate change risks. Anticipate taxes to drive down emission and associated market mechanism	None published	Price in line with the SCC calculated by the World Bank	Source 1			
Shell	Private Company	GHG Project Screening Value (PSVs)	2000	None stated	$40/tonne	None applied	Apply the price on all future investment including production, manufacturing, distribution, refining, and marketing, to evaluate risk of project exposure to future regulation. Only cover scope 1 and 2 emissions.	Improve investment rates of returns to future regulations. Put price on mitigation strategies and prove economic of the options. Raise project manager's sensitivity to GHG costs that push for consideration of innovative GHG management opportunities and strategies	Investment in natural gas, biofuels, and gas-gathering system that reduce flaring. Projects are required to be submitted with gas and energy management plan that includes improvement options and alternatives regarding to emission reduction.	Also adopted a internal cap and trade program but concluded that complexity created challenge on implementation	Source 1	Source 2	Source 3	
BP	Private Comp	Carbon Pricin	2010	3.5 Mte reduction and zero net growth in operational emissions by 2025	$40/tonne; $80/tonne for stress test	None applied	Apply price on evaluation of certain large project or in region with existed carbon regulation. Do not apply globally but only industrialized countries until January 2019	Mitigate risk that 2/3 of direct emission expected to be regulated by carbon policies by 2020	2.5 Mte GHG reduction since 2016. Reached the target of zero net growth in operational emissions in 2018	Fulfilled the goals by not only using shadow price but also multiple energy efficiency upgrade measures. It was unclear the sole impact of price on paper and how the shadow price was factored in energy efficiency planning	Source 1	Source 2		
Royal DSM	Private Company	Carbon Pricing	2016	45% by 2025	€ 50/tonne (USD $55.84/tonne)	None applied	Evaluation of large capital expenditure projects that include impact of scope 1 and 2 emission	Use price higher than EU ETS that help mitigate carbon regulation which affect its operation and supply chain	Embed carbon costs into decision-making that sparked innovation and behavioral change among employees	Demonstrate leadership by publicly supporting and adopting carbon pricing	Source 1	Source 2		

Hybrid Carbon Fee Shadow Price Program Matrix

ORGANIZATION	ORG TYPE	PROGRAM	YEAR STARTED	CARBON / CLIMATE GOALS	CARBON FEE	SHADOW PRICE	IMPLEMENTATION	REVENUE USE	BENEFITS	CHALLENGES	RESULTS/IMPACTS	OTHER NOTES OR INSIGHTS	SOURCE 1	SOURCE 2	SOURCE 3
Swarthmore College	University	Swarthmore Carbon Charge program	2016	Carbon neutrality by 2035	Flat tax (1.25%) or ~$23/ton	$100/ton shadow price for forecasting capital projects	Levied a flat tax of 1.25% on the budget of campus entities, selected based on the SCC, to generate $300k, and then departments individually contributed more to a carbon fund	Green Revolving Fund for EE projects, Research/Program Admin, Education/Behavior Change efforts	Generates revolving energy fund for climate projects; combined use of tax as well as shadow price	None identified	None published	Additionally gave departments the option to contribute independently to the carbon fund	Source 1	Source 2	
Microsoft	Private Company	Microsoft Carbon Fee program	2012	75% reduction by 2030	$15/ton	$15/ton as line item in budget statements	Covers emissions associated with data centers, offices, air travel, and labs	Purchasing green power & carbon offsets to attain carbon neutrality	Since introducing the fee, Microsoft has met annual carbon neutrality goals	Price remains lower than both the SCC and what the carbon price is under several other price models like the emissions trading scheme. To become carbon neutral, Microsoft primarily uses this fee to purchase offsets or PPAs, rather than investing in strategies for internal behavior changes	As reported by Microsoft, enormous impacts on emissions reduced, renewable energy investments -- primarily due to the size of the company and purchase of offsets. Affected departments now incorporate this fee into their budgeting	Using the fee is used to meet carbon neutrality goals through purchasing offsets/green power is taking the easy way out. It's a PR boon for sure, to be able to claim carbon neutrality, but a rather inaccessible method for organizations that are smaller and far more constrained in resource	Source 1	Source 2	
Disney	Private Company	Carbon Solutions Fund	2009	50% reduction by 2020	$10-20 per ton	$10-20 per ton	Allocate fee from each business segment based on annual emissions. Use price as part of the capital planning process for construction and IT projects	Energy efficiency and offset investment in forest carbon credits	Generate revenue to offset emission that the company can't reduce	None identified	Generated $35 million till 2013. The emission in 2012 had be cut off from 2006 baseline	Behavioral and operational change in company's business, such as energy efficiency upgrade and reduced energy consumption	Source 1	Source 2	Source 3

Internal Carbon Price - Tasks & Timeline

Updated April 2020

★ denotes deliverable

	STATUS	DURATION	DELIVERABLE	2019											2020				NOTES
				FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	
PHASE 1. RESEARCH																			
Research existing carbon taxes/fees in practice	Complete	Feb - May 2019	Example carbon tax matrix				★												
Compare carbon fee vs. shadow price	Complete	Apr - May 2019	Pro/con comparison matrix				★												
Set up interviews with external city staff, U-M faculty, technical experts	Complete	April 2019																	
Review city budget process	Complete	April 2019																	
Legal review to identify potential constraints to program design	Complete	Apr - May 2019																	
Greenhouse gas inventory review	Complete	May - Jun 2019																	
Select internal carbon price policy	Complete	September 2019																	
PHASE 2A. ECONOMIC MODEL & ANALYSIS																			
Review Washington Carbon Tax Assessment Model	Complete	Jun - Aug 2019																	
Collect data inputs for model	Complete	Jun - Nov 2019																	
Build economic model for A2 carbon price	Complete	Sep 2019 - Feb 2020	Model template & instructions																
Select and model 3 pricing scenarios	Complete	Sep 2019 - Feb 2020																	$5, $10, and $42/metric ton
Report on model outputs and analysis	Complete	Dec 2019 - Feb 2020	Graphs, tables for report																
Select optimum starting carbon price	Complete	Feb 2020														★			
PHASE 2B. PROGRAM DESIGN & STAKEHOLDER ENGAGEMENT																			
Create program parameters (price, scaling, fund, billing schedule and structure)	Complete	Aug - Sep 2019	Presentation											★					
Collect feedback on program design from OSI and Finance	Complete	Sep - Oct 2019																	
Revise tax or program parameters based on feedback	Complete	Nov - Dec 2019	In final report																
DELIVERABLES																			
Develop final deliverables for submission to client	Complete	Jan - Apr 2020	FAQs, instructions, fund application															★	
Write and submit final report to school and client	Complete	Jan - Apr 2020	Final report															★	
LAUNCH PROGRAM - RECOMMENDED ACTIONS																			
Develop instructions for including carbon price & guiding questions	Complete	Feb - Apr 2020	FAQs															★	
Calculate each department's starting internal carbon fee based on their energy bill usage and fleet fuel usage	Complete	Feb - Apr 2020																	
Propose list of suggested spending strategies for internal service fund	Complete	Feb - Apr 2020	In final report																
Propose pilot study/inaugural program to City Administrator and City Council	Not started	FY 2021																	
Create an internal service fund to collect fees from pilot departments	Not started	FY 2021																	
Deploy communication and education materials to inform employees of new price of carbon and program (see below)	Not started	FY 2021																	
Organize meeting with heads of affected departments to share details of the new program, answer questions, and discuss impacts and implications of internal carbon fee	Not started	FY 2021																	
Facilitate follow-up meeting with departments to collect their feedback on experience and engagement with program	Not started	FY 2022																	
Revise price level or program based on employee feedback and results on revenue, emissions reductions	Not started	FY 2022																	
Begin spending carbon price revenue funds	Not started	FY 2022																	
Partner with DTE to automate energy bills and allow for more accurate carbon fee calculation and efficient billing	Not started	FY 2022																	
Scale program and raising price level or expanding coverage	Not started	FY 2022																	
COMMUNICATIONS PLAN - RECOMMENDED ACTIONS																			
Research messaging and communications tools	Not started	FY 2021																	
Meet with A2 communications staff to discuss messaging materials	Not started	FY 2021																	
Create communications plan or toolkit for educating staff	Not started	FY 2021																	
Create and send out monthly energy reports to inform employees	Not started	FY 2021																	
Review communications/education materials with departments in focus group carbo	Not started	FY 2021																	
Revise communications plan based on feedback from employees and communications team	Not started	FY 2021																	
Develop a case study documenting work and results	Not started	FY 2021																	

Appendix F: List of Carbon Price Matrices References

Carbon Fee Matrix

Yale
Source 1
Yale Carbon Charge. (n.d.). Retrieved April 25, 2020, from https://carbon.yale.edu/project-overview

Source 2
Gillingham, K., Carattini, S., & Etsy, D. (2017, October 31). Lessons from first campus carbon-pricing scheme. Retrieved April 25, 2020, from https://www.nature.com/news/lessons-from-first-campus-carbon-pricing-scheme-1.22919

Washington State
Source 1
Washington Initiative 1631, Carbon Emissions Fee Measure (2018). (n.d.). Retrieved April 25, 2020, from https://ballotpedia.org/Washington_Initiative_1631,_Carbon_Emissions_Fee_Measure_(2018)

Source 2
Roberts, D. (2018, September 28). Washington votes no on a carbon tax - again. Retrieved April 25, 2020, from https://www.vox.com/energy-and-environment/2018/9/28/17899804/washington-1631-results-carbon-fee-green-new-deal

Mahindra and Mahindra
Source 1
What happens when one of India's biggest companies adopts an internal carbon price. (n.d.). Retrieved April 25, 2020, from https://cbey.yale.edu/our-stories/what-happens-when-one-of-india’s-biggest-companies-adopts-an-internal-carbon-price

Boulder, CO
Source 1
Arostegui, D., Brinks, R., Callihan, R., Louis-Prescott, L., & Mechak, L. (2018). *Recommendations for Implementing a Carbon Tax in Boulder, Colorado*. Nicholas School of the Environment of Duke University. Retrieved from https://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/16588/MP%20Report%20Draft_Revised.pdf?sequence=1&isAllowed=y

Source 2

City of Boulder, Colorado, CAP TAX. (n.d.). Retrieved April 25, 2020, from https://bouldercolorado.gov/climate/climate-action-plan-cap-tax

British Columbia
Source 1

British Columbia's Carbon Tax. (n.d.). Retrieved April 25, 2020, from https://www2.gov.bc.ca/gov/content/environment/climate-change/planning-and-action/carbon-tax

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Lindsay, B. (2019, April 4). How B.C. brought in Canada's 1st carbon tax and avoided economic disaster. *CBC News Network*. Retrieved from https://www.cbc.ca/news/canada/british-columbia/carbon-tax-bc-1.5083734

Shadow Price Appendix

European Bank for Reconstruction and Development (EBRD)

Source 1
European Bank for Reconstruction and Development. (2019). *Methodology for the economic assessment of Ebrd projects with high greenhouse gas emissions*. Retrieved from https://www.ebrd.com/news/publications/institutional-documents/methodology-for-the-economic-assessment-of-ebrd-projects-with-high-greenhouse-gasemissions.html

Source 2
Peszko, G. (2013). Appraising transformational impact of Ebrd projects on the low carbon economy and use of shadow price of carbon. European Bank for Reconstruction and Development. Retrieved from https://ec.europa.eu/clima/sites/clima/files/docs/0072/1_4_en.pdf

City of Vancouver

Source 1
City of Vancouver, British Columbia, Canada. (n.d.). Internal Corporate Carbon Pricing Policy. Retrieved from https://policy.vancouver.ca/ADMIN019.pdf

Source 2
Smith, D. (2017). Metro Vancouver's Proposed Carbon Pricing Policy. Sustainability Group, City of Vancouver. Retrieved from https://vancouver.ca/files/cov/2017-06-21-carbon-pricing.pdf

Source 3
Targets and Actions, City of Vancouver. (n.d.). Retrieved April 25, 2020, from https://vancouver.ca/green-vancouver/goals-and-target.aspx

Source 4
Canadian Urban Sustainability Practitioners. (2019, April 14). *Internal Carbon Pricing - City of Vancouver* [Video file]. Retrieved from https://www.youtube.com/watch?v=OuUynLfsW24

Minnesota Public Utilities Commission

Source 1
State of Minnesota, Office of Administrative Hearings. (n.d.). *Environmental and Socioeconomic Costs Carbon Report*. Retrieved from https://mn.gov/oah/assets/2500-31888-environmental-socioeconomic-costs-carbon-report_tcm19-222628.pdf

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Minnesota Large Industrial Group. (2018). *Minnesota Large Industrial Group's Petition for Reconsideration*. Retrieved from https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={C0CD2461-0000-C61A-A6FC-4D0280326B1C}&documentTitle=20181-139243-01

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Shell
Source 1
Bhan Ahluwalia, M. (2017). *The Business of Pricing Carbon: How Companies are Pricing Carbon to Mitigate Risks and Prepare for a Low Carbon Future*. Center for Climate and Energy Solutions. Retrieved from https://www.c2es.org/site/assets/uploads/2017/09/business-pricing-carbon.pdf

Source 2
Gillespie, A. (2016). *Shell's Experience in Developing and Applying an Internal CO2 Project Screening Value*. Royal Dutch Shell. Retrieved from https://unfccc.int/files/focus/mitigation/technical_expert_meetings/application/pdf/04_shell_angus.pdf

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Our Carbon Pricing Principles. (n.d.). Retrieved April 25, 2020, from https://www.bp.com/en/global/corporate/sustainability/climate-change/our-role-in-advancing-the-energy-transition/carbon-pricing/our-carbon-pricing-principles.html

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Nikolova, A., & Laemel, R. (2016, August 12). The Business Case for Carbon Pricing. Retrieved April 25, 2020, from https://cbey.yale.edu/our-stories/the-business-case-for-carbon-pricing

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Hybrid Carbon Fee Shadow Price Program Matrix

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Carbon Charge Fund. (n.d.). Retrieved April 25, 2020, from https://www.swarthmore.edu/sustainability/carbon-charge-fund

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Graf, N., & Winslade, A. (2018). *Case Study: Carbon Charge Program*. Swarthmore College. Retrieved from https://secondnature.org/wp-content/uploads/SWARTHMORE-Case-Study-Carbon-Charge-Program.pdf

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