EXPLORING CARBON PRICING FOR THE CITY OF TORONTO PROJECTS AND INITIATIVES

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The concept of carbon pricing is frequently misunderstood, so it is our first goal to ensure that we all have a common understanding of some key terminology. The key terms that need to be defined are "Social Cost of Carbon," (SCC) "carbon pricing," "shadow pricing," and "carbon tax." The SCC is essential for understanding shadow pricing; and carbon pricing is, practically speaking, a synonym of shadow pricing. None of the former three concepts are explicitly connected to the concept of a carbon tax.

Social Cost of Carbon (SCC)

The essential idea behind the SCC, is that when greenhouse gasses (GHGs) and smog-forming gases are emitted (or specifically carbon), there is a cost to the community which is not normally accounted for. This cost is a real monetary cost associated with the environmental damage caused by carbon emissions, often taking the form of increased healthcare costs, reduced property values, and coping with the disastrous effects of climate change.

David Pearce of the University College London defined SCC as "the estimate of the monetary value of world-wide damage done by anthropogenic CO_2 emissions," and "the monetary value of the damage done by emitting one more tonne of carbon at some point of time." He further adds:

> *The usual time reference is the current period, but the resulting 'marginal damage cost' can be expected to rise for future emissions owing to the fact that greenhouse gases cumulate in the atmosphere. Damage is a function of the cumulated stock, so one extra tonne in the future will have a higher associated damage than an extra tonne released now. Additionally, as incomes grow, so the monetary value of damage is likely to grow, owing to an associated higher willingness to pay to avoid warming damage.*[1]

William D. Nordhaus of Yale University offers a more concise definition, describing the SCC as such: SCC "designates the economic cost caused by an additional ton of carbon dioxide emissions (or more succinctly carbon) or its equivalent. […] It is the change in the discounted value of the utility of consumption per unit of additional emissions, denominated in terms of current consumption."[2]

These definitions point to the key economic factor involved in the SCC. For corporations and governments that must make decisions based on budgets and cost-benefit analyses, the SCC is a helpful metric for making better-informed decisions. The SCC is a theoretic price which results from the emission of carbon.

One might be tempted to say that the most desirable carbon emissions level is zero, and therefore we should always adopt whichever policy leads to the lowest level of emissions humanly possible.

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[1] D. Pearce, "The Social Cost of Carbon and Its Policy Implications," *Oxford Review of Economic Policy* 19, no. 3 (September 1, 2003): 363, https://doi.org/10.1093/oxrep/19.3.362.

[2] William D. Nordhaus, "Estimates of the Social Cost of Carbon: Concepts and Results from the DICE-2013R Model and Alternative Approaches," *Journal of the Association of Environmental and Resource Economists* 1, no. 1/2 (March 2014): 273, https://doi.org/10.1086/676035.

However, as Pearce writes, it is “rarely zero […] because reducing pollution is not costless. It makes sense to reduce pollution so long as the benefit of doing so exceeds the costs. But as soon as a further incremental (‘marginal’) reduction in pollution incurs greater costs than benefits, that is the time to declare the policy measures optimal and not go any further.”[3] With enough money, one could bring the emissions of virtually any project to zero or close to it, but if we invested all our resources into a single project we would not have any left over for future projects.

Environmental degradation leads to increased scarcity of primary natural resources, which in turn leads to a general increase in the cost of goods, which results in an average decrease in Gross World Product (GWP), affecting everyone on Earth to some extent, especially those who are poorest and least tolerant of economic loss. This is the point where we incur a SCC.

We can divide SCC contributors into two types—greenhouse gases and smog-forming emissions—and two main categories: normal and catastrophic. In the first category, Nordhaus identifies average surface temperature as being the key indicator of social cost, because such temperature increases cause events such as “precipitation, water levels, extremes of drought or freezes, and thresholds like the freezing point or the level of dikes and levees.”[4] He divides these impacts into four general areas for the purposes of developing a SCC estimation model:

- agriculture: a general decline in agricultural production results from increased temperatures, thus increasing the cost of agricultural goods,
- energy: the cost of producing energy rises, and the demand for energy rises, leading to increased prices,
- sea-level rise: threatens the productivity of any industry which takes place near a coast, and requires expenditures on maintaining and repairing infrastructure affected by coastal erosion, and
- *other*: includes sectors such as “manufacturing, services, mining, etc.” and nonmarket areas such as “ecosystem effects, gardening, amenities, etc.” which are also believed to be hampered by increasing surface temperatures.[5]

The second category, that of catastrophic events related to climate change, is described by Martin L. Weitzman of Harvard University as “the probability of a disastrous collapse of planetary welfare is nonnegligible, even if this tiny probability is not objectively knowable,” and he attempts to establish a model for assessing “high-impact, low-probability catastrophes.”[6]

[3] Pearce, “The Social Cost of Carbon and Its Policy Implications,” 363.
[4] William D. Nordhaus, *Managing the Global Commons: The Economics of Climate Change* (Cambridge, Mass: MIT Press, 1994), 50.
[5] Nordhaus, 52–53.
[6] Martin L Weitzman, “On Modeling and Interpreting the Economics of Catastrophic Climate Change,” *Review of Economics and Statistics* 91, no. 1 (February 2009): 1, https://doi.org/10.1162/rest.91.1.1.

While many of these risks seem like they would primarily affect rural areas, as Harriet Bulkeley of Durham University has pointed out, cities face a special set of challenges related to climate change. “Climate change,” she writes, “will add stress to urban areas that are already under pressure from the effects of, for example, population growth, ill health, urban expansion, inadequate services, decaying infrastructure or persistent poverty.”[7] She specifies some of these climate change-related risks include “sea-level rise, increased incidence of severe weather, changes in rainfall patterns leading to periods of flooding and drought, and increased temperatures and temperature extremes.” She also mentions “extreme events (e.g. wind-storms, floods, heat extremes and droughts),” “health,” and “energy use.”[8]

Of particular importance to the City of Toronto would be the categories of extreme events, health, energy use, and water availability. Bulkeley gives some examples of direct and indirect impacts on cities in various climate change scenarios (see table 1).

In summary, then, the SCC is an important metric for understanding the economic impact of climate change, and although it is difficult to accurately predict, it is ultimately a real cost that everyone will eventually have to pay for, and the cost to cities like Toronto will be significant.

Carbon Pricing and Shadow Pricing

Carbon pricing and shadow pricing are, essentially, a practical extension of the SCC, used to account for a projected SCC in planning decisions. The two terms appear to be used virtually interchangeably in the literature, and in this paper, unless otherwise specified, the two terms are used synonymously. However, we will briefly discuss the distinction between these terms.

According to the New Palgrave Dictionary of Economics, we can generally think of there being two types of prices: market prices and shadow prices. A market price is what a business or government would typically use “for costing inputs and for valuing sales,” and these are hard dollar values which are set by a market. Shadow prices, on the other hand, are prices which “reflect social costs and social benefits, in order to calculate what might be termed social profit.” These vary “depend[ing] on the government’s objective function and on the constraints it faces” and “should be such that the social profit from the project is positive if and only if the project increases the value of the government’s objective function.”[9] The author notes that one benefit of shadow pricing is that “local project evaluators are better equipped to analyse the physical consequences of a project, and this localized knowledge should be used in conjunction with centrally determined shadow prices to evaluate the social profitability of projects.”[10]

[7] Harriet Bulkeley, *Cities and Climate Change*, Routledge Critical Introductions to Urbanism and the City (London: Routledge, 2013), 18.
[8] Bulkeley, 20.
[9] Ravi Kanbur, “Shadow Pricing,” in *The New Palgrave Dictionary of Economics*, ed. Palgrave Macmillan (London: Palgrave Macmillan UK, 2008), 1, https://doi.org/10.1057/978-1-349-95121-5_1314-2.
[10] Kanbur, 2.

We could also think of shadow pricing as allowing us to consider externalities. One particular externality, or shadow price, is the SCC. Thus, we can say that carbon pricing is shadow pricing, as used when accounting for the SCC in planning decisions. The basic idea behind carbon pricing, is to add a value that represents the SCC to a planning document whenever one studies the feasibility of a government project. This can be used in two ways: either (a) when deciding between alternative new constructions or purchases, to demonstrate that an option that may initially appear cheaper, is actually more expensive due to the SCC; or (b) when deciding whether or not to invest in a retrofit or reconstruction which would result in reduced carbon emissions, to determine whether or not the total social cost of the carbon being reduced, outweighs the upfront cost of the project.

To illustrate the first case, let us take the example of a new vehicle fleet purchase. Let us say that there are two vehicles under considering: the diesel vehicle would cost $\$x$ and the electric vehicle would cost $\$x'$. Let the estimated price of carbon be $\$y$ per tonne. The projected total carbon emissions of the diesel vehicle are *z* and for the EV are zero. In this case, we would choose the EV over the diesel if and only if, $z(\$y) \geq \$x' - \$x$. In other words, if the cost of the carbon emitted by the diesel vehicle is greater than or equal to the difference between the purchase prices of the two options.

In the second case, we could think of the example of retrofitting a building to be more energy efficient. In this case, instead of choosing between two possible purchases, we are choosing between undertaking a project or not undertaking it, so we are only comparing the cost of the project itself against the projected carbon emissions savings that would result from it. Let us say that $\$x$ is the cost of the project, $\$y$ the carbon price, and z' the estimated **reduction** in carbon emissions that would result from undertaking the retrofit. In this instance, we could say that the project will be undertaken, if and only if $z'(\$y) \geq \$x$. In other words, if the cost associated with the reduction in carbon emissions is greater than or equal to the cost of the project.

In the case of Toronto specifically, budgeting standards require that a project of the nature described in this paper, would need to be paid for within twenty years. This does not change the basic equations listed above, but sets a certain limit around the carbon price calculation. Rather than looking at carbon emissions over the entire life of the vehicle, infrastructure, or property, we would look at the projected costs and emissions over a period of twenty years.

Carbon tax

We must briefly address the term *carbon tax*, only to clarify that a carbon price is *not* a carbon tax. A carbon tax would be an additional fee charged to carbon emitters within the jurisdiction of a body with taxation authority, such as a province or country. Carbon pricing, however, is an internal accounting practice, which helps determine the allocation of an existing budget.

Models for Determining the Social Cost of Carbon

Several models (also known as integrated assessment models (IAMs)) have emerged in the literature for calculating the shadow price, based on the damages component of the SCC. Three of the most prominent are the Policy Analysis of the Greenhouse Effect (PAGE) model, the Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) model, and the Dynamic Integrated Climate and Economy (DICE) model.

The PAGE model is characterized by dividing damages into three categories—"economic, noneconomic, and catastrophic"—and calculating them as a fraction of GDP.[11] The FUND model is noted for calculating damages "separately for eight different market and nonmarket sectors: agriculture, forestry, water, energy, sea level rise, ecosystems, human health, and extreme weather."[12] The DICE model is used to estimate the effect of climate change on "consumption and investment," and "changes in production of market and nonmarket goods and services." It "includes the expected value of damages with low-probability, high-impact 'catastrophic' climate change."[13]

All three of these models may have a certain utility, but for the purposes of this paper we will rely on the DICE model. These models are open source and theoretically available for anyone to use, but they would require the skills of an economist to properly utilize. The DICE model is advantageous, since the results of that model have been published much more recently than the other two, giving us the most up-to-date estimates possible.

Calculating the Social Cost of Carbon

The SCC, by its nature, is difficult to calculate precisely. The literature gives prices as ranges, based on the level of acceptable risk. On the lower end of the risk scale, we are looking at costs which are high probability-low impact. On the high end of the risk scale, we are looking at costs which are low probability-high impact. An example of a high probability-low impact risk could be something which is almost guaranteed, such as the continued rise in average surface temperature of the Earth, which directly results in increased energy costs. An example of a low probability-high impact event would be an extreme weather event brought on by climate change which results in massive injuries and infrastructure damage. The estimate can also vary depending on the likelihood of carbon-limiting actions being taken, since as more carbon is emitted, the cost per tonne increases. Roughly speaking the DICE model proposes a carbon price of anywhere between US$36 and US$134 (CA$45-$168), rising to US$91-$334 (CA$114-$420) by the year 2050.[14]

[11] M. Greenstone, E. Kopits, and A. Wolverton, "Developing a Social Cost of Carbon for US Regulatory Analysis: A Methodology and Interpretation," *Review of Environmental Economics and Policy* 7, no. 1 (January 1, 2013): 25–26, https://doi.org/10.1093/reep/res015.
[12] Greenstone, Kopits, and Wolverton, 26.
[13] Greenstone, Kopits, and Wolverton, 26.
[14] William D. Nordhaus, "DICE-2016R Model," October 9, 2017, https://sites.google.com/site/williamdnordhaus/dice-rice.

Methodologies

The methodologies to determine the level of appropriate carbon pricing for the City of Toronto's projects are mainly consisted of three components, namely literature reviews, jurisdictional scans and project example analysis.

Firstly, literature reviews were conducted to help determine how to price carbon. This included doing multiple academic reviews, as there are numerous literatures on SCC and marginal abatement cost (MAC) of carbon, and we wanted to draw information from these literatures to reflect on our analysis. Government reports were also extremely important in determining appropriate method and level of shadow pricing, particularly the Environment and Climate Change Canada (ECCC)'s Social Cost of Carbon (SCC) model.

Second, we have conducted jurisdictional scans to determine standard practices, and the appropriate level of carbon price for City of Toronto. We have strived to look mainly into the public sector examples, as well as some private sector examples to see how City of Toronto can best determine the appropriate level of Carbon Pricing for its projects and initiatives.

For the analysis, we have looked at the carbon pricing policies in the jurisdictions of:

1) Metro Vancouver Regional District (MVRD)'s Carbon Price Policy for Metro Vancouver Projects and Initiatives
2) New York City (NYC)'s Social Cost of Carbon for Geothermal Systems
3) Canadian Corporate Practices (CDP), CN railways in particular. (Practice for CN railways was selected because of its well-established carbon pricing policy and perceived relevance with the public sector)

And finally, we have conducted project example analysis to observe the impact of shadow price. We have utilized the existing financial model used by the City of Toronto's Environment and Energy Division (EED)'s engineering team to observe the impact of the proposed level of shadow pricing. To realize this, we probed into the case of Geothermal installation on **Waterfront Neighbourhood Centre Project**. City of Toronto has previously conducted a feasibility study on Geothermal retrofit on this facility, and the modified the financial model included carbon savings realized with the inclusion of carbon pricing to see how much financial impact the implementation of carbon price brings to the project and whether the inclusion of carbon price could actually make differences in decision making.

We will discuss the findings from the different components of the methodologies in details in the following sections.

Environment and Climate Change Canada (ECCC)'s assessment of Social Cost of Carbon (SCC)

Next, we will look at the ECCC's assessment of SCC as it provides valuable guidance to set the City's carbon pricing level, and it is also important to align City of Toronto's carbon pricing initiative with a federal framework.

In 2010 and 2011, ECCC led an interdepartmental review of approaches to value GHG emissions, from which the adoption of SCC values was recommended[16]. SCC values presented in the publication were based on research and analysis conducted by U.S Interagency Working Group on Social Cost of Carbon 2010[17]. ECCC bases its SCC estimates on the U.S Interagency Working Group's research, as they adopt internationally accepted methodology to estimate the level of SCCs. SCC estimates are significant, as they can help value CO2 emission changes in cost-benefit analysis where the goal is to provide informed analysis to the decision makers, through which the incremental climate change mitigation benefits associated with a policy action can be quantified[18].

Canadian Social Cost of Carbon (SCC) Estimates for Period 2010 – 2050 (in C$ 2012, discounted at 3%)[15]

Year	Central	95th Percentile
2010	34.1	131.5
2013	37.4	149.3
2015	39.6	161.1
2016	40.7	167.0
2020	**45.1**	**190.7**
2025	49.8	213.3
2030	54.5	235.8
2035	59.6	258.9
2040	64.7	281.9
2045	69.7	300.9
2050	74.8	319.8

Table 1. ECCC's SCC Estimates for 2010 – 2050 (Updated)

In May 2013, U.S Interagency Working Group has released the technical update documents with new SCC estimates, to reflect the changes in the Integrated Assessment Models (IAMs) over the past years. For example, Dynamic Integrated Climate-Economy (DICE) model was modified to better reflect actual sea-level variation, Climate Framework for Uncertainty, Negotiation and Distribution (FUND) model included more detail in land loss potential from sea-level rise and Policy Analysis of the Greenhouse Effect (PAGE) model included damage functions constrained by GDP, which made the SCC estimates more realistic.[19]

In 2016, following the update on U.S estimate and the technical corrections, Following the update on U.S estimate and the technical corrections.[20] In its estimate, ECCC laid out the estimates of SCC over the course of 40 years, from 2010 to 2050. The projected increases in SCC ranges from $34.1 (2010)

[16] Environment and Climate Change Canada, "Technical Update to Environment and Climate Change Canada's Social Cost of Greenhouse Gas Estimates", March 2016, 3, http://ec.gc.ca/cc/default.asp?lang=En&n=BE705779-1#SCC-Sec1
[17] Ibid.
[18] Ibid.
[19] Environment and Climate Change Canada, "Technical Update to Environment and Climate Change Canada's Social Cost of Greenhouse Gas Estimates", March 2016, 4, http://ec.gc.ca/cc/default.asp?lang=En&n=BE705779-1#SCC-Sec1
[20] Ibid, 6.

to $74.8 (2050) for the central estimate (lower bound, average central tendency estimate of the three models – DICE, PAGE, FUND - considered in U.S. SCC estimation), and from $131.5 (2010) to $319.8 (2050) for 95th percentile (upper-bound, high-cost, low-probability climate change impacts) For the year of 2020 (which includes the current year 2018), the central estimate is $45.1, and 95th percentile is $190.7. Detailed breakdown of the SCC estimates from 2010 – 2050 is demonstrated in the figure 1.

The aforementioned ranges of federal SCC estimates will be considered in determining the appropriate level of City of Toronto's carbon pricing for the further analysis.

Jurisdictional Scan

Case: 1. *Metro Vancouver Regional District (MVRD)*

First case for the jurisdictional scan is Metro Vancouver Regional District Board (MVRD)'s "Carbon Price Policy for Metro Vancouver Projects and Initiatives"[22]. MVRD's example is extremely important in designing City of Toronto's internal carbon pricing policy, because not only it is one of the few public-sector examples, but also MVRD is one of the pioneering Canadian municipalities that began incorporating carbon pricing into its decision making, and therefore is relevant in the Canadian Context.

MVRD had first planned on adopting mechanisms to capture carbon savings/costs into its decision making in as early as 2010, as stipulated in its 2010 Corporate Climate Action plan.[23] Nonetheless, there were not enough understanding and incentives at the time, and thus, this initiative did not materialize. The discussion for the policy re-gained momentum in 2016, with the ratification of Paris Agreement and the subsequent establishment of climate goals for Canadian provinces and municipalities. For Metro Vancouver, the goal is to achieve 80% of GHG reductions by 2050 (compared to 2010 level)[24]. Internal carbon price policy was approved by the MVRD board on June 2017 as a strategic tool to help MVRD achieve its climate goal[25].

MVRD has decided on $150/tonne CO2e as the upper limit for the internal carbon price that it would be willing to pay as a shadow price to account for the cost of GHG emissions[26]. This $150/tonne CO2e would include B.C.'s already existing Carbon Tax of $30, which denotes that up to $120/tonne CO2e of incremental Metro Vancouver Carbon Price will be levied for Life Cycle

[22] Metro Vancouver Regional District, Board Meeting Agenda June 23, 2017, 13, http://www.metrovancouver.org/boards/GVRD/RD_2017-Jun-23_AGE-Revised.pdf
[23] Metro Vancouver, Corporate Climate Action Plan, June 16, 2010, 16, http://www.metrovancouver.org/services/air-quality/AirQualityPublications/CorporateClimateActionPlan.pdf
[24] Metro Vancouver Regional District, Board Meeting Agenda June 23, 2017, 25, http://www.metrovancouver.org/boards/GVRD/RD_2017-Jun-23_AGE-Revised.pdf
[25] Metro Vancouver, Metro Vancouver Update." July 2017. http://www.metrovancouver.org/metroupdate/issue-34/493/Internal Carbon Price Policy to reduce corporate emissions
[26] Metro Vancouver Regional District, Board Meeting Agenda June 23, 2017, 20, http://www.metrovancouver.org/boards/GVRD/RD_2017-Jun-23_AGE-Revised.pdf

Costs Analysis for the City-owned projects[27]. This incremental \$120/tonne CO_2e is to be the maximum amount of price the MVRD can add for its decision-making purposes, which indicates that most of its design and procurement decisions will involve lower figures. The details of how much carbon price will be added on for the alternatives that involve lower GHG emissions are not decided yet, and MVRD is still in the process of determining the suitable level of carbon price for such alternatives.

Aside from the regular board meeting agendas that discussed the approval of internal carbon pricing policy, it was difficult to uncover what kind of impacts this policy brought in MVRD decision making process, and what has been the overall experience like for MVRD over the last couple of months? We were fortunate to have a conference call with **Mr. Conor Reynolds,** the Program Manager for Air Quality and Climate Change Policy. He helped us to better understand the process of policy implementation and provided insights on the questions we previously had.

The major findings from the conference call are as follows.

1) Spillover effect

As MVRD instituted the \$150/tonne carbon pricing, this created tangible spillover effects. Other member cities in MVRD have also began to consider carbon pricing. For example, City of New Westminster conducted a feasibility study to implement internal carbon pricing policy and is currently looking at the similar level (\$150) of carbon price as MVRD[28]. City of Vancouver is looking to institute more ambitious target of \$200/tonne[29]. So far, there are two municipalities in B.C that have explicitly expressed intention to use their own version of internal carbon price policy, but more municipalities are expected to be onboard once the practice is established and the track records are generated to communicate benefits of carbon price policy.

2) Feasibility studies / Application

Since the implementation of internal carbon price policy, MVRD has included this figure in numerous feasibility studies or analyses. In this section, two distinct examples will be shared. One example is when the inclusion of internal carbon price made significant impact to change the decision; the other is when the inclusion of internal carbon price did not have much impact, and the final decision did not change.

YES: Major rebuild of liquid wastewater facility

MVRD was looking to rebuild a liquid wastewater facility, and Metro Vancouver hired consultants to conduct analysis and give recommendations. The project manager provided carbon price to the

[27] Ibid.

[28] City of New Westminster, 'Updated Corporate Energy and Emissions Reduction Strategy – Proposed Vision, Goals and Evaluation Criteria', March 5, 2018, 65. http://newwestcity.ca.granicus.com/DocumentViewer.php?file=newwestcity_e50e217250e3dba99abd1a34e17e7616.pdf&view=1

[29] City of Vancouver, Corporate Carbon Pricing Policy: Discussion Paper, March 2018, 5.

consultants to be considered, and it was included in the life-cycle and cost-benefit analysis. The consultants have found that the inclusion of the carbon price into the analysis would make significant impact on the final decision, and low-carbon option should be considered for rebuilding the liquid wastewater facility[30]. We were not able to verify the details outlining the different options and the actual progress of this project.

NO: Building a second intake to water reservoir in Coquitlam Lake

MVRD was looking to build a second intake to water reservoir in Coquitlam Lake. They were contemplating on where and how to build this intake and were exploring different options. The engineering team included carbon price in the valuation and analysis and found that the emissions from the construction would be similar, regardless of the which option they pursued, and in this scenario, the inclusion of carbon price did not have significant impact on decision, and the final decision did not change[31].

An interesting point raised during the discussion was that among the cases that MV encountered after putting the internal carbon price policy into place, 90%~95% of the time, the final decision would not change because the NPV of the project after considering the long-term benefits from implementing the carbon price was not great enough to justify the more costly, low-carbon option. However, for the remaining 5% or 10% of the time, decision may change if the NPV of the after considering the long-term benefits derived from using carbon price were comparable with the conventional options, while realizing significant reduction in carbon emission[32].

Then there is a question of 'what is the significance of internal carbon price if the decisions stand more or less the same most of the time, even with the inclusion of this number?'. In MVRD's case, it was still important to use carbon price, as a tool to communicate decisions in a transparent manner, as well as to provide sound rationale for the decisions made.

Case: 2. *New York City (NYC) - Social Cost of Carbon (SCC) for Geothermal Systems*

Another noteworthy case for gaining insights in designing City of Toronto's Carbon Pricing for the projects and initiatives would be the New York City's SCC for geothermal systems model. In January 2015, a bill for the 'A Local Law to amend the administrative code of the City of New York, in relation to geothermal systems' was first introduced as the part of legislation to promote the use of geothermal systems in the city-owned facilities throughout the city, which is an energy-efficient form of cooling and heating buildings compared to the conventional system[33].

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[30] Conor, Reynolds (Program Manager for Air Quality and Climate Change Policy, MVRD), interviewed by Jeremy Andrews and Edward Kim, March 27, 2018, Vancouver, B.C.

[31] Conor, Reynolds (Program Manager for Air Quality and Climate Change Policy, MVRD), interviewed by Jeremy Andrews and Edward Kim, March 27, 2018, Vancouver, B.C.

[32] Ibid.

[33] The New York City Council, Int 0609-2015 -Legislation Details (With Text), July 2015, 1.

In the 2015 report 'Geothermal Systems and their Application in New York City'. the Mayor's Office of Sustainability called on more buildings in New York to consider geothermal power, highlighting that geothermal systems can achieve significant overall energy savings of around 25% to 30% when compared to conventional options like furnaces and natural gas fueled boilers[34]. NYC's Geothermal SCC estimates have been implemented for the new construction of city-owned buildings and the retrofitting of city-owned buildings' heating & cooling systems that are commissioned after February 1, 2017[35]. There are already a handful of city-managed facilities that uses geothermal heating and cooling system, including the Queens Botanical Garden, the Brooklyn Children's Museum and the Lion House at the Bronx Zoo[36].

From the NYC's case of geothermal studies, numerous takeaways for the City of Toronto can be found in the City council's report. Some of the main findings from the report are:

- If portions of the existing heating and cooling system (i.e. space heating equipment, ductwork …) could be utilized in the Ground Heat Pump (GHP), the capital cost necessary for the geothermal retrofit is expected to be lower[37]
- When assessing the feasibility of the project, the initial capital expenditures should be compared with the project's long-term energy savings potential as well as the associated operations and maintenance costs over time[38].
- Recently purchased equipment with relatively high efficiency is outside the scope of discussion. It is simply not economically sound to do so, and there are more potential for savings to be realized when the older, less-efficient equipment with approximately 10 -20 years old are replaced[39].

The New York City council has determined progressively increasing SCCs for geothermal projects starting from 2017, and we have listed the numbers in the table 2 below, with the reference to Canadian dollars, according to the stipulated conversion rate.

The social cost of carbon (SCC) values stipulated in the NYC Council's Legislative document are:

Year	Dollar Value per Metric Ton of CO2 Equivalent (in USD)	Dollar Value per Metric Ton of CO2 Equivalent (in CAD)
2017	128	165
2018	132	170

[34] The City of New York, Geothermal Systems and their application in New York City, February 2015, 4, http://www.nyc.gov/html/planyc/downloads/pdf/publications/2015_Geothermal.pdf
[35] The New York City Council, Int 0609-2015 -Legislation Details (With Text), July 2015, 2.
[36] Otterman, Sharon. "The New, Green Pride of St. Patrick's Cathedral Is Underground." The New York Times. March 14, 2018. https://www.nytimes.com/2018/03/14/nyregion/st-patricks-cathedral-geothermal.html.
[37] The City of New York, Geothermal Systems and their application in New York City, February 2015, 4, http://www.nyc.gov/html/planyc/downloads/pdf/publications/2015_Geothermal.pdf
[38] Ibid.
[39] Ibid.

2019	136	175
2020	140	180
2021	142	183

Table 2: NYC's SCC values for Geothermal Systems[40]

***Converted using XE Converter, exchange rate on April 3, 2018. All figures are rounded off**

Along with the ECCC's SCC estimate and the MVRD's internal carbon price, NYC's SCC for geothermal systems will also be taken into consideration in determining the internal carbon price for City of Toronto.

Case: 3. Canadian National Railway Company (CN)

We decided to take CN as a case study, in order to gain a better understanding of private sector practices with regards to carbon pricing. The company has released a *Carbon Disclosure Project* (CDP) report for the last few years now. In 2016 they reported not having any internal carbon pricing program,[41] and in 2017 they reported using one for the first time, giving a range of $16-$30 per tonne.[42] The same figure, converted to US dollars, is noted in the official CDP report.[43]

According to the most recent report, the company's "Supply Management Department" uses an internal carbon price "to inform fuel-related procurement decisions, by [their] sales and marketing department to price transportation and logistics services for the customer, and by [their] taxation department to comply with carbon tax payments."[44] They also report that this "will be used to drive investment decisions into fuel-efficiency and alternative cleaner energy solutions," including a decision to invest $550 million in "equipment expenditures, including 90 new high horsepower locomotives" and $5 million "in an EcoFund to support and engage employees on energy reduction projects through the EcoConnexions program."[45]

Ultimately CN is a poor example to follow due to the difference in how internal carbon pricing is applied in private corporations, versus how carbon pricing is used by governments. From CN's documents, it is clear that their primary concern is mitigating business risks that are caused by climate change. There is nothing wrong with this practice, since for them, they are considering the risk of how, for example, higher surface temperatures may reduce their agricultural customer base. However, the risks to a company versus the risks to a government responsible for a territory and permanent population are vastly different.

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[40] The New York City Council, Int 0609-2015 -Legislation Details, July 2015, 3.

[41] CN - Canadian National Railway Company, "Carbon Disclosure Project 2016," 2016, 7, https://www.cn.ca/-/media/Files/Delivering-Responsibly/Environment/CDProject-2016-en.pdf.

[42] Ibid.

[43] CDP, "Putting a Price on Carbon: Integrating Climate Risk into Business Planning," October 2017, https://b8f65cb373b1b7b15feb-c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3.rackcdn.com/cms/reports/documents/000/002/738/original/Putting-a-price-on-carbon-CDP-Report-2017.pdf?1507739326.

[44] CN - Canadian National Railway Company, "Carbon Disclosure Project 2017," 7.

[45] CN - Canadian National Railway Company, 7.

CN's price is on the low end of the risk scale provided by modelling, in contrast to governments which are typically on the higher end. We suggest therefore that it would be more prudent to follow the example of governments, considering the risk factors involved are more comparable.

Waterfront Community Centre Geothermal Project Feasibility Study

In this section, before we look at a case for which City of Toronto has already conducted a feasibility study and observe the impacts of different levels of shadow price on cost savings, debt payback period and Net Present Value (NPV), we would like to discuss the scope and the objective of this project, and how the savings will be calculated.

Waterfront Neighbourhood Centre Project, previously named as Harbourfront Community Centre, is a non-profit, city-owned facility that houses gymnasium, kid's playground, commercial kitchen and outdoor basketball court[46]. City of Toronto conducted feasibility study on this site, to determine whether doing geothermal heating and cooling system would make financial sense.

For this analysis, we utilized the existing financial analysis model used by City of Toronto's engineering team for the purpose of feasibility study, which was modified to include the shadow price. The purpose of Lake Based Ground Source Heat Pump (GSHP) project is to realize positive NPV within the project lifetime of 20 years (which is also the recoverable debt period)[47]

Currently, the Lake Based GSHP project only makes financial sense if Air-Handling Unit (AHU) schedule revision is completed simultaneously. We want to see whether doing Lake Based GSHP standalone could make sense without revising the AHU schedule.

GHG Reduction	% Reduction	Tonnes	Tonnes Saved
Current Building		209	0
Revised AHU schedules	27%	152.57	56.43
Geo on current building	**66%**	**71.06**	**137.94**
Geo & revised AHU Schedules	**70%**	**62.7**	**146.3**

Table 3. Projected GHG reductions for Waterfront Neighbourhood Centre GSHP Project[48]

This is because as shown in the table 3, GSHP when done on its own, can realize the most amount of GHG reduction, and doing revisions for AHU schedules does not add much marginal benefit in terms of reducing CO2 emission.

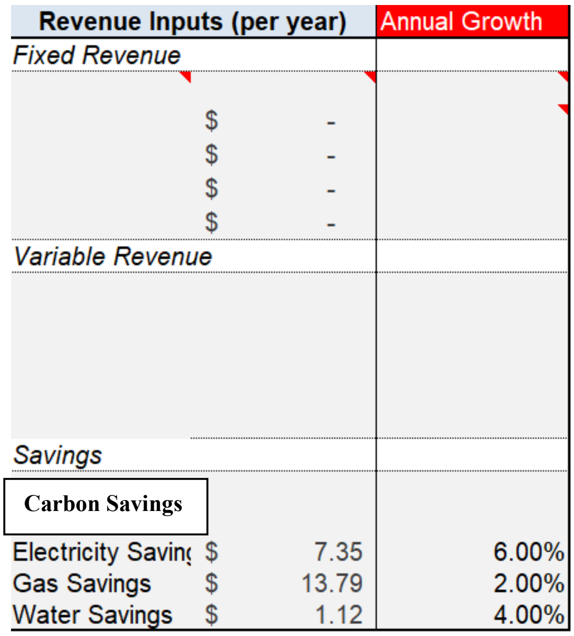
[46] Waterfront Neighbourhood Centre, 'About', http://waterfrontnc.ca/about/
[47] City of Toronto, Financial Analysis, TREO Business Case - Waterfront, EED, March 18, 2018
[48] City of Toronto, Assumptions, TREO Business Case - Waterfront, EED, March 18, 2018

	REVISED AHU SCHEDULE		Option 1 - Lake Based GSHP	
COSTS	Cost of Upgrade	$ -	Cost of Upgrade	$ 750,000
Revenue/Savings /Cost Avoidance	Electricity savings ($/Year)	$ 11,415	Electricity savings ($/Year)	$ 7,348
	Gas savings ($/Year)	$ 7,543	Gas savings ($/Year)	$ 13,794
	-		Water savings ($/Year)	$ 1,121

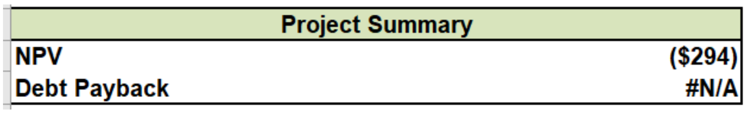
* If savings from 'revised AHU schedule' are not included, the geo system would not meet the required payback

Table 4. Projected Cost savings for GSHP and AHU option

The main idea here is to include amount of carbon savings calculated by:



Revenue Inputs (per year)		Annual Growth
Fixed Revenue		
	$ -	
	$ -	
	$ -	
	$ -	
Variable Revenue		
Savings		
Carbon Savings		
Electricity Savin(	$ 7.35	6.00%
Gas Savings	$ 13.79	2.00%
Water Savings	$ 1.12	4.00%



Project Summary	
NPV	($294)
Debt Payback	#N/A

Carbon Savings =

$$\frac{Proposed\ Shadow\ Price * Tonne\ of\ CO2\ saved}{1000\ (Units\ in\ 1000s)}$$

and then put that number into the carbon savings tab (Figure 1, Left) in order to calculate NPV and debt payback (Figure 1, Right) in the financial analysis model.

Using this model, we will move on to observe the impact of shadow pricing for the Waterfront Neighbourhood Centre GSHP Project.

Figure 1. Snapshots from the Financial model[49]

[49] City of Toronto, Financial Analysis, TREO Business Case -Waterfront, Environment and Energy Division, March 18, 2018

Impact of Shadow Pricing (Waterfront Neighbourhood Centre Project)

In order to demonstrate the effect of applying a shadow price to a city project, we have used the WNC project as an example. We have applied a range of different carbon prices to illustrate how a shadow price affects the net present value and payback period of the project. Table 5 shows the results assuming a project which combines both the geothermal retrofit and the air handling unit revision, while Table 6 shows the results if only the geothermal retrofit were to be undertaken.

Table 5: Geothermal + Revised AHU

Shadow Price (per tonne)	$0	$24	$150	$170	$190
NPV (in 1000s)	$111	$160	$420	$461	$502
Payback period (years)	17	16	12	11	11

Table 6: Geothermal only

Shadow Price (per tonne)	$0	$24	$150	$170	$190
NPV (in 1000s)	($294)	($247)	($2)	$36	$75
Payback period (years)	>20	>20	>20	19	18

We include five different possible shadow prices, each representing a different scenario:

- $0 → No shadow price (current practice)
- $24 → Typical internal carbon price used by a private corporation
- $150 → Price being used by Metro Vancouver
- $170 → Price being used by New York City
- $190 → High percentile price recommended by the Canadian government

In the tables above, any scenario that results in a payback period of over twenty years indicates a project that would be considered nonviable according to the City's budgeting standards. The real project under considering is the combined geothermal + AHU project, and this one is under considering precisely as it is considered viable. The table using geothermal only is a hypothetical example, to illustrate why many projects might never be engaged due to their failure to meet these budgetary standards. Theoretically, any city-owned facility could be converted to using geothermal heating, but would not be considered as feasible, because the city has not been taking into account the full price of the project. In this example, with an estimated shadow price of $170/tonne, we can see that the project involving only the geothermal retrofit would be viable.

Recommendations

We recommend, firstly, establishing a shadow price of **$170/tonne**. This price would be in accordance with estimates from the academic literature, as well as being in line with the practices of other cities. Even if the shadow price only makes a different in a small number of projects, it is still worth doing, because the carbon price is a cost that the city will eventually have to bear, so taking it into account from the beginning should result in better-informed decisions regarding the feasibility of various projects and procurements.

Secondly, we recommend involving key partners and stakeholders from the early stages of a project. The mindset of using a shadow price has to be something that is tackled jointly, so engaging groups such as the finance department, utility department, and engineering, could help to make the whole endeavour run more smoothly.

Thirdly, we recommend increasing the shadow price on a regular basis. As noted earlier, the shadow price rises over time, both due to inflation and due to the fact that carbon in the atmosphere is cumulative, so the cost associated with each unit of carbon rises as more carbon emissions enter the atmosphere. Establishing a regular increment based on inflation and projected SCC increase would help keep the shadow price at a level which is realistically reflective of the true price.

Lastly, we recommend reviewing the shadow price on a regular basis, about every 1-2 years. The research regarding the SCC and carbon pricing is constantly evolving, and it’s possible that the DICE model and other models will have updated results in a year or two from now.

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Appendix 1: Climate Risks and impacts for cities[50]

Climate risks	*Examples of direct impacts in cities*	*Examples of indirect impacts for cities*
Extreme events	Damage to infrastructure systems, property, livelihoods and life from wind-storms, flood events, heatwaves and droughts	Risks to economic production chains Risks to urban food supplies
Health	Physiological effects of heatwaves and cold Changes in incidence of vector-borne diseases Physical- and mental-health impacts of extreme events	Risks to wider systems of health care and support
Energy use	Changes in winter and summer energy demand Increased use of air conditioning leading to brownouts	Risks to hydro-power energy systems Increased loss of transmission as temperature increases reduce energy supply
Water availability	Reduced precipitation and groundwater recharging limits water availability Retreat of glaciers reduces urban water supplies Increased demand for water as temperatures increase Reduction in water quality as river flow decreases	Risks to economic production chains Risks to urban food supplies

[50] Excerpt from Harriet Bulkeley, Cities and Climate Change, Routledge Critical Introductions to Urbanism and the City (London: Routledge, 2013), 21.