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Measuring carbon intensity in Quebec at the city level

BRYAN CAMPBELL
Emeritus Professor
Department of Economics
Concordia University
CIRANO Researcher and Fellow

MICHEL MAGNAN
Full Professor
John Molson School of Business
Concordia University
CIRANO Researcher and Fellow

ROBERT NORMAND
Projects Director CIRANO

ELIZABETH LABONTÉ
Research Assistant, Polytechnique Montréal

LÉO LAMY-LALIBERTÉ
Research Assistant, Polytechnique Montréal

If you want to measure success in curbing carbon emissions, look no further than the world's cities. They hold the key to managing global and national climate risks (KPMG, 2022). Actions taken by municipal governments in achieving carbon neutrality can cause a significant ripple effect for both the general public and the private sector. Unfortunately, most cities cannot fulfill that potential: too few have the resources for even measuring carbon emissions. A CIRANO report (Campbell et al. 2025) proposes a tool to help with this challenge through a carbon emissions dashboard. This may just be the best tool for a municipal body looking to reduce its emissions.

Municipal services tend to generate up to 3% of a community's total emissions. However, the ability of municipal authorities to curb these emissions and work toward carbon neutrality is a challenge that touches on other jurisdictions. For example, most emissions coming from cities are the result of activities over which municipal authorities have limited control.

Despite numerous calls and requests, few cities have put in place systematic processes for measuring greenhouse gas (GHG) emissions. Many are put off by the complexity of collecting climate data and the need to set up costly systems and infrastructures. In addition, all disclosures must meet regulatory reporting and auditing requirements.

Municipalities have information on their emissions; what they don't have is the resources nor the framework to properly assess what needs to be done

Municipal budgets are rich sources of information on how much GHG is being emitted by Quebec's cities. Their line items can help determine the most appropriate measures for reducing emissions. Setting up systems to exploit this financial information could enable cities to independently measure their carbon footprint. While this seems logical for achieving a carbon-neutral society, few cities have put in place systematic processes for measuring carbon emissions, owing to a lack of resources. In order to provide municipal organizations with a simple and rigorous framework, we have developed a carbon emissions dashboard.

The dashboard allows us to estimate carbon emissions using recognized reference tools, such as the *Ecoinvent* database, which evaluates and monitors the environmental performance of products, processes and services. It does this through Life Cycle Assessment, measuring environmental impact from start to finish (Green Gas Protocol, 2021).

Most cities' carbon emissions come from heating and equipment, transportation and waste management operations

We are interested in the decisions municipal administrations make and the emissions that result from them. Using the *Greenhouse Gas Protocol* (GHGP, 2021), a key reference in this area, we focus on two types of emissions:

Scope 1 emissions result from sources directly controlled by the organization and are therefore their responsibility. At the municipal level, these would be emissions that result from fuel used by municipal vehicles, waste and residual materials, and industrial activities carried out by the town.

Scope 2 emissions result primarily from an organization's physical infrastructure (buildings) and its energy (electricity and gas) consumption. *Scope 3 emissions*, which result from the value chain, have not been included in the study due to methodological difficulties and the fact that cities have less direct control over them.

The next step in this study was to identify spending items that were both under direct control of the municipal administration and highly carbon-intensive. In addition to carbon intensity, we selected four criteria to act as filters: 1) represent day-to-day activities of the municipality; 2) recur year to year; 3) are common to towns of the same size; and 4) account for more than 1% of the operating budget.

After taking into account these filters, we consulted with key people working in municipal administrations and selected three spending categories. They were those responsible for the largest share of Scope 1 and Scope 2 carbon emissions: 1) stationary energy (e.g., for heating and operating equipment); 2) transportation (e.g., fuel consumed); and 3) waste management (e.g., waste collection and treatment, and wastewater treatment). The three spending categories that were chosen are consistent with recommendations from various international references.

We have made the assumption that subcontracting activities, such as snow clearance or waste management, are carried out by the city itself (insourced). This assumption makes it possible to compare carbon intensity activities between cities, whether or not they were outsourced or insourced.

We have excluded activities that affect an administration's emission levels but not the city's itself. This is the case with public transit: having no public transit reduces the administration's emissions, but raises overall emissions for its citizens.

There are other municipal activities that can generate significant carbon emissions, but we have not included them due to the lack of data to accurately assess their carbon impact. Examples include industrial parks and police services, for which it is difficult to find emissions indicators and to attribute impacts. In the case of police services, for example, cities fund the services but do not monitor how they're delivered.

Estimating emissions involves some methodology challenges

Understanding spending on carbon-intensive activities brings up an important methodology issue. These expenditures can fall under several categories in a financial statement. For example, many municipal services use electricity or natural gas for heating. Similarly, many municipal departments use gas-powered vehicles, not only for transport, but also for leisure activities and snow clearance. It is best to identify what is spent on heating and cooling buildings as opposed to the energy used to fuel combustion engine vehicles.

For our study, samples of invoices and additional information were gathered from the municipal accounts, allowing us to infer how the energy was divided.

A second issue involves supplier invoices for outsourced services such as snow clearance, which are often not very detailed. For instance, they rarely indicate the fuel consumption required to provide the service. We decided to consult the tender specifications and interview the people providing the service, and came out with the amounts on the invoices that represented the cost of fuel. Once we identified the typical invoices for the purchase of carbon-intensive inputs, we reconciled the data collected with reference tools such as the Ecovint database and came away with a picture of the Scope 1 and Scope 2 emissions that fell under the purview of the cities.

In terms of methodology, we looked at how to obtain reliable and comparable measurements. The *Greenhouse Gas Protocol* (GHGP, 2021) provides a set of default emission factors for business activities in specific sectors. These emission factors are averages based on detailed data sets and are identical to those used by the Intergovernmental Panel on Climate Change (IPCC). These represent specific emission factors that are consistent with *Canada's Greenhouse Gas Reporting Program* (Government of Canada, 2019).

From financial statements to greenhouse gas emissions

Through this work, we have developed a prototype dashboard that focuses on the carbon intensity of budget items. We divided this into three critical areas of sustainable development: 1) energy used to heat and cool buildings; 2) fuel for transportation and 3) the management of residual materials and wastewater treatment.

In our report (Campbell et al. 2025), we selected four Quebec cities, each representative of four categories of municipality: Trois-Rivières (100,000+ inhabitants), Victoriaville (25,000–99,999 inhabitants), Varennes (10,000–24,999 inhabitants) and Nicolet (less than 10,000 inhabitants).

This article presents the carbon intensity scorecard for municipal budget expenditures, based on our 2023 experience in Victoriaville. This detailed illustration offers insight into our methodology. For each item listed in the first column, the reported expenditure represents the total amount allocated across all relevant budget items associated with that specific municipal function. Two key parameters, the imputation key and the emission intensity factor, are central to this exercise. By annually updating the imputation key to reflect price fluctuations, the dashboard enables the tracking of year-over-year changes in GHG emissions and carbon intensity. This, in turn helps us assess over time the effectiveness of the city's GHG reduction practices.

	Expenditures	Imputation key	Effective quantity	Intensity factor: emission in kg of CO_2 equivalent	Emission in kg of CO_2 equivalent	Carbon intensity: emission in kg of CO_2 equivalent/$
	(1)	(2)	(3) = (1) ÷ (2)	(4)	(5) = (3) x (4)	(6) = (5) ÷ (1)
Stationary energy						
Natural gas	$314,546	0.15248	2,072,868	1.9/m^3	3,938,450	12.52
Electricity	$2,804,686	0.1031	27,190,320	0.14125/kWh	384,063	0.14
Total	***$3,119,232***				***4,322,513***	***1.39***
Transportation						
Diesel and gasoline	$1,435,231	1.866	769,585	2.60/liter	2,003,850	1.40
Total	***$1,435,231***				***2,003,850***	***1.40***
Residual materials and wastewater treatment						
Residual materials	$2,011,686	*imputed*	10,364,432	0.53788/kg	5,570,823	2.77
Wastewater treatment	$1,023,933	*imputed*	11,822,963	2.11E-01/m^3	2,492,517	2.43
Total	***$3,035,880***				***8,063,340***	***2.66***

Dashboard for estimating carbon intensity on a per-dollar basis, Victoriaville, 2023
Sources : Campbell et al. 2025, Energir, INRS (2023), City of Victoriaville accounting records

In the category of heating and cooling buildings (stationary energy), Victoriaville city records show that $314,546 was spent on natural gas. According to Energir, the average selling price per cubic metre of natural gas in 2023 was 15.248 cents. This figure then becomes the imputation key for natural gas expenditures. We then divided the natural gas expenditure by the imputation key and came up with the effective quantity of natural gas consumed during this period: 2,072,868 m^3.

To calculate GHG emissions resulting from that natural gas consumption, we used a set of analyses from the Institut national de la recherche scientifique (INRS). It estimates the intensity factor of natural gas consumed in Quebec at 1.9 kg of CO_2-equivalent per m^3 of natural gas (INRS, 2023). By multiplying natural gas consumption by this intensity factor, we calculate that 3,938,450 kg of CO_2-equivalent were emitted by the city's natural gas consumption in 2023. Dividing these emissions by total expenditure gives a carbon intensity of 12.52 kg of CO_2-equivalent per dollar spent.

In comparison, spending $1 on electricity generates emissions of 0.14 kg of CO_2-equivalent, well below the 12.52 for an equivalent purchase of natural gas. Here, the imputation key is a weighted average, with different uses subject to different tariffs. The imputation key takes into account the fact that some of Hydro Québec's billings are for electricity used and not just consumption in kWh. As a result, it cannot be directly transposed to other municipalities without an in-depth analysis of their electricity bills.

For transportation, the imputation key and the intensity factor are weighted according to diesel and gasoline consumption respectively. Accounting for both spending and consumption of fuel requires cross-checking across different city departments. The carbon intensity of $1 of fuel expenditure is estimated at 1.4 kg of CO_2-equivalent and is fairly consistent between cities, meaning that the model could be transposed to other cities. In other words, once the expenditure is known, we could use the dashboard parameters to arrive at province-wide estimates of emissions and carbon intensity.

Finally, in the case of residual materials (including organic materials) and wastewater treatment, the imputation keys are inferred because the expenditure (in $) and the quantity (in kg or m^3) are known. They could serve as a reference for other cities where the basic information is not available or is less reliable. Waste management and wastewater treatment are major GHG generators and have a relatively high carbon intensity. The possibility of transposing the model to other cities is based on an analysis of waste collection practices (selective, composting) and the processes used for water treatment.

Several strategic choices have a major impact on a city's emissions

Using natural gas rather than electricity to heat buildings multiplies the carbon intensity per dollar spent by almost 100. Similarly, using diesel rather than gasoline increases the carbon intensity of fuel expenditures.

Selective waste collection and composting also have a major impact on the carbon intensity of waste management, as does wastewater treatment. The latter can easily influence the estimated level of emissions by a factor of 2 to 3. A major issue underlying the estimation of emissions is the reliability of the gross quantities of treated waste and wastewater. Our estimates show variations of 1 to 6 between different cities in terms of the carbon intensity of waste management expenditures.

In addition, some municipalities have their own police force, while others use the Sûreté du Québec. Since the Sûreté du Québec covers a vast territory, it is difficult to assess the impact on total carbon emissions for a particular town. Similarly, some towns carry out their own activities, while, for others, the regional county municipality (RCM) takes care of them.

There are four factors likely to affect the reliability of carbon emission measurement: 1) the traceability of the carbon intensity of municipal activities through their financial information system; 2) the availability of carbon intensity figures when municipal activities are outsourced; 3) the conditioning or treatment applied in the management of waste, solids or wastewater; and 4) the accounting classification itself.

Resolving these issues can take different forms and requires certain assumptions and interventions. For the way forward in the medium term, it's best to use a few basic reference points rather than looking for additional details.

Three recommendations

Our work has led us to make three recommendations related to the accounting and disclosure of Scope 1 and Scope 2 emissions.

Recommendation 1: With a view to sustainable development and transparency, the amount of energy associated with service purchases should be part of the information required during calls for tender. In addition, subcontractors' invoices for transport services should be broken down by the different types of energy provided.

Recommendation 2: Again, with a view to sustainable development and transparency, city operations' financial information systems should be accompanied by additional records that reflect energy consumption and/or purchases, whether that's for buildings or vehicles. This would make it easier to estimate end-of-period carbon emissions and disclosures.

Recommendation 3: The management of residual waste and wastewater is a major source of greenhouse gas emissions. Composting, on the other hand, is a form of waste management that offers a neutral carbon impact. A more selective approach to waste management is an important consideration for any city wishing to lessen its carbon footprint.

Is it possible to adapt a GHG emissions dashboard to a wider range of cities?

Rather than it being a comparison tool, a dashboard helps cities establish their own diagnoses and measure emission changes over time. The dashboard indicators offer a good starting point for managing decarbonization. Comparative analyses between cities can be useful, but our aim is for a better understanding of the overall carbon impact.

Our discussions with municipal officials revealed an interest from them for a tool that measures GHG emissions, one that would be adaptable to their budgeting processes. We are continuing our approach with a larger sample of cities so that we can eventually have a more generalized approach and further validation of the measurement tool. Our target is to contact 20 to 30 cities with populations of between 2,000 and 100,000 (representing 43% of the Quebec population). Having this level of diversity will make it possible to integrate factors such as urbanization (relative population density) and surface area when determining carbon intensity. It will also make our methodology robust in light of the idiosyncrasies of various cities.

Even a simple and agile approach to measuring carbon emissions is fraught with uncertainties. Every city is different and requires a number of different approaches. As part of our ongoing work, we are aiming to systemize the process. We want to develop a more exhaustive set of parameters for cities' financial and non-financial information systems and place it on a larger scale. Our ultimate aim is to transfer this expertise to the relevant government bodies and have it be used as a public policy tool that can be disseminated to Quebec municipalities.

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