COMMUNITY ENERGY AND GREENHOUSE GAS INVENTORY, 2015

Full Report: March, 2018

Overview

This document offers an estimate of energy use and greenhouse gas emissions for the City of Charlottetown for the baseline year of 2015.

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Table of Contents

Executive Summary

This document provides an estimate of energy use and greenhouse gas (GHG) emissions attributable to the entire City of Charlottetown. The population of Charlottetown is estimated at 37,200 as of mid-2015, just over 25% of Prince Edward Island's (PEI's) official population estimate at that time.

City GHGs in 2015 are estimated at 11.61 metric tonnes of carbon dioxide equivalent (tCO_2e) per capita, which is about 25% below PEI's GHGs of 15.53 tCO_2e per capita when including GHGs from *"stack emissions"* of imported electricity. Stack emissions from electricity imports are excluded in PEI's GHG Inventory, yet they are relevant to provincial energy policy, to address global warming, and are included in municipal GHG inventories across Canada and the world. This allows for a better *apples-to-apples* comparison.

Urban areas generally benefit from greater density in the built environment which reduces GHGs associated with space heating and transport, etc. Charlottetown's GHGs are lower partly due to a higher percentage of households that are apartments or condos (41.1%) compared to the provincial average (18.7%). While floor space in an apartment/condo averages *more than half* that of a typical single detached dwelling, the overall energy use in a typical apartment/condo is *less than half* compared to an average detached dwelling on PEI. The high proportion of commercial and institutional (C&I) space in the City per capita compared to the rest of PEI increases the City's per capita energy use and GHGs in the sector.

Tourist gasoline sales are excluded in the City's inventory per common protocol in GHG accounting for cities, as are fuel sales for shipping of commodities, cruise ships, tourist-related aviation and air passengers that do not live or travel by air for work purposes from within the Charlottetown area.

For GHGs from municipal solid waste (MSW), City emissions per capita appear less than those associated with the province. This is because much of the Capital Region's MSW is burnable waste which is sent to the District Energy System (DES), thus reducing the amount of MSW from the City that is landfilled and reducing landfill GHGs. Agriculture GHGs from within the City are estimated at less than 0.1%; 20.3% of PEI's GHGs in the inventory for 2015 as submitted to the UNFCCC in 2017 are attributed to agriculture.

Overall, GHGs for the City in 2015 are estimated to be 432,027 $tC0_2e$. This includes all GHGs, and a small amount of additional tCO_2e occurring from emissions in the upper atmosphere plus heat-radiating fossil soot particles, each due to commercial aviation attributable to Charlottetown. Though normally excluded in GHG inventories, these added emissions from aircraft are relevant to reducing warming so are included here.

The 100-year global warming potential ($GWP_{100\text{-}yr}$) of black carbon (BC) particles attributable to the City for all other fuels is estimated at about 24,000 tCO_2e. Usually BC warming is excluded in GHG inventories however it has been included here. The $GWP_{100\text{-}yr}$ of Charlottetown's GHGs plus BC particle emissions and warming attributed to emissions in the upper atmospheres from aircraft such as from contrails totals 456,027 tCO_2e in 2015; or 12.26 tCO_2e per capita.

Community energy expenditures are estimated at $176 million in 2015. Long-term global warming damages from the City's GHGs in 2015 are estimated at $146 million. Premature mortalities from air pollution in Charlottetown, attributable to current fuels in use by society, are estimated at 7 deaths per year with these economic damage costs estimated at $85 million/year. The energy, climate, and air pollution costs associated with energy use today are estimated at $407 million/year in 2015 (2017-CAD).

Overview

Tables 1 and 2 summarize energy use and greenhouse gas (GHG) emissions for the City of Charlottetown. Figure 1 shows the percentage shares of secondary energy use.

Table 1: City of Charlottetown Community Energy Use by Source, 2015

	Natural Units		*GJ*	*tCO_2e*
Electricity	370,172,517	kWh	1,332,622	141,881
District Energy	100,082	MWh	359,301	24,042
Fuel Oil	48,278,170	L	1,867,400	132,041
Gasoline	32,286,468	L	1,130,026	74,231
Diesel	9,667,312	L	370,258	26,338
Propane	3,695,275	L	93,527	5,706
Aviation Fuel	3,780,000	L	131,121	19,830
Wood	4,277,178	kg	54,723	812
Biogas	624,131	m^3	14,556	576
Total			5,353,533	432,027

Note – A gigajoule (GJ) is a unit of energy equivalent to about 277.778 kilowatt-hours (kWh) of energy. A kWh is a familiar unit of energy used by electric utilities for billing as a unit of energy consumption. In simple terms, 1,000 watts of power, which is similar to the full load drawn by some regular-sized microwaves, for a one hour period, results in 1 kWh of secondary energy consumption.

Figure 1: Charlottetown's Secondary Energy Use, 2015

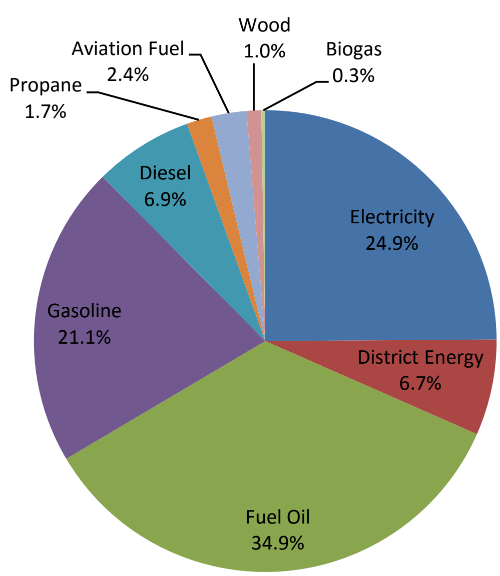


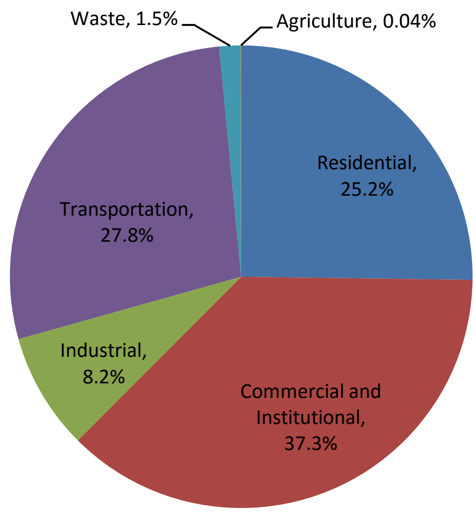
Table 2: City of Charlottetown Greenhouse Gas Inventory, 2015	
	Tonnes CO_2e
Residential	108,936
Commercial and Institutional	161,000
Industrial	35,286
Transportation	120,235
Onroad	*100,051*
Offroad	*71*
Marine	*283*
Aviation	*19,820*
Waste	6,400
Landfill	*5,400*
Compost	*1,000*
Agriculture	170
Enteric Fermentation	*140*
Manure Management	*30*
GHGs in tCO_2e	432,027
Per Capita tCO_2e from GHGs, Charlottetown	11.61
Per Capita tCO_2e from GHGs, PEI	15.53
Percentage Below PEI Average	25%
Factor for Inclusion	
Black Carbon (BC) Particles (tCO_2e)	24,000
Total tCO_2e	**456,027**
Excluded Factor (among others)	
Tourism-related gasoline	37,110
Per Capita Emissions for Charlottetown in 2015 including:	
GHGs + BC expressed in tCO_2e per capita	**12.26**
Incl. tourism-related gasoline, tCO_2e per capita	13.26

Global warming potentials (GWPs) of greenhouse gases (GHGs) and black carbon (BC) particles should be included in the community energy and GHG inventory as each result in warming. With GHG inventories typically 100-year GWP values ($GWP_{100\text{-}yr}$) are used and expressed in metric tonnes of carbon dioxide equivalent emissions (tCO_2e). Other timescales and metrics to account for climate change are relevant to inform decision-makers.

Tourism-related gasoline sales, shipping (commodities/cruise ships), tourism-related aviation, and so on, could remain excluded from the community energy and GHG inventory but are important to be aware of as these are causes of global warming from human activity that must be addressed.

Figure 2 shows a snapshot of the City of Charlottetown's GHG emissions estimates sector-by-sector for the year 2015.

Figure 2: Greenhouse Gas Emissions by Sector, 2015



Note – Figure 2 excludes effects of black carbon (BC) warming particles, with exception of aviation in the transport sector where BC is included. Warming effects of BC particles for all other fuels are shown separately in Table 2.

Estimates of energy expenditures for the City of Charlottetown are $176 million in 2015 (expressed in 2017-CAD). Energy expenditures by secondary energy source are shown in Table 3.

Table 3: City of Charlottetown Energy Expenditures, 2015

	$Millions Nominal 2015-CAD	*$Millions 2017-CAD*
Electricity	$62.3	$64.3
Oil	$42.6	$44.0
Gasoline	$34.6	$35.7
Diesel	$11.1	$11.4
District Energy	$11.6	$12.0
Aviation Fuel	$4.3	$4.5
Propane	$2.9	$3.0
Wood	$0.9	$1.0
Total Expenditures ($M)	$170.4	$176.0

Energy services offer society tremendous benefits. Yet these services have significant externalized social costs. The business costs, climate costs, and air pollution costs of the current energy infrastructure are shown in Table 4. There may be ways to minimize the social costs by increasing energy efficiency and incorporating clean energy in order to provide the same quality energy services we enjoy today at similar costs, but with far greater overall net benefits to our community and society.

Table 4: City of Charlottetown Energy, Climate, and Air Pollution Costs, 2015

	$M-2017-CAD
Energy Costs	$176
Climate Costs	$146
Air Pollution Costs	$85
Business Plus Social Costs of Energy	$407

In the following sections, community energy and GHG estimates by each sector are summarized. An estimate of the warming from black carbon particle emissions is given. The energy use, expenditures, and GHGs of the City's operations are given briefly.

Residential Sector

In Table 5 residential energy use and GHGs in the residential sector are summarized for the City. Figures 3 and 4 show GHG emissions by secondary energy source and energy use by end-use, respectively.

Table 5: Residential Energy Use and GHGs, 2015

	Natural Units		*GJ/Year*	*tCO_2e*
Electricity	109,449,454	kWh	394,018	41,950
Oil	21,591,754	L	835,169	59,053
District Heat	14,292.13	MWh-th	51,452	3,433
Propane	2,420,423	L	61,261	3,737
Wood	1,803,123	kg	32,456	762
Total			1,374,356	108,936

Figure 3: Residential Greenhouse Gas Emissions by Secondary Energy Source, 2015

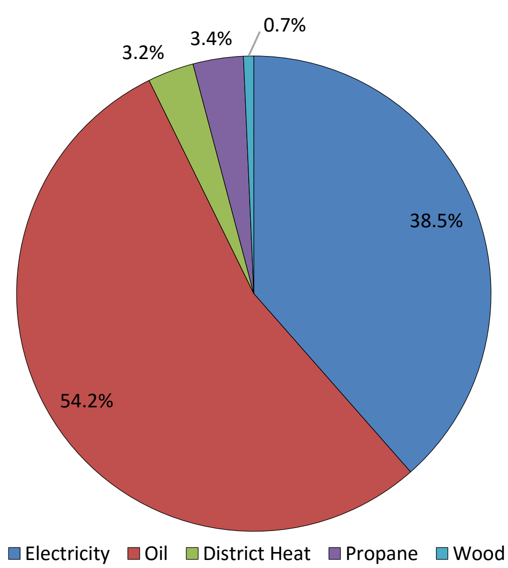
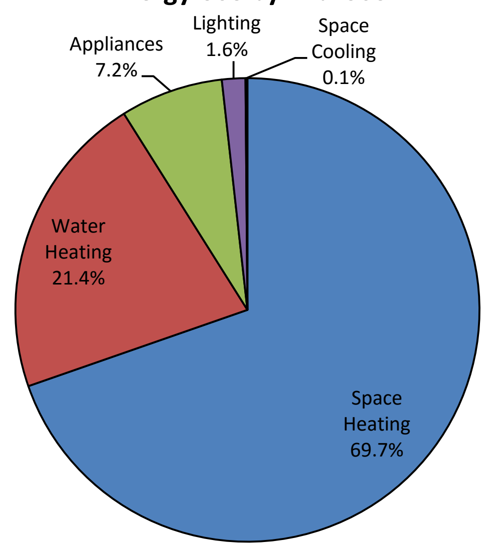


Figure 4: Residential Secondary Energy Use by End-Use



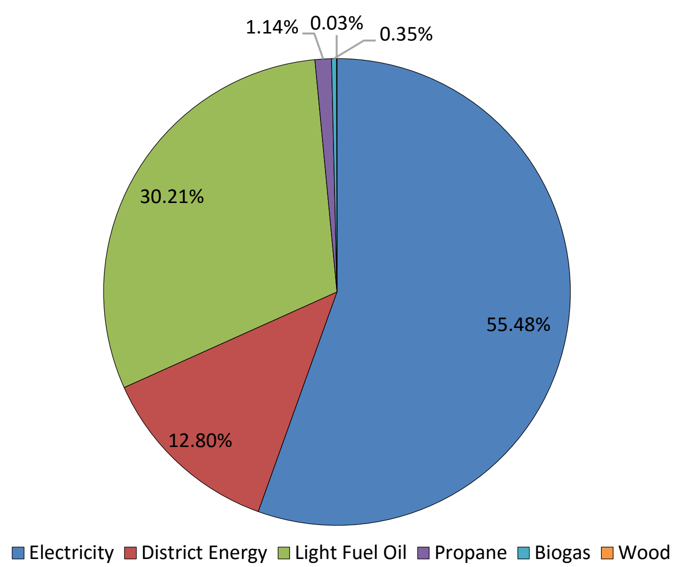
Commercial and Institutional Sector

Table 6 summarizes the City's commercial and institutional (C&I) sector energy use and GHGs. Figure 5 shows GHG emissions by secondary energy source.

Table 6: Commercial and Institutional Sector Energy Use and GHGs, 2015

	Natural Units		*GJ*	*tCO_2e*
Electricity	233,021,399	kWh	838,877	89,313
District Energy	85,790	MWh	308,845	20,609
Light Fuel Oil	17,779,799	L	687,723	48,628
Propane	1,185,302	L	30,000	1,830
Biogas	624,131	m^3	14,556	576
Wood	2,222,222	kg	20,000	45
Total			1,900,000	161,000

Figure 5: Commercial and Institutional Greenhouse Gas Emissions by Secondary Energy Source, 2015



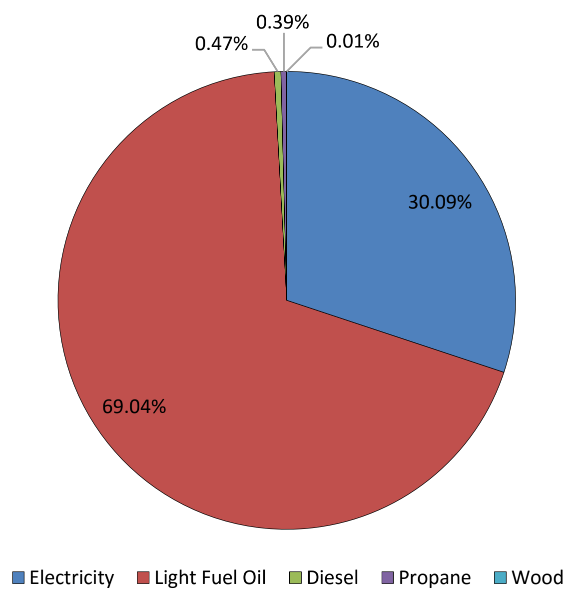
Industrial Sector

Table 7 provides estimates of the City's industrial sector energy use and GHGs. Figure 6 shows GHG emissions by secondary energy source.

Table 7: Industrial Sector Energy Use and GHGs, 2015

	Natural Units		*GJ*	*tCO_2e*
Electricity	27,701,664	kWh	99,726	10,618
Light Fuel Oil	8,906,618	L	344,508	24,360
Diesel	59,178	L	2,267	165
Propane	89,550	L	2,267	138
Wood	251,833	kg	2,267	5
Total			451,033	35,279

Figure 6: Industrial Greenhouse Gas Emissions by Secondary Energy Source, 2015



Transportation Sector

This section summarizes estimates of transportation sector energy use and GHGs from the onroad, offroad, marine, and aviation subsectors which are attributable to the City of Charlottetown.

Onroad Transport

Table 8 provides a summary of onroad transportation sector energy and GHGs. Figure 7 shows GHG emissions by secondary energy source.

Table 8: Onroad Transportation Energy Use and GHGs, 2015

	Natural Units		*GJ*	*tCO_2e*
Gasoline	32,211,738	L	1,127,411	74,055
Diesel	9,549,212	L	365,735	25,996
Total			1,493,146	100,051

Figure 7: Onroad Transport Greenhouse Gas Emissions by Secondary Energy Source, 2015

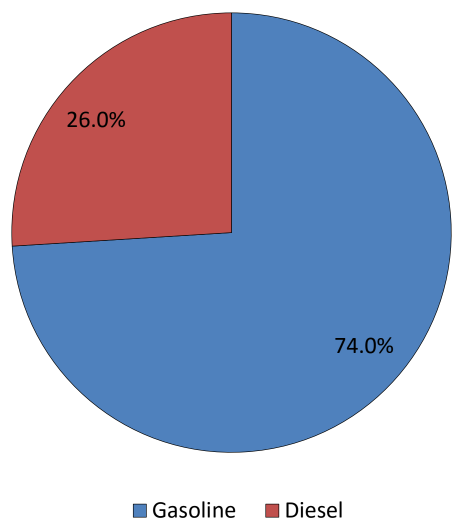


Table 9 shows details that are used as estimates of the number of onroad vehicles, vehicle kilometers traveled per vehicle, fuel consumption rates, quantities of fuels and GHGs by vehicle type.

Table 9: Charlottetown Onroad Transport, Fuel, and GHG Estimates, 2015

Total, all vehicles	Light-Duty Vehicles up to 4.5 tonnes	Medium-Duty Trucks 4.5 tonnes to 14.9 tonnes	Heavy-Duty Trucks 15 tonnes and over
Number of registered vehicles by type			
23,020	21,720	440	860
Average annual km traveled by vehicle type			
	15,090	8,390	14,450
Average annual fuel consumption rate in Litres (L)/100 km			
	10.9	30.1	39.1
Calculated fuel consumption (L), onroad registered vehicles			
	35,790,820	1,111,170	4,858,960
Calculated GHG emissions (tCO_2e), onroad registered vehicles			
	83,836	3,037	13,177

Assumes 90% of litres are motor gasoline for light-duty vehicles (LDVs) and 10% diesel for LDVs.
Uses fuel consumption rate multiplier of 1.05 for LDVs to account for urban city/highway fuel economy.
Assumes diesel used for medium and heavy trucks on PEI.
Data from Canadian Vehicle Survey (2009) is scaled by population growth and to Charlottetown for 2015.[1]
Number of MDVs and HDVs is conservatively increased by multiplier of 1.15 given provincial GHG data.
Excludes fuel and GHGs associated with tourism traffic.

Offroad Transport

Table 10 show energy and GHGs from offroad transport. For the City's inventory this subsector of transport includes estimates for all lawn mowing, golf carts, farm tractors, and snowmobiles, etc.

Table 10: Offroad Transportation Energy and GHGs, 2015

	Litres	*GJ*	*tCO_2e*
Gasoline	21,130	740	50
Diesel	6,883	264	21
Total		1,003	71

Marine Transport

For marine transport the main energy and GHGs occur in the City due to shipping of commodities and cruise ships. Each of these energy requirements and GHG sources are excluded from Charlottetown's inventory. Table 11 includes energy and GHGs from recreational watercraft attributable to Charlottetown's residents and primarily this includes sea-doos, small yachts or sportfishing boats, and auxiliary engines of sailboats.

Table 11: Marine Transport Energy and GHGs, 2015

	Litres	*GJ*	*tCO_2e*
Marine Diesel	52,040	1,993	156
Marine Gasoline	53,600	1,876	127
Total		3,869	283

Aviation

Over 310,000 air passengers were enplaned and deplaned at the Charlottetown Airport in 2015.[2] About half of all air passengers were Islanders.[3] This is scaled to the population of Charlottetown. Globally averaged air passenger distances traveled per flight is obtained for the year (nearly 1,900 km/flight). A multiplier of 1.33 is used since many times air travel by Islanders is not directly from initial departures to final destinations. This multiplier results in over 2500 km of air travel per air passenger enplaned and deplaned at the local airport, which may be conservative. A fuel consumption rate of 3.5 L/100 km traveled for air passengers is deemed representative of commercial aviation.[4] A modest multiplier of 1.1 is used to account for the fact that many public and private employees on PEI either work in the City or are residents themselves that use air travel for work purposes.

At common cruise altitudes of 10-12 km when air is often supersaturated with H_20 contrails form and persist for many hours, increasing radiative forcing or warming.[5] A radiative forcing index (RFI) factor is applied to determine CO_2e of emissions in upper atmospheres.[6] For black carbon (BC) emissions of fossil soot in the fuel, a 100-yr surface temperature response (STRE) per unit emission function for BC and primary organic matter (POM) is used.[7]

Table 12 shows energy and tCO_2e in aviation including GHGs, the RFI factor, and the 100-yr STRE for BC and POM in fossil soot. Best practices would include each these sources of global warming from human activity, instead of excluding their warming effects.

Table 12: Aviation Energy and GHGs, 2015			*GHGs*	*RFI**	*100Yr-STRE**	*Total*
	Liters	*GJ*	*tCO2e*	*tCO2e*	*tCO2e*	*tCO2e*
Aviation Gasoline	37,800	1,267	94	94	3	191
Jet Fuel (A-1)	3,742,200	129,854	9,662	9,662	314	19,639
Total	3,780,000	131,121	9,756	9,756	317	19,830

* RFI - Radiative forcing index factor for total aircraft.
* Refers to 100-year surface temperature response (STRE) of BC and POM per unit emission function in fossil soot of jet fuel, somewhat different than 100-yr GWP of BC used for all other fuels in this inventory.

Waste

Table 13 summarizes the GHGs associated with municipal solid waste and compost. The GHGs associated with waste are significantly higher at the provincial level. Municipal solid waste (MSW) from the capital region is often fed into the PEI Energy Systems energy-from-waste facility, reducing tonnage to landfills.

The Island Waste Management Corporation (IWMC) offered detailed data, and analysis with the disposal manager of IWMC helped the City to better estimate the composition of the various materials being landfilled, including those in the MSW stream that cannot received by PEI Energy Systems waste-to-energy facility (due to system downtimes, etc.) Using this information, Partners for Climate Protection (PCP) software is used to quantify resultant GHG emissions given the MSW stream tonnages and composition of materials. For compost, the provincial value of three kilotonnes of CO_2e for the year of 2015 is scaled down by a factor of one third.

Table13: Waste GHGs

	tCO_2e
Municipal Solid Waste	5,400
Compost	1,000
Total	6,400

Agriculture

There is some agricultural land within the City of Charlottetown. To estimate GHGs associated with the agricultural sector, GHGs associated with agricultural soils and other possible trace sources were excluded. Estimates of GHGs from enteric fermentation in ruminants such as cattle, and manure management, were provided for 2015. Tables 14 and 15 respectively show estimates of GHGs from enteric fermentation and manure management.

Table 14: Enteric Fermentation GHGs, 2015

100 Year GWP biogenic-methane (CH_4)
34

	Head	*kg CH_4 per head per year*[8]	*tCO_2e*
Dairy Cattle	30	118	120
Beef Cattle	10	47	16
Total	40		136

Table 15: Manure Management GHGs, 2015

100 Year GWP of Nitrous Oxide (N_20)

298

kg N excretion per head per year	*EF kg N_20 per kg N excreted*	*EF kg CH_4 per head*	*kg CH_4*	*CH_4 related tCO_2e*	*kg N_20*	*N_20 related tCO_2e*
100	0.02	6	180	6.12	60	17.88
70	0.02	1	10	0.34	14	4.17
Total				6.46		22.05

Note - Methodology for GHG quantification, including parameters used in columns 1-3, are available in reference.[9]

Black Carbon Particles

BC is about one million times more potent at warming the Earth in terms of radiative forcing than CO_2, per unit mass emitted, but BC has a very short lifetime in the atmosphere compared to CO_2. In terms of radiative forcing, black carbon may be the second-leading cause of observed global warming to date, after CO_2, and roughly tied with CH_4. As such, removing black carbon emissions is among the fastest ways of slowing global warming, although all emissions must be addressed simultaneously.

To estimate the global warming potential (GWP) of emissions of black carbon (BC) particles, two approaches are used. As discussed, a 100-year STRE for BC in fossil soot from aviation fuel is used as a proxy for the GWP in that sector. A small fraction of aviation fuel is assumed to have a BC emissions factor (EF) associated with aircrafts climbing and the rest is assigned a lesser BC EF for cruising altitudes. The emissions that resulted directly from GHGs released from the aviation fuel burned, expressed in tCO_2e, plus a radiative forcing index factor for emissions occurring in the upper atmosphere, and BC emissions as stated, are encapsulated within the GHG inventory CO_2e value under aviation in Table 2.

For all other fuel sources, in terms of BC emissions, it is necessary to approximate these based on available literature. One paper offers a way to estimate BC EFs for various fuels.[10] This process results in an estimate of roughly 26 tonnes of BC emitted in 2015.

The globally averaged 100-year GWP of BC, which is 900 times greater in terms of warming as CO_2 per unit mass emitted, is adjusted for the Canadian region using specific forcing pulse (SFP) values, as these are proportional to GWP; thus the $GWP_{100\text{-}yr}$ of BC is calculated as 931 times greater than CO_2 per tonne emitted.[11,12] Multiplying the BC emissions estimated for 2015 of about 26 tonnes, by BC's $GWP_{100\text{-}yr}$ for the Canadian region results in about 24,000 tCO_2e.

Air Pollution

Air monitoring data of fine particles ($PM_{2.5}$) and ground level ozone (O_3) is obtained from the air monitoring station in the City for the years 2011-2013. A health effects equation is used to estimate premature mortalities from air pollution exposure in the City. Premature mortality due to air pollution in Charlottetown is estimated at 7 (2-14) deaths annually. The economic damage costs of air pollution for Charlottetown are estimated at $85 million/year ($24-$170 million/year).

A main aspect of the social costs of air pollution is the value of the lives lost prematurely. The U.S. Environmental Protection Agency's (EPA's) statistical value of life established in 2010 of $9.1 million

(2009-USD) is used and adjusted for inflation.[13] A 1:1 relationship between USD and CAD is assumed, similar to the period from early 2009 to late 2014.

For non-mortality costs, such as morbidity costs that do not result in death, U.S. EPA values were recently estimated at 7% of mortality costs.[14] However, other studies in the economics literature indicate considerably higher non-mortality costs. A comprehensive analysis of air pollution damages at every air quality monitor in the U.S found that the morbidity cost of air pollution (mainly chronic illness from exposure to particulate matter) might be as high as 25% to 30% of the mortality costs.[15] A central estimate for non-mortality costs of about 16% is obtained by averaging the 7% and 25% values. Mortality plus non-mortality costs are thus calculated as approximately $12.14 million per premature death due to air pollution.

To put our modeled air pollution mortality estimates into context, in 2008 the Canadian Medical Association (CMA) estimated that exposure to $PM_{2.5}$ and O_3 air pollution was responsible 21,000 premature deaths each year in Canada, including about 80 chronic premature deaths on PEI, with annual illness costs in 2008 on PEI of $28.2 million (2006 CAD).[16] Encapsulated in this, according to the study, were about 10 annual acute deaths on PEI. CMA projected annual chronic mortality attributable to air pollution from $PM_{2.5}$ and O_3 exposure would be 105 deaths for PEI in 2017. No value was assigned to any chronic premature deaths and the value of life assigned for acute deaths was only $2.4 million (2006 CAD). CMA authors stated (footnote 17, pg. 20 of 113):

> "These economic damages are based on acute premature mortality cases. Given the high economic value assigned to avoiding premature mortality, the corresponding economic damages for chronic premature mortality would be much higher."

Other recent studies have had mid-range estimates of air pollution mortality rates of about 7,800-14,400 premature deaths/year in Canada.[17,18] When scaled to the population of Charlottetown, our estimate of air pollution mortalities is low compared to the CMA and these other two studies.

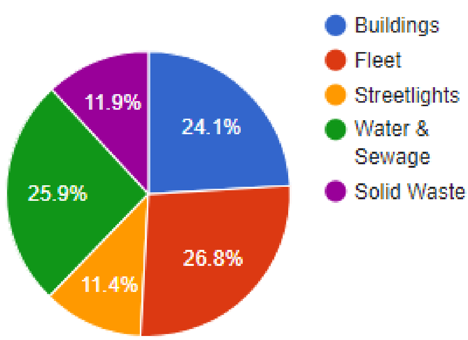
The main contributor to air pollution mortality is $PM_{2.5}$. One study shows of 7,790 annual air pollution deaths estimated in Canada with 7,100 deaths attributable to $PM_{2.5}$. Population-weighted ambient concentrations of $PM_{2.5}$ in Canada were found to be 7 micrograms per cubic meter ($\mu g/m^3$) in that study. This compares to concentrations of $PM_{2.5}$ measured in Charlottetown which averaged $6.3 \mu g/m^3$ over the three years of data. So, the City's mid-range estimates of mortalities are reasonable and conservative.

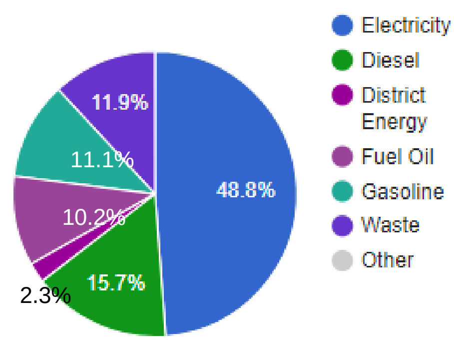
The City of Charlottetown has cleaner air than many places worldwide. Newcomers to Charlottetown from highly polluted places such as China often place an extremely high value and comment on the superior air quality and environmental conditions found here, even compared to larger urban centres in Canada. While the air is cleaner in Charlottetown, our findings suggest air pollution is still a health concern. Evidence suggests there is no safe threshold to $PM_{2.5}$. Concentrations of $PM_{2.5}$ of only a few $\mu g/m^3$ have been shown deleterious to human health. One highly cited study recently found for every 5 $\mu g/m^3$ of $PM_{2.5}$ there was an increased risk of lung cancer by 18%.[19] This alone suggests the results obtained here may be conservative.

City Operations: Energy Use, Expenditures and GHGs, 2013-2016

Corporate greenhouse gas (GHG) emissions across the City of Charlottetown's operations are estimated at 7,420 tonnes of carbon dioxide equivalent in 2016 (tCO_2e/year), 3.8% below 2015 GHGs. Expenditures in the inventory for 2016 were roughly $3.5 million. Figure 8 shows corporate GHGs by sector and source in 2016.

Figure 8: Corporate GHG Emissions by Sector and Source, 2016





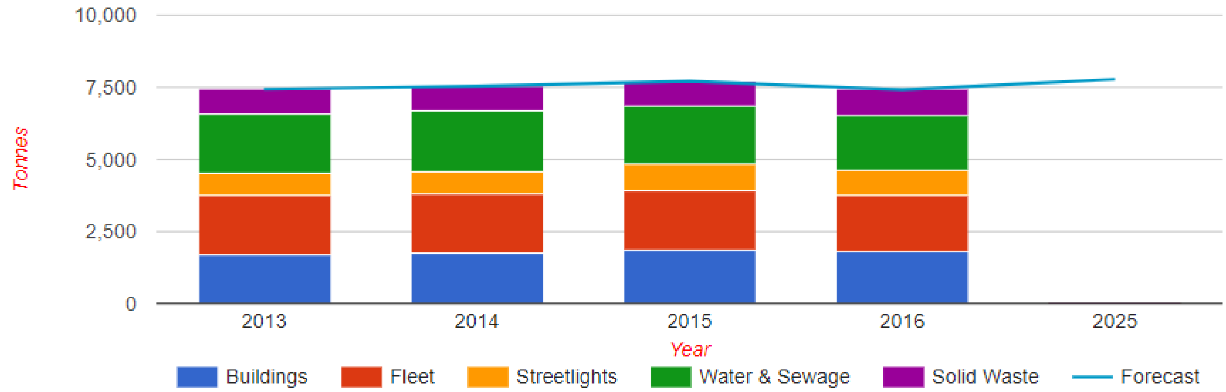
Note: Electricity is estimated to have amounted to 48.8% of GHGs in 2016.
Electrical energy accounted for 52.1% of all energy consumption.

Given software limitations, the City's corporate operations inventory uses a somewhat lower GHG intensity for electricity sector of (280 grams of CO_2e/kWh) than the community inventory uses. For the corporate energy, expenditures, and GHG estimates the City uses software such that there is no way to account for biogas energy used, nor methane leakage from digesters, and in future there is no way to properly account for onsite solar energy generation, etc. This skews information a bit.

It is notable that the community energy and GHG inventory encapsulates the energy and emissions from City operations, so the quantities from both the community and corporate operations should not be added together.

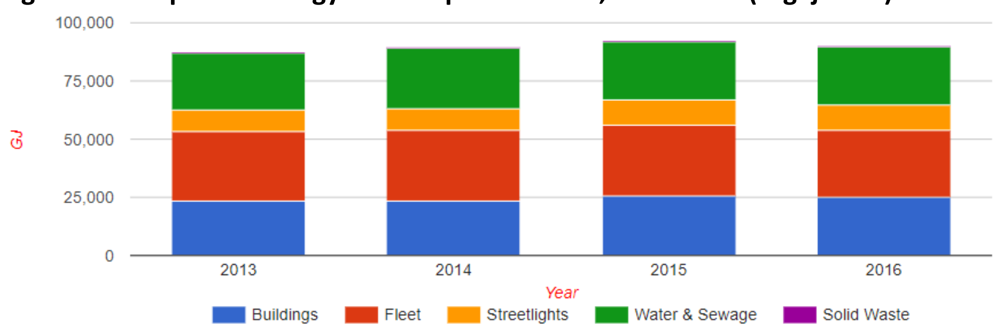
Figure 9 summarizes corporate GHG emission trends from 2013 to 2016, with a business-as-usual projection to 2025 developed in earlier modeling. Figures 10 and 11 respectively summarize trends in a) energy consumption, and b) expenditures related to both energy and solid waste for the period 2013-2016. Please note our corporate GHG inventory remains a work in progress.

Figure 9: Corporate GHG Emissions Trends, 2013-2016 and Business-As-Usual GHG Projection in 2025 (tCO_2e/year)



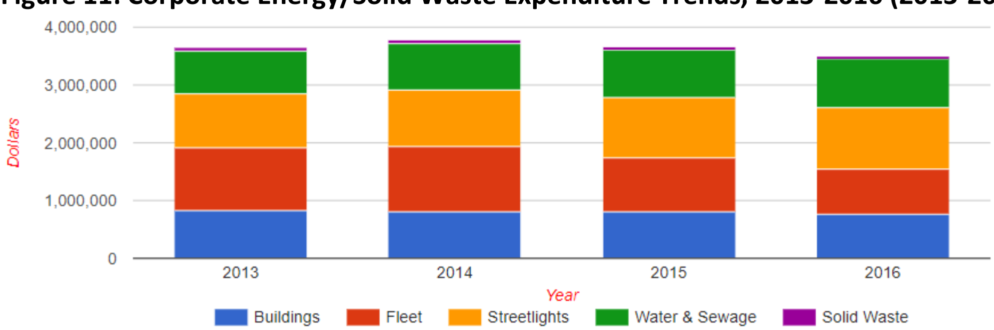
Note: In the business-as-usual projection, a) water and sewage growth assumes a neighboring municipality connects to our sewage infrastructure, increasing consumption by about 10%; and b) building growth includes the possibility of a new fire station. This could eliminate a current fire station. The new building would be better constructed with more efficient technologies but would be larger than the existing station. For this reason, a projected growth of 5% is allocated over the next 10 years; c) fleet growth considers the possibility of a 5-car expansion in the police fleet (5%); d) streetlights forecast is set at 0% due to the adoption of LED lighting systems; and e) solid waste increase is set at 0.1% per year based on the impact of a 1% population increase on our public park waste stream. The forecast does not include the possibility of reduced carbon intensity from the electricity grid through municipal solar photovoltaic generation, etc. GHG emissions may also increase as City population increases may necessitate additional services, etc.

Figure 10: Corporate Energy Consumption Trends, 2013-2016 (Gigajoules)



Note: 2015 energy consumption spike due partly to higher heating degree days (colder winter), increased snow clearing, and water & sewage demand from more snow melt flowing into sanitary sewer. 1 GJ = 277.8 kWh

Figure 11: Corporate Energy/Solid Waste Expenditure Trends, 2013-2016 (2013-2016 Nominal CAD)



Note: Recent petroleum products have been low price in comparison to historic levels.

Acknowledgements

The City of Charlottetown would like to thank the Federation of Canadian Municipalities, the Province of PEI's efficiencyPEI Office, and Maritime Electric Company Limited for their financial contributions in support of this work. Maritime Electric is thanked also for having provided Charlottetown with detailed community-level monthly electricity consumption data by rate-class. The Island Regulatory and Appeals Commission are thanked for having provided detailed monthly data on fuel sales for 2015 to assist with our estimates of energy expenditures. Air monitoring data used to estimate air pollution mortalities is from the Water and Air Monitoring Division of the Government of Prince Edward Island Department of Communities, Land and Environment. Sincerest thanks to the PEI Department of Communities, Land and Environment for making air monitoring data available to us. Thanks also to both the Climate Change Secretariat of the Department of Communities, Land and Environment and to efficiencyPEI for valuable technical expertise, guidance and insights. Thanks to the Island Waste Management Corporation for data and analysis of municipal waste streams. Thanks also to those professors who provided their expertise on both air pollution health impacts, as well as on the warming associated with emissions of black carbon. Thanks to various other individuals and organizations who in one way or another contributed to this document. Thank you to the dozens of "in-kind" contributors who have agreed to support this project during 2018 and help our City develop a community energy plan which when implemented will help to significantly reduce our greenhouse gas emissions.

Supplemental Information

Overview

This supplementary information provides additional descriptions and data for sections in the main document. Topics covered in this document include the following:

SI.1) Population Projections;

SI.2) Energy and Emissions Methodology;

SI.3) Exclusions;

SI.4) Business-As-Usual Projection;

SI.5) Energy Expenditures;

SI.6) Social Cost of Carbon; and

SI.7) Social Costs of Air Pollution

SI.1) Projection of Populations

The contemporary population of PEI and recent population projections for the province are highlighted. A population projection for the City of Charlottetown is given.

The population projection for the City of Charlottetown is made within the context of official provincial population estimates, plus census population figures available for PEI and the City. The 2016 Census Population by Statistics Canada counts PEI's population as 142,907, up from 140,204 in the 2011 Census. These are not population estimates.

Official population estimates released by Statistics Canada indicate the population of Prince Edward Island, as of July 1, 2016 was 149,472 compared to census population count for the same year of 142,907. [20, 21] The official population estimate for PEI, as of July 1, 2017, is 152,021.

In terms of population trends for PEI and Charlottetown, the province's official population projections were laid out clearly in an editorial to *The Guardian* newspaper in early 2013.[22] According to official population projections released by the PEI Statistics Bureau, "by 2050, P.E.I.'s population will drop below 130,000, and continue declining."[23]

> "What is worrying about these official population projections is that they may be too optimistic. They are based on three key assumptions: (1) that outmigration from P.E.I. will be matched by an equal number of people migrating here from other provinces (i.e., that inter-provincial migration will net out at zero); (2) that the 'fertility rate' will remain steady at its current level, rising slightly from 1.63 to 1.68 from 2012 to 2052 (P.E.I.'s fertility rate declined steadily between 1950 and 2000); and (3) that P.E.I. will attract 300 new immigrants per year, and retain 75 per cent of them. If any of these three assumptions is overly optimistic, P.E.I.'s future population will be both smaller and older than the official negative projections. Of the three factors, immigration has the greatest room for a positive upside, given a vigorous and strategic effort."[24]

Since the PEI's Statistics Bureau put out its 2012 population projections to 2050, which projected PEI's population could fall below 130,000, population projections have been revised upward each subsequent year. Earlier provincial population projections are no longer available online, except for PEI's total population projections from 2016-2055, and 2017-2016 (see Figures 12 and 13, respectively).

The 2016-2055 population projections show the population on PEI reaching over 160,000 in 2033, and remaining stable below 162,000 by 2055. In 2017, the population projections reach 160,000 in 2022 and nearly 200,000 by 2056. If the Province's population action plan can be effectively executed over the coming decades, PEI's population could be on the order of 75,000 persons higher by the mid 2050's than previously projected in 2012, nearly half of the Island's current population. The uncertainty implied in the wide-ranging recent population projections makes it a bit more challenging to do long-term community planning.

With the uncertainty in regards to anticipated population changes in the coming decade, it is challenging to estimate the projected energy use and GHG emissions in a business-as-usual case of incremental changes to a low carbon energy system, or future demand for energy services and associated GHGs if our residents and businesses across the City accelerate the transition to sustainable energy.

Figure 12: PEI Total Population Projection, 2016-2055[25]

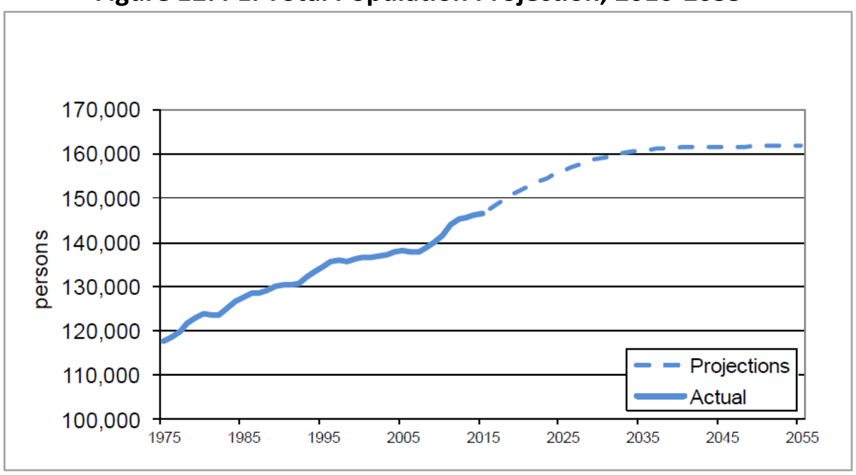
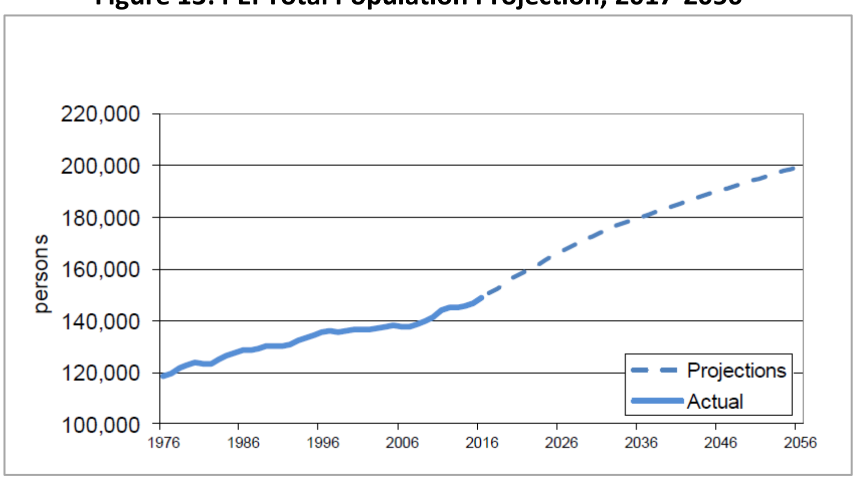


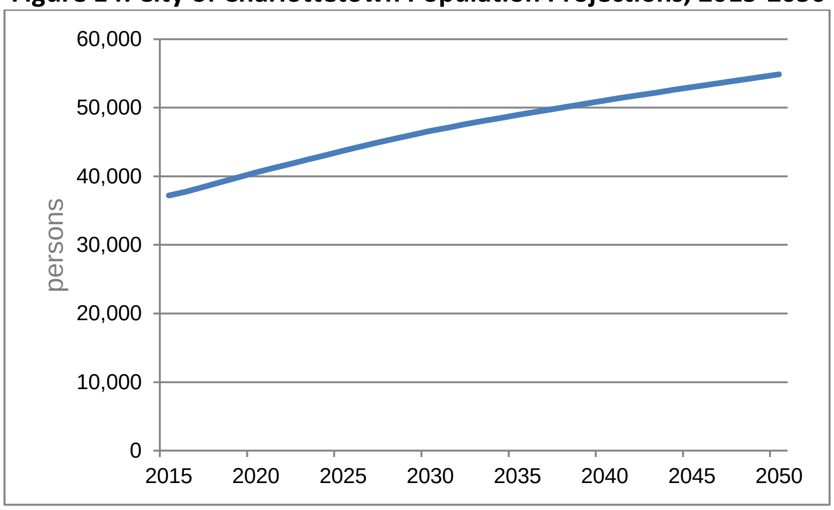
Figure 13: PEI Total Population Projection, 2017-2056[26]



For this analysis, the City uses census population data from both 2011 and 2016 noting that these are not official population estimates and better statistics may be available. The 2016 provincial census population count is 4.6% below the official provincial population estimates. The City's census population census figures are used along with provincial census population and official population estimates between 2011 and 2016. With available data, for the year 2015 it is estimated that the City of Charlottetown's population is approximately 37,200 versus the 2016 census population count of 36,094. The estimate is slightly higher than the census population in 2016 but given the official population estimates, our 2015 City population estimate seems realistic.

Figure 14 shows City of Charlottetown population projections from 2015 to 2050 that are to be used for the Community Energy and Greenhouse Gas Inventory here and in forthcoming energy and GHG reduction strategies. The estimates are based on the province's population projections from 2017-2056, and are adjusted to reflect the slightly higher population growth rate implicit by recent census counts in the City compared to provincial population counts and official estimates overall.

Figure 14: City of Charlottetown Population Projections, 2015-2050



The projections are higher than population projections that have been made in the past for the City. The City of Charlottetown is becoming increasingly diverse, thanks to immigration policies and a focus on population growth provincially. Over 11% of Charlottetown's residents have a mother tongue that is a non-official, non-Aboriginal language. Residents across Charlottetown speak over 75 languages.[27] At this point it time given the focus on the province's population action plan it does appear possible that such growth within the City proper is attainable.

SI.2) Energy and Emissions Methodology

Overview

In the Community Energy and GHG Inventory, energy quantities are shown as secondary energy. For district heating, however, it is quite possible the data on "energy consumed" refers to primary energy, in the sense the values may be representative of the energy content in the fuels prior to combustion or being delivered in a convenient form to the point of end-use, but it is impossible to verify this for certain. This is discussed within SI.2 under District Energy.

Estimates exclude most upstream energy and GHGs associated with mining, refining, and transporting finished/secondary energy products of petroleum, etc. That said, as noted below, GHGs associated with the transmission and distribution line losses in the electricity system are assumed to be additive to the carbon intensity per kWh of electricity metered at end-use.

For this Community Energy and GHG Inventory, energy and GHG conversion factors are obtained from Partners for Climate Protection (PCP) software and used in most cases.[28] For wood and aviation fuels, no values are available in PCP so British Columbia's most recent Best Practices Methodology for Quantifying GHG Emissions is used.[29] In some cases, such as quantifying the tCO_2e of biogas leakage from the two-stage anaerobic digesters at the Charlottetown Resource Recovery Facility, otherwise known as the wastewater treatment plant, updated GWPs are used based on the Intergovernmental Panel on Climate Change's (IPCC's), Fifth Assessment Report (IPCC AR5) in 2014.[30] Table 16 shows GWP values from IPCC AR5.

TABLE 16: $GWP_{20\text{-}yr}$ and $GWP_{100\text{-}yr}$ with climate-carbon feedbacks (cc fb) in response to emissions of non-CO_2 gases (cc fb in response to the reference gas CO_2 are always included)[31]

	Lifetime (years)	GWP_{20}	GWP_{100}
CH_4[b]	12.4[a]	86	34
HFC-134a	13.4	3,790	1,550
CFC-11	45	7,020	5,350
N_20	121[a]	268	298
CF_4	50,000	4,950	7,350

Notes: Uncertainties related to the climate–carbon feedback are large, comparable in magnitude to the strength of the feedback for a single gas. Yet, inclusion of climate-carbon feedbacks is always considered more complete.
a) Perturbation lifetime is used in the calculation of metrics.
b) These values do not include CO_2 from methane oxidation. Values for fossil methane are higher by 1 and 2 for the 20 and 100-year metrics, respectively.

The Government of Canada's National Inventory Report (NIR) of GHGs in 2017 for year 2015 does not use updated GWP values from IPCC AR5 in 2014. It uses values from IPCC's AR4. The $GWP_{100\text{-}yr}$ value of methane (CH_4) in Canada's 2017 NIR is 25 as compared to the updated GWP values for biogenic and fossil CH_4 of 34 and 36 correspondingly per IPCC's AR5.

PCP uses outdated GWP values in its software to calculate CO_2e.[32] The $GWP_{100\text{-}yr}$ for CH_4 is considered 21 and for nitrous oxide (N_2O) it is 310; values considered current in the 1990s. Given uncertainties of estimating the City's energy use, the energy and CO_2e conversion values from PCP software are deemed reasonable for use in most cases (with exception of electricity-related CO_2e/unit energy as discussed in this section under Electricity). Where gaps exist, B.C.'s methodology relies on IPCC AR4 values for calculating GWPs for wood and aviation fuel, and in the case of biogas leakage from the two-stage anaerobic digesters at the Charlottetown Resource Recovery Facility/Waste Water Treatment Plant, the IPCC AR5 value is applied to account for warming due to biogenic CH_4.

Energy Conversion Factors

Table 17 shows the energy conversion factors used for key energy sources to go between natural units of secondary energy to GJ of energy.

Table 17: Energy Conversion Factors (GJ/unit)

Energy Source	*GJ*	*Unit*
Electricity	0.003600	kWh
Fuel Oil	0.038680	L
Gasoline	0.035000	L
Heavy Fuel Oil	0.042500	L
Kerosene	0.037680	L
Propane	0.025310	L
Diesel Stationary	0.038300	L
Natural Gas	0.038430	m^3
Above values derived from reference.[33]		
Wood Fuel (Residential - 0% moisture or MC)	0.018000	kg
Wood Chips (50% MC)	0.009000	kg
Above values for wood from reference.[34]		
For wood, different values on energy (ie. - 25% MC for firewood, <10% pellets, 45% wood chips, etc.) are available, but lack corresponding/sufficient climate values.[35, 36]		
Aviation Gasoline	0.03352	L
Jet Fuel (Jet A-1)	0.0347	L
Above values for aviation/jet fuel.[37]		

GHGs from Stationary and Mobile Sources

The GHGs from stationary and mobile sources are shown in Table 18 and 19 respectively.

Table 18: Emission Factors for Stationary Sources[38] (tonnes CO_2e/unit)

	tCO_2e	*tCO_2e*	*Natural Units*
Electricity	0.000280	0.000383	kWh; low-mid est.
Light Fuel Oil	0.002735	NA	L
Heavy Fuel Oil	0.003145	NA	L
Propane	0.001544	NA	L
Diesel Stationary	0.002790	NA	L
District Energy	0.240225	0.06673	per MWh; per GJ
Wood Fuel - Residential (0% MC)	0.00042	NA	kg
Wood Chips (50% MC)	0.00002	NA	kg

Table 19: Emission Factors for Mobile Sources (tCO_2e/L)[39]

	Light-duty Auto	Light-duty Truck	Heavy-duty Vehicle	Off-road Vehicle
Gasoline	0.002299	0.002299	0.002352	0.002361
Diesel	0.002732	0.002733	0.002712	0.003007
Aviation Gasoline	0.002489			
Aviation Turbo Fuel (A-1?)	0.002582			
Values for aviation in reference.[40]				

Electricity

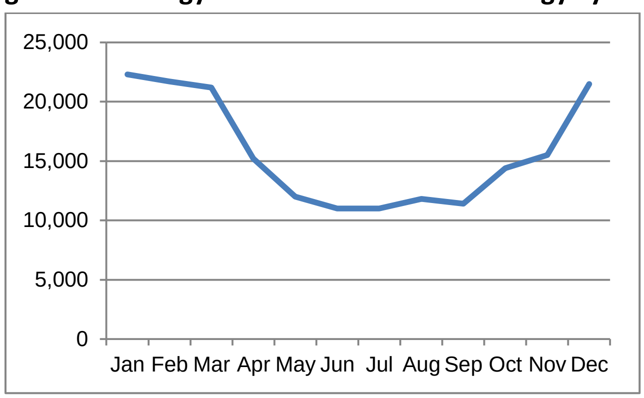
Electricity data for the Charlottetown census subdivision area, also known as the City proper, was requested for 2015 and data was received from Maritime Electric Company Limited (MECL). Monthly data is separated by rate class: residential, general service, small industrial, streetlighting, etc. Data is further sorted to better reflect the metered residential, C&I, and industrial sector electricity consumption across the City in the calendar year. Residential rate class consumption is allotted to that sector. All general service customers go to the C&I sector, all small industrial goes to that sector except for the City operation accounts in that rate class. These are put into the C&I sector. Please note that no individual customer data was requested or collected by the City, thus respecting the privacy of households, businesses, and organizations.

An electric vehicle infographic produced by the Province of PEI in 2017 allows for calculations to be made to derive a carbon intensity value per kWh of electricity consumption.[41] The resultant carbon intensity of a kWh implicit from the infographic is about 358 grams of CO_2e per kWh. MECL says transmission and distribution (T&D) losses are about 7%. This means for 1 kWh of metered electricity consumption there is 1.07 kWh of electricity supply required, so in the case of the electricity sector for each 1 kWh of metered electricity it is assumed to result in about 383 gCO_2e after accounting for T&D losses.

District Energy

Information on the district energy system (DES) is available from a number of sources.[42, 43, 44] A figure on energy consumed for a given year makes it possible to estimate the annual energy consumed as 189,000 MWh, seen month-by-month Figure 15.

Figure 15: "Energy Consumed" in District Energy System



This amount of energy appears high even though information about the DES says it covers over 4.5 million ft^2 of floor space. Based on this floor area, the maximum implied floor space serviced by the DES for space conditioning (mainly heating and a bit of cooling) and water heating would be 422,708.8 m^2. This implies the secondary energy use intensity for those services provided across the DES' network is around 1.6 GJ/m^2. A large portion of energy services in the City are provided to the commercial and institutional (C&I) sector and to the residential sector by the DES. Yet Natural Resources Canada's Comprehensive Energy Use Database (NRCan's CEUD) indicates the Atlantic region's average secondary energy use in the C&I sector for all energy purposes, not just for space conditioning and water heating, totals <1.1 GJ/m^2.[45] In the residential sector, the CEUD indicates average all-purpose energy intensity for PEI in 2014 (the most recent year available) was <0.7 GJ/m^2.[46] Since a vast majority of households connected to the DES appear to be apartments/condos, their energy intensity overall and for space heating in particular should be even lower than in the C&I sector.

Details regarding the DES are unobtainable from the PEI Energy Systems which is owned by Enwave Energy Corporation. Accessible information from the company may in future resolve apparent discrepancies and would firm up the City's overall estimates of this Inventory.

A GIS technician with the City used available information on the DES' distribution network along with information about the residential building stock to find the maximum possible number of households, including the types of households that may be connected to the DES. Table 20 shows the maximum possible number of households by type and the assumed residential households estimated to be connected to the DES.

Table 20: Total Estimated Residential Households by Type of Dwelling Using the District Energy System (DES)

	Max Possible Households	*Percent of Max on DES by Dwelling Type*	*Assumed Residential Households on DES*
Total Apartments	1629	67%	1090
Total Attached Homes	9	50%	5
Total Single Detached	9	50%	5

Given the apparently excessive energy intensity of the building areas being covered by the DES from available information, two tests are performed to assess if the MWh of energy consumed in Figure 14 is more likely to be secondary thermal energy delivered to the point of end-use, rather than being MWh of energy consumed in terms of the energy content embodied within the fuels prior to their combustion, thus before accounting for any inefficiency of combustion and the distribution losses to end-use.

In the first test, since case studies state 16-17 million litres/year of oil are being displaced with the district energy system, calculation are able to show if 189,000 MWh of district energy/year is secondary energy use comprised of 83% MSW plus wood waste and wood chips, as long as the displaced oil refers to oil-based distributed space and water heating systems of a certain thermal efficiency overall, then it is possible the energy consumption figure of 189,000 MWh/year via the DES could refer to secondary energy use consumed at end-use. That said, given the extremely energy-intensive building stock this case would imply, it appears somewhat more likely that the 189,000 MWh/year value refers to energy content embodied within the fuels themselves that are being burned within the DES facilities, prior to combustion or distribution losses.

The second test is performed to demonstrate more expected energy intensity values result if we assume the energy consumed number (189,000 MWh) is energy content of the fuels. The fuel mix of the DES varies, but a breakdown of fuel mix is assumed with the percentages of supply mix deemed to represent energy content prior to combustion.

Assumptions are made of the fractions of heavy versus light fuel oils consumed. Estimates of thermal efficiencies for various combustion units in the DES facilities, as well as estimates of primary and secondary distribution losses based on discussion with a professor at UPEI's School of Sustainable Design Engineering, and an engineer with prior affiliation to the DES; and available literature. One study shows the inefficiency of steam distribution lines can significant but the DES in Charlottetown only has a single large customer connected to steam distribution that is close to the main district heating facility.[47]

A recent study reviews literature and finds the impact of heat losses in the main lines (primary network) accounts for approximately 2% to 5% of the total distributed heat if the insulation is in good condition, but in the secondary network they can account for 12% to 37% of the distributed heat.[48] There is uncertainty as information is not obtained from the company. Assumptions of thermal efficiencies, primary and secondary distribution efficiencies must therefore be made.

Table 21 shows secondary energy use estimates in the DES assuming 189,000 MWh/year of estimated energy consumed is energy content in fuels prior to combustion. Again, the supply mix is assumed to be 41% energy-from-waste, 42% wood chips/residuals, and 17% oils, based on one case study (each vary somewhat), and assuming the percentages of supply mix again refers to energy content prior to combustion. Thermal efficiencies of combustion units are assumed 75% for energy-from-waste, 80% for biomass, and 85% for heavy and light fuel oils. It is assumed fuel oil mix is split 50/50. Primary and secondary distribution losses are assumed to be 4% and 30% respectively based within aforementioned ranges in literature.

Table 21: Secondary Energy Use Estimate in District Energy System (DES) If MWh/Year of Energy Consumed is Energy Content Before Combustion

	Primary Energy Supply Mix (% and MWh of Energy Content in Fuels)	
Waste-to-Energy	Wood Chips and Residuals	Heavy and Light Fuel Oils (50/50)
41%	42%	17%
77,490	79,380	32,130
	Thermal Efficiencies (%)	
75%	80%	85%
58,118	63,504	27,311
	Primary Distribution Efficiency	
	96%	
	Secondary Distribution Efficiency	
	70%	
	Secondary Energy Use (MWh)	
39,055	42,675	18,353
Total Secondary Energy Use (MWh)		**100,082**
Residential Secondary Energy Use from DES (MWh)		**14,292**
C&I Sector Secondary Energy Use from DES (MWh)		**85,790**

Data on average household sizes per dwelling by household type in the residential sector is available for PEI from the Natural Resource Canada's (NRCan's) Comprehensive Energy Use Database (CEUD) for the residential sector.[49] Floor space covered by the DES is assumed to be 420,000 m^2 or about 4.52 million ft^2 as case studies of the DES cite an area of >4.5 million ft^2. Energy use for space heating and water heating in the residential sector available in the CEUD for PEI are used to calculate the residential energy use in Table 22.

Table 22: Residential District Energy System Heating by Household Type

	Single Detached	*Attached Homes*	*Apartments*
Secondary Energy Use Per Dwelling by End-Use (GJ)			
Space Heating	77.22	73.17	31.49
Water Heating	22.41	26.31	14.80
Number of Households	5	5	1,090
Total Floor Space by Household Type	819	791	104,924
Total Heat Energy by Household Type (GJ)	498.15	497.40	50,456.10
Total Heat Energy by Household Type (MWh)	138.38	138.17	14,015.58
Total District Energy Delivered (GJ)	51,451.65		
Total District Energy Delivered (MWh-th)	14,292.13		

Floor spaces of the assumed residential areas can be added and this results in about 106,500 m^2 of floor area. When assumed residential floor space is subtracted by the assumed overall floor space overall, it is estimated that 313,500 m^2 of floor space is attributable to space conditioning and water heating by the DES. These numbers are summarized in Table 23.

Table 23: District Energy Floor Space (in m^2)

313,500	C&I Estimate (Subtraction, given below estimates)
106,500	Residential Estimate (Approximation)
420,000	TOTAL (About 4.52 million ft^2. Cited as "over 4.5" million ft^2.)

From this second test, it is still possible to show on the order of approximately 15 million litres of oil/year are displaced in terms of energy content in fuels prior to combustion, or distribution losses. Given it was colder in 2015 than most of the years in the recent historical record, the heating degree days were higher than usual in 2015, it is arguable over 16 million litres of oil were displaced, although it is difficult to say without actual data from the company. As well, the energy intensity of space conditioning and water heating in the C&I sector is about 1 GJ/m^2 from the DES based on above assumptions, and that for residential sector space and water heating is only 0.48 GJ/m^2. Overall energy intensity for end-use space conditioning and water heating across the entire 420,000 m^2 of approximate floor space that is serviced by the DES is about 0.86 GJ/m^2. Given NRCan's CEUD for PEI in the residential sector and the CEUD for the Atlantic Canada region in the C&I sector, this is a value deemed far more reasonable than is >1.6 GJ/m^2. For this reason, it is ultimately assumed the 189,000 MWh/year of energy consumed, cited in one of the case studies, refers to energy content embodied in the fuels prior to combustion.

To determine a GHG emissions factor from the DES, a value is provided by the company. Since there is no clarity given regarding what the tCO_2e/MWh refers to by the company, it may be before distribution losses are accounted for, or at end-use, the City makes its own calculations given the tonnages of fuels assumed to be combusted in Table 21 (above) and then accounts for the estimated energy losses to end-use which increases the GHG emissions factor somewhat relative to the company's number. The tonnages of MSW and wood chips/residuals implied in Table 21 are on the order of those cited in case studies of the DES. GHGs from oils combusted are estimated. The composition of MSW tonnage into the PEI Energy Systems facility is estimated in discussion with Island Waste Management Corporation. While a lot of plastics are diverted, a significant percentage of tonnage of burnable waste into the energy-from-waste plant is said to be plastic, which results in GHGs. The GHG emissions factor is ultimately estimated at 0.2402 tCO_2e/MWh of energy consumed or metered at end-use after accounting for all losses. The emissions factor estimated by the City is compared to the one supplied by the company and is considered realistic. It is hoped more accurate information regarding system characteristics like thermal efficiency, distribution losses, secondary energy use and emissions associated with the District Energy System may become more readily available in the future.

Wood Heat

For residential wood, 0% moisture content (MC) is assumed. For all other wood, a 50% MC is assumed. These values are not ideal since wood is never bone dry, for instance, and this skews the energy content per kg of wood. That said it is necessary to correlate energy use with tCO_2e. Biogenic CO_2 is addressed in SI.3 under Exclusions. Wood burning results in CH_4, N_2O, and BC particle emissions. To account for the non-CO_2 GHGs associated with burning wood, BC's 2016/2017 Best Practices Methodology for GHG Quantification Guide is used, which necessitates using assumptions about wood with 0% MC, which is unrealistic, and 50% MC, when sometimes MC may be closer 45%. A source for energy content of wood sources with various MCs is obtained but could not be utilized for the time being as it is without CH_4 and N_2O emission values.

Residential Sector

The residential sector refers to household energy and excludes transportation. Secondary energy use for PEI's residential sector is obtained from NRCan's CEUD.[50] It gives detailed estimates of residential secondary energy use and GHGs excluding emissions in the electricity sector. Most recent available data for calendar year for the CEUD of 2014 is used. Census data from Statistics Canada in 2016 is used to characterize Charlottetown's residential building stock compared to PEI in general.[51] Metered electricity consumption data by rate class for the entire City is obtained from MECL for the calendar year of 2015.

The CEUD for PEI's residential sector shows the share of secondary energy that is electricity was 12.9% in 2014, and wood's share of household energy was 26%. These numbers may be reasonable for the province, but it is expected that in the City there is a lesser share of biomass used for residential heating compared to other towns, villages, and rural areas.

The most recent biennial Home Heating Survey commissioned by the PEI Energy Corporation is obtained.[52] Raw data from confidential respondents who participated in the survey and are residents in the Charlottetown area is sorted and analyzed to compare differences between provincial and City home heating.

With analysis of NRCan's CEUD, combined with Statistics Canada data on the number of dwellings and type of households, along with MECL electricity data and the home heating survey information, estimates for shares of secondary energy sources in the residential sector are established. These are reviewed with the energy programs officer at efficiencyPEI. Estimates are scrutinized by an internal advisory group for additional for guidance.

For practical purposes, the CEUD data on overall household secondary energy use by type of dwelling is assumed indicative of Charlottetown's energy use. Data from MECL on electricity consumption suggests a higher share of electricity is used for space and water heating than the provincial average. Data from the Home Heating Survey reaffirms this. Although the sample size was limited the Home Heating Survey suggests there is less biomass heating in the City than PEI as a whole.

In the CEUD wood heating is modeled as inefficient compared to electricity which increases the secondary energy use in space heating and water heating to a degree. The residential building stock, in some cases, is very old in the City of Charlottetown which increases its secondary energy use, although there is also newer housing stock in cases. For practical purposes, a decision is made to apply electricity data from MECL and apply provincial secondary energy use values from the CEUD to the City. Mainly wood heating is assumed to be less than for the province and district energy estimates are added.

Table 24 shows the total energy use in GJ per household in terms of energy use by end-use. This is broken out by each type of dwelling. In the table are total households by type, the total floor space and the average floor space per household by type of dwelling.

An observation in Table 24 is that apartments and condos in the City or Province typically require less than 48% of the energy compared to average single detached households, yet the floor space of an average apartment or condo is almost 59% of an average single detached household. So, with well *over half the floor space* compared to a single detached home, an apartment/condo typically requires *less than half the energy*. The important insight is greater density can reduce energy demand.

Table 24: Charlottetown Residential Energy Use (GJ) Estimates per Household by End-Use and Building Type, 2015

	Single Detached	*Attached Homes*	*Apartments*	*Mobile Homes*
Total Energy Use Per Household (GJ)	109.28	107.66	51.94	97.11
Energy Use by End-Use (GJ)				
Space Heating	77.22	73.17	31.49	72.15
Water Heating	22.41	26.31	14.8	16.54
Appliances	7.44	6.82	5.46	7.12
Lighting	2.03	1.31	0.19	1.24
Space Cooling	0.18	0.05	0	0.06
Floor Space Per Household				
Total Floor Space (m^2)	163.87	158.14	96.26	98.91
Total Floor Space (ft^2)	1,764	1,702	1,036	1,065
Total Floor Space by Building Type (m^2)	1,174,915	324,985	637,247	26,210
Energy Intensity (GJ/m^2)	0.67	0.68	0.54	0.98
Energy Intensity (GJ/household)	109.28	107.66	51.94	97.11
Total Households by Building Type	7,170	2,055	6,620	265
Building Type by Share %	44.5%	12.8%	41.1%	1.6%

Next, Table 25 shows total estimates of energy use for all of the households in the City by each type of household and by end-use. The total energy use across all households in the City are shown by type of household and shown in GJ of energy both by end-use and energy source.

Table 25: Charlottetown Residential Energy Use Estimates by End-Use, Energy Source and Building Type, 2015

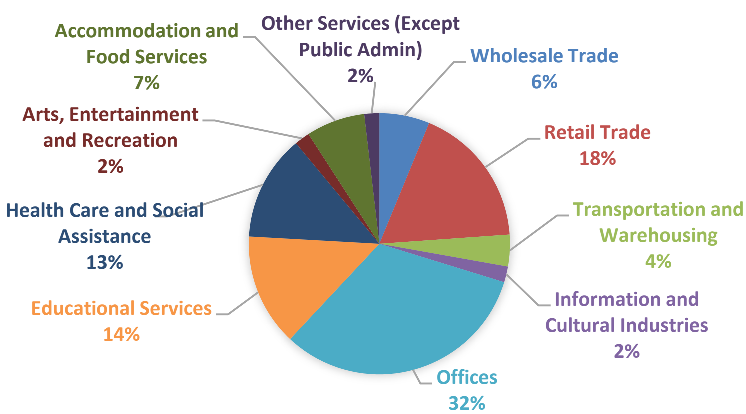
	Single Detached	*Attached Homes*	*Apartments*	*Mobile Homes*
Total Energy Use by Each Household Type (GJ)	783,537.60	221,241.30	343,842.80	25,734.15
Energy Use by End-Use (GJ)				
Space Heating	553,667.40	150,364.35	208,463.80	19,119.75
Water Heating	160,679.70	54,067.05	97,976.00	4,383.10
Appliances	53,344.80	14,015.10	36,145.20	1,886.80
Lighting	14,555.10	2,692.05	1,257.80	328.60
Space Cooling	1,290.60	102.75	0.00	15.90
Electricity (GJ) (Appliances, Lighting, Space Cooling)	69,190.50	16,809.90	37,403.00	2,231.30
Space Heating (GJ)				
Electricity	130,111.84	35,335.62	48,988.99	4,493.14
Oil	373,339.395	101,130.086	114,727.517	14,626.609
District Heat	386.10	365.85	34,324.10	0.00
Propane	27,683.37	7,518.22	10,423.19	0.00
Wood	22,146.70	6,014.57	0.00	0.00
Water Heating (GJ)				
Electricity	25,058.55	8,431.94	15,279.69	683.56
Oil	124,261.52	41,718.87	61,665.51	3,699.54
District Heat	112.05	131.55	16,132.00	0.00
Propane	8,033.99	2,703.35	4,898.80	0.00
Wood	3,213.59	1,081.34	0.00	0.00

Note – biogenic CO_2 from wood heating and district energy is excluded. Normally, such GHGs are excluded from the GHG inventory but must be reported in a separate memo to the UNFCCC.

C&I Sector

It is a challenge to estimate energy use and GHGs in the City's C&I sector. NRCan's CEUD has data on secondary energy use for the Atlantic region in the C&I sector. The region's C&I sector energy use by activity is shown in Figure 16. The City's energy use in the C&I sector would be somewhat different.

Figure 16: Atlantic Canada's C&I Sector Secondary Energy Use by Activity



Unlike residential and transportation sectors, no data for PEI is available for the C&I sector in the CEUD. Regional secondary energy use in the C&I sector is analyzed. An observation when comparing the Atlantic region's secondary energy sources to those of other provinces is that the C&I sector in Atlantic Canada uses a higher share of electricity than any of the other provinces. Most recent values in the CEUD for Atlantic Canada suggest nearly 55% of all secondary energy use in the C&I sector is electricity. No other province/region in the CEUD has an electricity share >50%, there are a couple of locations in the 40%+ range, and other provinces have around a 1/3 share of secondary energy use being electricity in the C&I sector. Based on discussions with the internal advisory group and representatives with the province it is deemed reasonable to use a value of a bit less than 50% electricity as a share of overall secondary energy use in the C&I sector for the City. Part of the basis for this is the fact there is the DES that provides space conditioning and water heating to an estimated 420,000 m^2 of floor space, including an estimated 313,500m^2 of floor space in the C&I sector. In contrast, in the C&I sector across many areas of New Brunswick are thought to be using more electricity for heating.[53]

It is assumed that the energy intensity value from the CEUD of about 1.07 GJ/m^2 within the C&I sector of Atlantic Canada is realistic for the City of Charlottetown. The electricity data from MECL for general service customers is applied to the C&I sector with estimates of secondary energy use from the DES. For the remainder, estimates of shares of energy from oil, propane, and wood are made.

There is more vagueness about the amount of floor space attributable to the C&I sector in Charlottetown. Data on total C&I floor space for the Atlantic region in 2014 from the CEUD is multiplied by the average growth rate of regional floor space over the previous five years of about 0.7% per year, for an estimated 49.145 million m^2 in 2015. Table 26 shows regional census population counts by province, which are not official population estimates but used to approximate what may be the floor space for PEI.

Table 26: 2016 Census Population

Province	Population Count
NFLD	519,716
PEI	142,907
NS	923,598
NB	747,101
Total	2,333,322

PEI's census population is 6.12% of the Atlantic Region. Floor space is assumed to be proportional to census population. Thus, a bit over 3 million m^2 of floor area is assumed to be attributable to PEI's C&I sector. Charlottetown's census population in 2016 represents just over 25% of the province. If everything scales uniformly in terms of population to C&I floor space, then it is expected the sector's floor space is just over 760,200 m^2 for Charlottetown. As mentioned in SI.2 on District Energy, 313,500 m^2 is thought to have most space conditioning and water heating covered by the DES. The City of Charlottetown is the province's capital city and hub of activity in the C&I sector. For this reason, it is suspected the floor space in the C&I sector is more than 760,200 m^2.

The City's GIS technician explored several ways to accurately obtain data or better estimate floor space, even volume of spaces. Data on the footprint for non-residential (including C&I and industrial sectors) suggests when accounting for multi-storey buildings, the floor space may be somewhat to significantly greater than 760,200 m^2 value.

To more accurately estimate the C&I floor space, a principle of collective wisdom of crowds is applied, albeit on a small scale.[54] A diverse range of estimates are requested from City staff, employees from public works, water and sewer, economic development, and other areas, and provincial employees from various departments, and an informal survey of guesses from others in the community is undertaken. In the end, it is thought by the average estimation of the crowd, that over half of the C&I floor space on PEI could reside in Charlottetown. Some basic information is provided to people and guesses are made. A round number of 1.9 million GJ of energy/year is assumed in the C&I sector, with the CEUD energy intensity for the region of about 1.07 GJ/m^2. About 59% of the C&I floor space of PEI's C&I sector floor areas is assumed to be within the City, and it is assumed provincial floor area is proportional to population with regional provinces. This means floor space in the C&I sector is less than 1.78 million m^2. When the assumption is shared with several who participated in the informal survey, and when put into context with information from the GIS technician at the City it serves as a realistic initial assumption.

Better information on floor space and other useful information could help firm C&I estimates in the future. When the province develops energy and GHG inventories for its operations more information will be available in the institutional sector. It is conceivable energy providers could be compelled to provide the City data in the next iteration of the community energy and GHG inventory.

Industrial Sector

Data from MECL shows no electricity customers in the City are in the large-industrial rate class. Small-industrial rates attributable to City operations are shifted to the C&I sector. The remainder is applied to the industrial sector. For industry, NRCan's CEUD aggregates data for the Atlantic region. The share of electricity within the industrial sector's secondary energy use is assumed to be between 20-25%. This is deemed to be reasonable for Charlottetown based on discussions from a cross-section of engineers and energy-practitioners. Other fuels are primarily assumed to be oil with tiny amounts from other sources.

Transportation Sector

For this sector, data is available from the Canadian Vehicle Survey and from NRCan's CEUD. Although the Canadian Vehicle Survey was last released in 2010 for the year 2009 prior to being discontinued, it has reasonably good information for the purposes of the City's onroad energy and GHG estimates. PEI-specific data appears more accurate than metrics used in PCP software. For example, the most recent Canadian Vehicle Survey suggests PEI's heavy-duty vehicle fleet is significantly less fuel efficient compared to the national average. The PCP method would involve using a value that may underestimate the fuel consumption and GHGs in the heavy-duty vehicle fleet.

For onroad vehicles, official population estimates for the province in 2009 and 2015 are compared. The official estimate for July 2015 for PEI in terms of population is compared to the City population project at the same time (as shown section SI.1). For simplicity, it is assumed increases in the number of vehicles are proportional to population growth and that vehicles per capita are the same in Charlottetown as PEI overall, as with vehicle kilometers traveled. Fuel economy is considered slightly worse in light-duty vehicles as it is figured more distance is traveled in the City where fuel economy tends to be worse than on the highway. The numbers of heavy-vehicles are adjusted roughly based on the evidence in the provincial inventory suggesting the number of heavy vehicles is increasing. This is done conservatively, since some of the growth may be attributable to activities outside of the City, such as trucking of natural gas to the Cavendish Farms facilities in New Annan.

Offroad transport includes non-road, terrestrial/land-based energy and GHGs. This includes estimates for all lawn mowing, golf carts, farm tractors, snowmobiles, etc. Since the overall fuel, energy, and GHGs are small in this category, all of the assumptions forming the basis for the estimate is not provided in detailed here.

With aviation, some detail is shown in the summary document. Global passenger-kilometers performed (trillions) is calculated in Table 27 based on reference.[55]

Table 27: Global annual air passenger-km performed (trillions/year)

Year	*Air passenger-km (trillions/year)*	*Multiplier/Projected Year-Over-Year Growth*
2013	5.8	
2014	6.1	1.06
2015	6.5	1.063
2016	7.0	1.065

The total global air passengers in 2015 were 3.464 billion.[56] Given the global air passengers, and global annual air passenger-km performed, it is calculated 1,887 km traveled is the average number of passenger km per flight. This global average is applied to air passengers estimated to be attributable to Charlottetown in 2015. It is assumed on average at least 1.33 flights occur from original departure points to final destinations. The result is an estimated 2,509 km traveled per average air passenger.

Fuel economy is deemed 3.5 L/100 km per air passenger traveled. GHGs are calculated. In addition, a radiative forcing index to account for total aircraft emissions doubles the $GWP_{100\text{-year}}$ value relative to the fuel burned.[57,58]

To account for black carbon (BC) emissions in fossil soot, 100-year surface temperature response (STRE) of BC and primary organic matter (POM) per unit emission function in fossil soot of jet fuel is used, somewhat different than 100-yr GWP of BC used for all other fuels in this inventory.[59] The STRE is defined as the near-surface air temperature change after timescales such as 20 or 100 years per unit continuous emission of X relative to the same for CO_2.[60]

Table 28: 100-Year Surface Temperature Response Per Unit Emission (STRE)

	Low	Mid	High
Black Carbon and Primary Organic Matter in Fossil Fuel Soot	1200	1550	1900

Multiplying the STRE in the table by 12/44 obtains the STRE relative to CO_2/C. Table 29 shows the black carbon emissions indices (BC EI) associated with both take-off and climb out versus cruise performance, available in the literature. A weighting for each BC EI is deemed within reason, based on input from researchers with expertise in this field of study, resulting in an overall g-BC/kg-fuel. Having an estimate of the kg of fuel burned associated with Charlottetown's residents and businesses, excluding the tourism effect, and having an estimate of the overall g-BC/kg-fuel burned makes it possible to estimate the $STRE_{100\text{-}yr}$. It is slightly different than the $GWP_{100\text{-}yr}$, but is used as a proxy for GWP in the aviation sector. BC emissions and warming are estimated using $GWP_{100\text{-}yr}$ for all other fuels.

Table 29: Black Carbon (BC) Emissions Indices (EI)	**BC EI**	**Weight**
Take-off and climb-out (0.20 g-BC/kg-fuel)	0.2	20.0%
Cruise performance above 7 km (0.035 g-BC/kg-fuel)	0.035	80.0%
Overall g-BC/kg-fuel	0.068	

Table 12 in the main document shows energy and tCO_2e including GHGs, a radiative forcing index or RFI factor for emissions in the upper atmospheres and the 100-yr STRE for BC and POM. It makes sense to account for this source of global warming from human activity, instead of excluding the warming effects of aircraft entirely, as often done. Whether $STRE_{100\text{-}yr}$ values or straight $GWP_{100\text{-}yr}$ values are used to account for black carbon, these emissions and their effects on warming should be included. The methodology used to attribute warming from air travel in community energy and GHG inventories is an area for future work so towns and cities can recognize the global warming damages being caused by this mode of transport. Mitigation measures could be implemented near-term and longer-term.

Waste

Information was obtained from the Island Waste Management Corporation. There is some limitation in obtaining high quality or accurate data given the nature of collections within the capital region which extends past the City proper. GHGs from the decommissioned East Royalty landfill are not estimated.

Agriculture

Data exists on head of cattle by location but is confidential and could only be made available for emergency purposes. Estimates of head of cattle could not be based on rough 2017 counts. The number of cattle in the City has decreased since 2015. Informal discussion with a provincial official, and some residents, helped form the basis for cattle head estimates. In any case, numbers are small. Links are referenced in the main document to assist others with GHG estimates based on assumed head of cattle. Agricultural soils can have significant GHGs associated but no estimates are given here. Per unit area of land, GHGs from agricultural soils in the City boundary are likely low. This is an area for future work, but overall the GHGs in agriculture will still be small in comparison to those associated with energy use.

There are significant lifecycle climate impacts from food production which is then imported into the City. These GHGs are excluded from the GHG inventory but could be addressed with different food choices.

Black Carbon Particles

The globally-averaged GWPs for black carbon (BC) are shown in Table 30.

Table 30: Globally-Averaged GWP of Black Carbon

$GWP_{20\text{-yr}}$	$GWP_{100\text{-yr}}$
3200	900

The GWP of BC varies by region. To visualize why this is the case, one can imagine places where BC emissions occur and are more likely to be deposited on snow, which increases warming relative to BC emissions resultant from another location. To determine $GWP_{100\text{-yr}}$ attributable to the City, specific forcing pulses (SFP) for BC are used to compare the Canadian region relative to the global average. These SFP values are proportional to GWP. Table 31 shows the SFPs in GJ/g for the global average and the Canadian region.

Table 31: Black Carbon Specific Forcing Pulse (GJ/g)

Global Average	Canadian Region
1.15	1.19

Comparing the SFPs results in a multiplier of about 1.035 to convert the globally-averaged SFP of BC to the Canadian region, which is proportional to the $GWP_{100\text{-yr}}$ of BC, increasing the globally-averaged $GWP_{100\text{-yr}}$ value from 900 to about 931 times greater than CO_2 per unit mass of emission.

Table 32 summarizes calculations of BC emissions converted to tCO_2e. The mass of fuel burned (in kg) is quantified. The net BC emission factor for submicrometer particles is given by:

$$EF_{BC} = EF_{PM}F_{1.0}F_{BC}F_{cont}$$

where EF_{PM} is the bulk particulate emission factor in g/kg; $F_{1.0}$ is the fraction of the emissions with diameters smaller than one micrometer, intended to separate BC from larger particles such as ash and char; F_{BC} is the fraction of the fine particulate matter that is black carbon; and F_{cont} is the fraction of fine PM that penetrates the control device. For combustion without emission controls, F_{cont} = 1.0.

The result is a value in g of BC/kg of fuel. Assumptions are made about the fraction of gasoline and diesel fuel burned based on different standards of technology (see F_{stand}), from newer to older standards that are higher emitting in terms of BC/kg of fuel. In these cases the same equation is used but each standard has a different EF_{PM}. The column on the far right of Table 32 indicates the resultant kg of BC by fuel type. Some simplifying assumptions are necessary. Approximately 26 tonnes of BC emissions are estimated in 2015, for a $GWP_{100\text{-yr}}$ of about 24,000 tCO_2e.

Table 32: $GWP_{100\text{-}yr}$ of Black Carbon of All Fuels (except aviation)

Fuel Type	Fuel Units	Total Fuel (kg)		EFPM, g/kg	F1.0	FBC	Fcont	g-BC/kg fuel	Fstand	kg-BC
Fuel Oil	48,278,170	40,529,524		0.25	0.9	0.29	1	0.07		2,644,551
Gasoline	32,286,468	24,059,876	New	0.15	0.85	0.34	1	0.04	0.67	695,330
			Mid	0.5	0.85	0.34	1	0.14	0.25	869,163
			Old	2	0.85	0.34	1	0.58	0.08	1,158,884
Propane	3,695,275	1,875,352		0.52	1	0.13	1	0.07		126,774
Diesel	9,667,312	8,120,542	New	1.5	0.86	0.66	1	0.85	0.67	4,609,220
			Mid	3.5	0.86	0.66	1	1.99	0.25	4,033,067
			Old	12	0.86	0.66	1	6.81	0.08	4,609,220
Heavy Oil	1,360,000	1,350,208		1.1	0.45	0.08	0.565	0.02		30,210
Light Oil	1,490,000	1,250,855		0.49	0.18	0.3	0.565	0.01		18,700
MSW	NA	22,000,000		12.6	0.1	0.035	0.05	0.00		48,510
Wood Waste	NA	35,230,000		2.2	0.86	0.05	0.7	0.07		2,332,931
Wood (0% MC)	NA	1,803,123		10	0.85	0.1	1	0.85		1,532,654
Wood (50% MC)	NA	2,474,056		2.2	0.86	0.05	0.7	0.07		163,832
Coal Electricity		25,000,000								
High-Grade		8,333,333		12	0.09	0.006	0.475	0.00		25,650
Lower-Grade		8,333,333		29	0.09	0.006	0.475	0.01		61,988
Coke		8,333,333		5.8	0.35	0.48	0.33	0.32		2,679,600
Natural Gas Electricity		35,000,000		0.002	1	0.06	1	0.00		4,200
Total kg-BC in Fuel										26,000,000
Tonnes BC in Fuel										26
tCO_2e due to BC										24,000
tCO_2e per capita from BC										0.65

Estimates in above table are subject to uncertainty but the inclusion of warming from black carbon particles is probably an important factor to recognize and address. In addition to causing warming, these particles harm human health.

SI.3) Exclusions

This section provides some information regarding aspects of the energy and emissions inventory that are currently excluded.

Electric Vehicles

Electric vehicles are not included in transportation. Instead, electricity consumed is provided as metered data by MECL. In terms of non- or reduced-gasoline-powered transportation, as of 2016, only 22 electric vehicles and 280 hybrid vehicles were registered as active on the Island.[61] An efficient electric vehicle (EV) can travel up to 6.4 km/kWh of energy versus a highly efficient internal combustion engine vehicle (ICEV) such as the Honda FIT, which has a combined fuel economy as low as 6.5 L/100km. Given the energy content in gasoline, this means an efficient EV requires 25% of the energy to travel the same distance as an efficient ICEV. It is possible to estimate the number of EVs and hybrid vehicles in Charlottetown. In the spring of 2017, contact was made with a provincial employee who indicated detailed transportation statistics are obtainable. This could be usefuel in future work.

Onsite Solar and Wind Energy

Onsite solar and wind energy estimates are not included in the summary inventory. For 2015 these numbers are small. Table 33 shows estimates of onsite solar PV and wind electricity generation for the baseline inventory year.

Table 33: Urban Solar PV & Wind Electricity Generation Statistics, 2015

	PV	Wind
Installed Capacity (KW_{-DC})	130.36	50
Annual Average Capacity Factor (CF)	14.4%	17.1%
Annual AC Energy Output (kWh)	165,000	75,000

Notes:

a) Installed capacity refers to normal operating facilities.

b) Average PV CF is about 14.5% over PEI (MECL, 2017). Mostly Charlottetown's capacity faces south with optimal tilt and little shade so estimates for solar seem reasonable.

c) Approximation of annual average wind CF at single known location (Superior Sanitation, 2017).

Solar energy also comes in the form of thermal energy. Examples include passive solar energy received through winter daylighting, or Cansolair units that may be operational in the City. Cansolair units were popular in PEI during the 2007/2008 heating season as home heating oil prices increased dramatically before crude oil prices came to a peak at over $140/barrel in 2008-USD by the summer of 2008. Holland College's Applied Science and Technology Building features a SolarWall installation.[62] Passive solar, Cansolair and SolarWall installations provide solar thermal energy for space heating but only the latter one is currently available on the marketplace. Variants of the Cansolair technology once made in Newfoundland are likely available. The SolarWall is also Canadian technology and other variations on the technology exist. No estimates are attributed here for solar thermal's passive or active contributions to space heating. This could be an area for future work.

Table 34 gives estimates of solar thermal energy in use for water heating in 2015 based on available energy ratings by a Nova Scotia manufacturer of glazed, flat-plate solar thermal collector hot water preheaters.[63] There is uncertainty about the number of operational installations. Local knowledge is used to estimate approximate numbers of installations. It is important to note the utilization of solar thermal energy can be limited when directed for water heating hence the lower capacity factors. Whenever solar thermal energy is put to work within a district heating system it is possible to obtain higher capacity factors even when the solar energy in northern latitudes is stored thermally with a combination of short-term storage in hot water tanks and seasonal storage in underground rocks.[64]

Table 34: Solar Thermal Estimates, 2015

	Installed Capacity Per System (kW-th)	Number of Systems	Total Installed Capacity (kW-th)	Solar Thermal Energy Per System (kWh-th/Yr)	Total Solar Thermal Energy (kWh-th/Yr)	Capacity Factor	Total Solar Thermal Energy (GJ/Yr)	Oil (L) Avoided	Energy Content of Avoided Oil (GJ/Yr)	tCO_2e Avoided
Two Panel Collectors	3.6	35	126	2,761	96,639	9%	347.9	24,500	948	67
Single Panel Collectors	1.8	15	27	1,697	25,458	11%	91.65	5,250	203	17

DES Electricity Generation Estimates

The district energy system has 1.2 MW of electrical generating capacity. The assumed capacity factor of 85% is deemed reasonable. Depending on the source of information, all of the electricity generated is either consumed within the facility, or some of it is sold to the grid. It is assumed the latter is likely the case. It is assumed a majority of the electricity generated, perhaps around 90%, is used to offset the onsite electrical energy demand of the DES and the remainder is exported. Due to the uncertainty in community energy quantities, the added secondary energy use and local electricity supply source is omitted.

Propane Use for Barbecues

Propane use for barbecues is excluded from residential energy use and GHGs. If half of the total households in the City average one 20 pound tank of propane per year, this is 37,160 liters of propane consumption, or 940.52 GJ/year in 2015, plus 57 tCO_2e and a small amount of BC from fuel combustion and grilling. Conventional barbeques result in a lot of additional smoke as foods are cooked which increases air pollutant emissions and health impacts.

Wood Burning in Fire Pits

Wood burning in fire pits is not estimated. This would result in high-levels of local exposure to air pollution from wood smoke and which could impact the health of children and the elderly. A lot of CO_2 would be released into the air per unit of energy, but it is considered biogenic. Within the context of the overall inventory and given the uncertainties, no quantities for wood burning in fire pits are provided here. If wood burning in campgrounds is included from residents' activities outside of the City for recreational purposes then the inefficient and polluting combustion of wood in fire pits could increase significantly.

Backup Electricity Generators

Gasoline and diesel fuel consumption in backup generators and associated emissions are excluded from the inventory. Although initial estimates are made by the City, none are detailed here. Overall, these numbers are small relative to uncertainties associated with energy and GHG quantification for the community-level at this time. Diesel consumption for backup generators within the City's corporate operations is accounted for.

Biogenic CO_2

In this section, the City relies upon recent literature related to CO_2 emissions from biomass combustion and contribution to global warming.

> "Carbon dioxide (CO_2) emissions from biomass combustion are traditionally assumed climate neutral if the bioenergy system is carbon (C) flux neutral, i.e. the CO_2 released from biofuel combustion approximately equals the amount of CO_2 sequestered in biomass. This convention, widely adopted in life cycle assessment (LCA) studies of bioenergy systems, underestimates the climate change impact of bioenergy.[65] Besides CO_2 emissions from permanent C losses, CO_2 emissions from C flux neutral systems (that is, from temporary C losses) also contribute to climate change: before being captured by biomass regrowth, CO_2 molecules spend time in the atmosphere and contribute to global warming."[66]

> "Following the Organization for Economic Co-operation and Development (OECD) convention, bio CO_2 emissions are removed from the atmosphere by the onsite biomass growth. If this closed perspective is adopted, bio CO_2 will decay from the air only because of the biomass regrowth. This means that there are no contributions from the rest of the C cycle components.

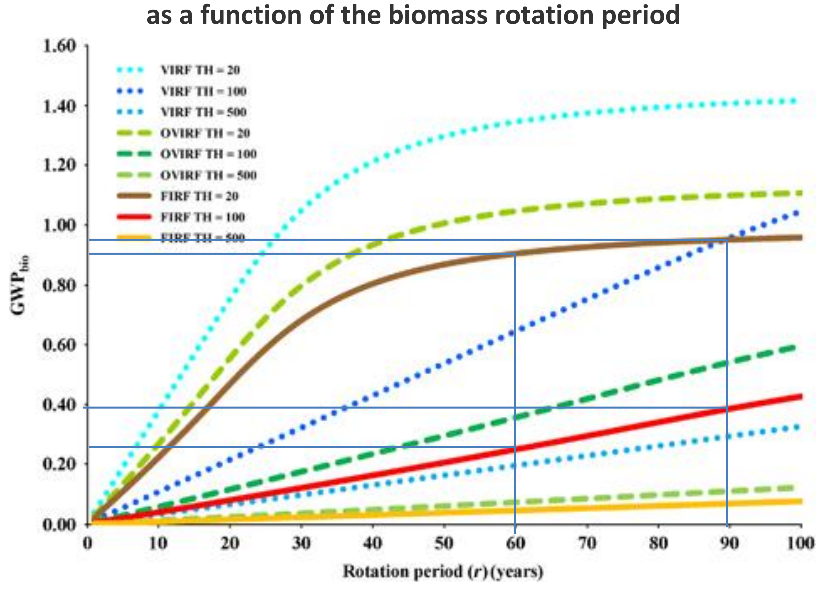
Since it is totally unphysical to neglect any CO_2 uptake from the oceans or other sinks, this option is considered here only to analytically demonstrate the inadequacy of the OECD convention through the inconsistent results obtained.[67] This approach is referred to as the vegetation [CO2] impulse response function (VIRF)."

"Oceans play a key role in the removal of CO_2 from the atmosphere. In this case, the ocean sink is added to the vegetation regrowth sink by considering a proper climate model, so giving a specific profile for the atmospheric decay of bio CO_2, the ocean and vegetation IRF (OVIRF)."[68]

"As considered in complex carbon cycle models, when a CO_2 molecule is released to the atmosphere can be removed by both the ocean and terrestrial biosphere. In this case, a complete IRF is used and the resulting atmospheric decay is referred to as the full IRF (FIRF).[69] In this analysis the FIRF is used (continued on the next page)."

Figure 17 shows the value of the GWP_{bio} index as a function of the biomass rotation period for the three different cases and for the three selected time horizons (THs). The curves have an exponential trend to a maximum, which has the same value for each method and can be better appreciated for TH=20 years.[70]

Figure 17: GWP_{bio} for TH equal to 20, 100 and 500 years as a function of the biomass rotation period



First, biogenic CO_2 is quantified before accounting for the GWP_{bio}, which here is integrated over a 100-yr TH using the FIRF approach for wood combustion, as shown in Figure 17 above. The bioCO_2 conversion factor per kg of wood is derived from reference.[71] BioCO_2 emissions are estimated to be over 36,000 tonnes in 2015 with 34,725 tonnes of bioCO_2 that year estimated to be emitted from wood combustion (see Table 35).

Table 35: Biogenic CO_2

	kg fuel	*$tBioCO_2/kg$*	*$BioCO_2$*
Wood Fuel - Residential (0% moisture)	1,803,123	0.001696	3,058
Wood Chips (50% moisture)	37,700,461	0.000840	31,667
	m^3	*$tBioCO_2/m^3$*	*$BioCO_2$*
Biogas (for energy use plus flared)	780,164	0.001864	1,454
$BioCO_2$ from biogas leakage	39,008	0.000674	26
Total $BioCO_2$			36,206

Next, the GWP of biogenic CO_2 for the wood burned in the community are converted using an index factor to adjust $bioCO_2$ to the $GWP_{100\text{-}yr}$ climate impact (or tCO_2e) after removals of CO_2 by both the ocean and terrestrial biosphere are accounted for in complex climate models.

The assumptions of 60-90 year rotation periods for forests are used. 80-100 years of regrowth is common for boreal forest.[72] The longer the rotation period the greater the GWP is for wood combustion. There are other factors to consider but this provides more realistic accounting of the climate impacts than those typically used for LCAs and GHG inventories. Including the climate impact of bioCO2 with a rotation period of 60-90 years could results in up to 8,700-13,500 tCO_2e of additional climate-relevant emissions, or more, which are excluded in this GHG inventory, depending upon assumptions such as the rotation period primarily, among others.

Table 36: GWP_{bio} 100-Yr Index After Removal by Both the Ocean and Terrestrial Biosphere (tCO_2e)

	60-Yr Regrowth	90-Yr Regrowth
Wood Fuel - Residential (0% moisture)	765	1,193
Wood Chips (50% moisture)	7,917	12,350
Total GWP_{bio} 100-Yr (tCO2e)	8,681	13,543

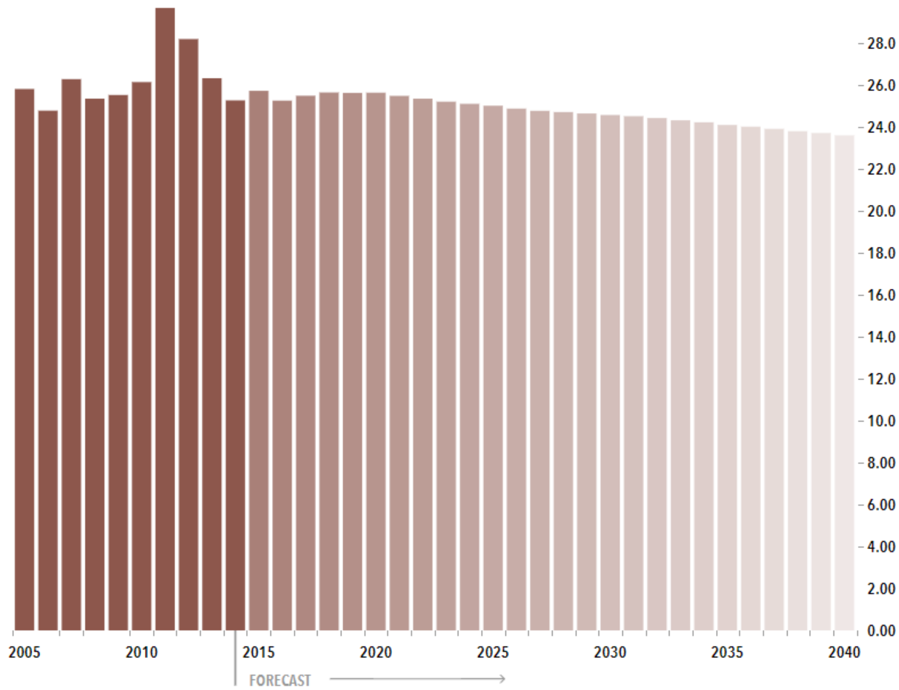
This discussion of biogenic CO_2 and its climate impact is limited. No GHG intensity per unit energy is calculated here, to compare climate impacts of wood combustion with other alternatives. This initial parameterization should be useful in the lead-up to the City's evaluation of options to reduce GHGs while minimizing environmental effects. In future, $BioCO_2$ resulting from biomass burning may be more clearly accounted for so these emissions get reflected in community/provincial/national energy-related GHG inventories. Conversion to biomass systems may result in community expenditures but continued exposure to carbon pollution pricing along with unnecessary air pollution effects on human health.

SI.4) Business-As-Usual Projection

The National Energy Board (NEB) provides a business-as-usual (BAU) reference scenario for Canada and PEI's energy future to 2040.[73] In the BAU scenario of incremental change the future energy demand is similar to today's, implying some energy efficiency improvements and behavioral changes. The BAU scenario offers a baseline outlook with a moderate view of energy prices and economic growth, and climate and energy policies announced at the time of analysis.[74] Renewables grow little, electricity use increases a bit, and the use of petrol decreases a bit.

Figure 18 shows the projected energy demand for PEI (not GHGs) under a BAU case. It is possible future energy demand for PEI is underestimated, since the latest population projections are far higher than those used in this model.[75]

Figure 18: Projected Energy Demand for PEI to 2040



Units are expressed in petajoules (PJ) of energy. 1 PJ = 1 million GJ

A recent study gives BAU projections and one of many possible 100% clean, renewable energy scenarios for all purposes across Canada by 2050.[76]

The City uses population projections in SI.1 to develop a BAU projection based on the following assumptions: per capita energy use and the GHG intensity per unit energy (applied to all GHG sources) each decrease by 0.5% per annum through to 2025, then by 0.75% annually through 2035 and then by 1% per year thereafter.

The projected energy demand for the City with BAU incremental change is higher than the one being projected by the NEB due to the likelihood NEB's does not account for the dramatic upward revisions to population projections released by the province and also the City population has increased more quickly than the province's overall. Population is expected to increase over 47% in the City while energy use increases less than 12% under this BAU case.

The City of Charlottetown's community GHGs including black carbon particle emissions are amount to roughly 456,000 tCO_2e in 2015, and increase to about 485,000 tCO_2e/year in 2025 before falling to 2015 levels by the late 2030s and eventually reaching about 387,000 tCO2e/year in 2050. The absolute decrease in the community's climate-relevant emissions is only 15.1% under this BAU scenario from 2015-2050.

The reason for the expected shortfall in meeting GHG reduction targets with BAU and incremental change is primarily due to population growth. Such a scenario is unacceptable in terms of climate change mitigation and far more ambitious GHG reductions will be needed.

Figures 19, 20 and 21 show population, energy use and GHGs projected respectively for Charlottetown given business-as-usual (BAU) incremental change. These projections are subject to revision.

Figure 19: City of Charlottetown Population Projection, 2015-2050

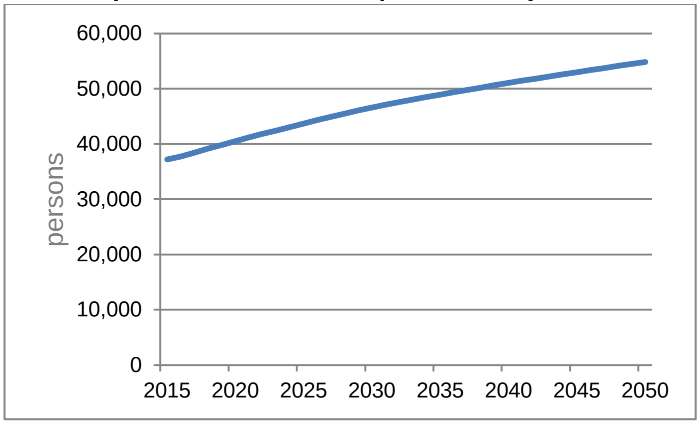


Figure 20: City of Charlottetown BAU Energy Projections, 2015-2050

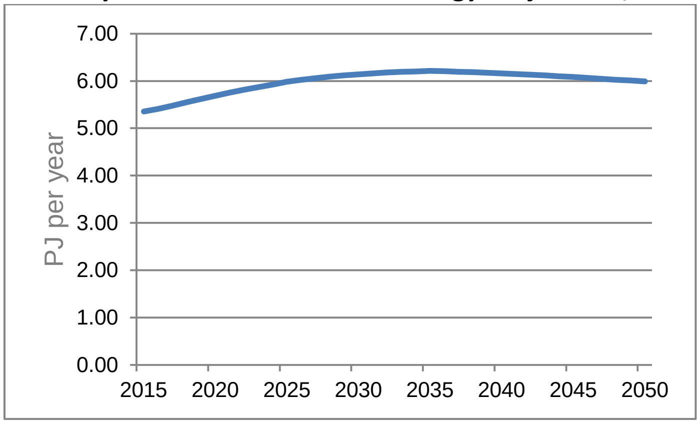
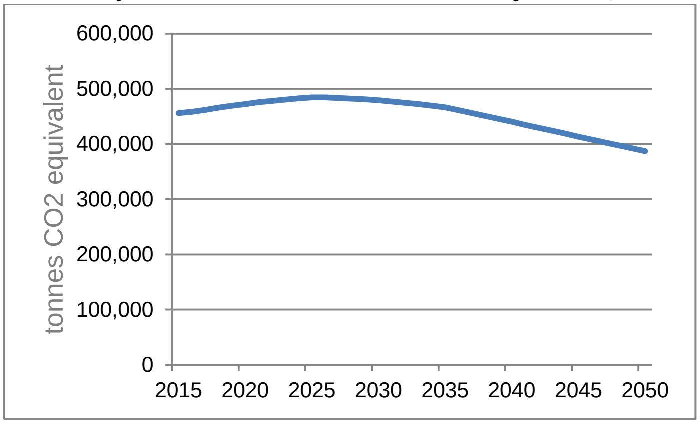


Figure 21: City of Charlottetown BAU GHG Projections, 2015-2050



Includes warming from GHGs and black carbon particles

SI.5) Energy Expenditures

Energy expenditures are estimated at $176 million in 2015 (2017-CAD) for the business cost of energy (Table 3 in the overview). To estimate expenditures in Table 3, volumes of petroleum sales are obtained from the Island Regulatory and Appeals Commission (IRAC) with the monthly petroleum sales by fuel type for the province in 2015.[77] This information has the annual total fuel sales and seasonality of fuel sales for each fuel type month-by-month. Adjustments are made to the seasonality of gasoline and diesel fuel sales to exclude tourism-related gasoline sales, and diesel sales associated with agriculture, fishing, and cruise ship traffic which are excluded in this inventory. With respect to heating oil and propane sales the seasonality is deemed to be representative of sales within Charlottetown.

IRAC's website has information available on all petroleum price adjustments for the 2015 year.[78] Volume data on monthly gasoline sales shows the percentages of gasoline sold in terms of regular unleaded, mid-grade, and premium. These percentages are weighted into an energy pricing model. Nearly 95% of gasoline fuel sold is regular unleaded, almost no sales of mid-grade gasoline fuel occur, and close to 5% of gasoline sold is premium.

It is assumed that about 90% of all gasoline sales are self-serve. For diesel, tank truck deliveries to fill tanks for backup generators do occur in some cases and those sales are priced higher than are pump prices. Since almost all diesel fuel sold at pumps is self-serve as it mainly occurs within the heavy-duty vehicle fleet, it is deemed reasonable for 90% of overall diesel sales in the City to be set at the self-serve approved prices, with the rest set at the full-serve pump price; an assumption made to speed up data processing time. Low-high values of approved pump prices are averaged, weighted by fraction of self-serve to full-serve prices, and by grade of fuel in the case of gasoline. For propane, bulk delivery prices from Irving are used.

There are a total of 31 petroleum price adjustment dates over the 2015 year made by IRAC. Each price update is matched to the seasonally adjusted fuel sales estimated for the City over the same period that these prices are in effect. Taxes are included.

For residential and other wood sales, current prices are available on a per cord basis. This is converted into kg of fuel sold. The price does not fluctuate due limited data. For district energy, City Hall, the Fire Station on Kent Street, and the Charlottetown Police Station are each connected to the DES. The total average cost paid by the City per MWh is assumed to be representative of the 100,082 MWh of thermal energy estimated to be delivered to end-use customers in 2015 via the DES.

For electricity, an audited statement including MECL's total revenues is obtained from the IRAC website for the 2015 period. PEI's total electricity supply in 2015 is available in the PEI Annual Statistical Review. It is estimated that about 10% of electricity is associated with Summerside Electric. Some MECL revenues would be attributable to MECL to transmission and distribution of electricity to Summerside Electric, and for transmitting electricity dedicated for export from the West Cape Wind Farm. Estimates are made to subtract these revenues. The remainder of total revenue in 2015 is divided by the electricity estimated to be metered to MECL customers. The result is a price per kWh that includes energy, demand and other charges. This value is used and 14% harmonized sales tax is added.

SI.6) Social Cost of Carbon

It is useful for government officials, policymakers, and the general public to be informed about the global social cost of carbon (SCC) when the issue of carbon pollution pricing arises. The SCC is a measure, in dollars, of the long-term damage done by a tonne of carbon dioxide equivalent (CO_2e) emissions in a given year. The SCC is unlikely to be near $10, $30 or $50 per tonne of carbon dioxide equivalent emissions (tCO_2e). While the U.S. EPA recently estimated the 2015 SCC as $39/tonne-$CO_2e$ in 2011 USD using a 3% discount rate and the Government of Canada has come to similar values, detailed peer-reviewed literature suggests the SCC may be far higher.

CO_2e emissions from energy use includes emissions of CO_2, other greenhouse gases such as methane (CH_4) and air pollution particles that cause global warming such as black and brown carbon, converted to CO_2e. All climate-relevant emissions must be considered. Black carbon and brown carbon or soot particles from fossil fuel and biomass burning may be the second-leading cause of global warming in terms of radiative forcing after CO_2 and ahead of CH_4, although the damage costs of these warming particles are often still ignored.

A review of recent literature found the range of the 2050 SCC is $500 ($282–$1,063) per metric tonne-$CO_2e$ emissions in 2013 U.S. dollars.[79] Based on their review the 2010 SCC was estimated as $250 (125–600) per metric tonne-CO_2e emissions in 2007-USD, with the mid-range estimate increasing 1.5%/year.

Several studies, including some important recent meta-analyses, estimate the damage cost of CO_2e emissions or the SCC. Most studies recognize, even if only informally or qualitatively, that there is some non-trivial possibility of severe impacts of climate change and a correspondingly very high SCC. The main point of contention is the plausible lower bound on the SCC.

The widely referenced FUND, PAGE, and DICE models, which are integrated assessment models (IAMs), estimate very small lower-bound estimates under some sets of assumptions regarding discount rates, risk aversion, equity weighting, extreme impacts, uncertainty, and other factors.[80] Yet, in a recent review and meta-analysis, authors argue against the assumptions that lead to the lowest estimates of SCC, and make a persuasive case that the lower-bound of the SCC should not be less than $125/tonne-$CO_2$ in USD[81]. They conclude that "the lower bound...of U.S. 125 per tCO_2 is far below various estimates found in the literature that attribute a high weight to potentially large climate change impacts...[and] therefore can be considered a realistic and conservative value" (p. 256). (See also[82, 83]).

In support of this, in another recent re-analysis of the SCC, authors find that incorporating the effect of climate change on the rate of economic growth – a feedback typically not included in standard low-end estimates of the SCC – can dramatically increase the SCC to hundreds of dollars per ton and higher.[84]

The SCC of emissions in a given year is also likely to increase over time as GDP, atmospheric GHG levels, and average temperatures increase. [85, 86] Given these higher-end range of estimates for the SCC, a recent study estimates the SCC increases from 2010 to 2050 at 2.0%/year in the low-SCC case, 1.6%/year in the mid-case, and 1.4%/year in the high-SCC case.[87]

In this document, the SCC is estimated at $250/tonne of CO2e in 2007-USD and is set to increase at a rate of 1.5%/year. This is brought to 2017-USD accounting for inflation. A 1:1 relationship between CAD and USD is assumed, similar to the period from early 2009 to late 2014. For the baseline year of 2015, this results in a SCC equal to about $320/tonne of CO_2e expressed in 2017-USD. Given estimates for the

City of Charlottetown of 456,027 tCO_2e, or 12.26 tCO_2e per capita in 2015, the SCC is $146.1 million/year; $3,928 per person per year.

The SCC appears far higher than previously thought. Discourse about values such as $10, $30, or 50/tonne-$CO_2e$ is likely to be insufficient. In addition to pricing carbon pollution explicitly, supplemental standards, legislation, regulations, policies and programs will be complimentary and are likely necessary to meet the goals of slowing global warming laid out in the Paris Agreement.[88]

It is important to educate people about the SCC based on persuasive cases that have been made in recent literature that the SCC is likely much higher than is often considered. When the public is aware of the damages being done and these societal costs are put into a sociopolitical sphere, individuals, businesses, and elected leaders can act accordingly.

SI.7) Social Costs of Air Pollution

A draft paper on this topic is provided on the following pages.

Potential Mortality from Air Pollution Exposure to Fine Particles and Ground-Level Ozone on Prince Edward Island[89]

Abstract

Prince Edward Island (PEI) Canada has cleaner air than many places worldwide. Newcomers to PEI from highly polluted places such as China often place an extremely high value and comment on the superior air quality and environmental conditions found on the Island, even compared to larger centres in Canada. While the air is cleaner on PEI, this paper offers potential premature mortality estimates from exposure to fine particulate matter ($PM_{2.5}$) and ground-level ozone (O_3) in the province. Potential mortalities attributable to $PM_{2.5}$ and O_3 are each broken out across PEI by county: Prince, Queens, and Kings County. Air pollution-related mortalities in the City of Charlottetown are estimated. Social costs from mortality and non-mortality costs are estimated for PEI as a whole, by county, and for the capital city.

Introduction

Acute (short-term) and chronic (long-term) exposure to fine particulate matter ($PM_{2.5}$), and exposure to ground-level ozone (O_3) results in minor illnesses, workdays lost, schooldays lost, lost productivity and wages, increased doctor and emergency room visits, hospitalizations, and is attributable to death.[90]

Exposure to outdoor air pollution from $PM_{2.5}$ is the 5th highest ranking risk factor for death globally, responsible for millions of deaths each year from heart disease and stroke, lung cancer, chronic lung disease, and respiratory infections. [91] Over 250,000 deaths per year are attributable to exposure to O_3 and its impact on chronic lung disease. [92] $PM_{2.5}$ is attributable to a substantially larger number of deaths than other, more well-known risk factors, such as alcohol use or physical inactivity.[93] It contributes to a similar number of deaths as does high sodium intake and high cholesterol. Two new studies have estimated outdoor air pollution from $PM_{2.5}$ plus O_3 causes 4.5-5 million deaths annually worldwide.[94, 95] These estimates did not account for the open burning of wood, animal dung, crop waste, and coal for indoor cooking and heating in developing countries known to cause 4.3 million deaths each year.[96]

The purpose of this paper is to offer preliminary estimates of potential mortality from air pollution exposure to $PM_{2.5}$ and O_3 on Prince Edward Island (PEI). The focus is not to review all of the epidemiological evidence of these health effects or to present any new localized epidemiological findings. Health effects from exposure to air pollution are established in literature.[97]

The Canadian Medical Association estimated 21,000 Canadians die annually of dirty air (CMA, 2008).[98] 2,682 Canadians were estimated to die/year of acute $PM_{2.5}$ and O_3 exposure in 2008. The value of statistical life for acute deaths was assigned as only $2.4 million per life lost in 2006 Canadian dollars (CAD). Illness costs including acute mortality, some illness costs, and excluding others were put at over $10 billion per year and rising (2006 CAD). No value was assigned for the majority of mortalities from chronic air pollution exposure.

In PEI, the CMA estimated exposure to $PM_{2.5}$ and O_3 air pollution was responsible for 80 chronic premature deaths in 2008, with annual illness costs of $28.2 million (2006 CAD). Encapsulated in this, according to the study, were 10 annual acute deaths on PEI. CMA (2008) projected annual chronic mortality attributable to air pollution from $PM_{2.5}$ and O_3 exposure would be 105 deaths in 2017. No value was assigned for chronic premature deaths. CMA (2008) authors stated (footnote 17, pg. 20 of 113):

> "These economic damages are based on acute premature mortality cases. Given the high economic value assigned to avoiding premature mortality, the corresponding economic damages for chronic premature mortality would be much higher."

This paper offers new estimates of premature mortality from air pollution due to $PM_{2.5}$ and O_3 exposure in the province of PEI based on hourly data obtained from the province. Annual premature deaths have been broken out for each county of the Island: Prince, Queens, and Kings County. Estimates of the number of annual deaths attributable to air pollution have been given for the City of Charlottetown. With improved attributions to account for the value of life, social costs from mortality and non-mortality costs have been provided for PEI as a whole, by each county, and for the capital city.

Methodology

This study draws upon existing research into the health effects of air pollution from $PM_{2.5}$ and O_3 and estimates potential mortalities across PEI that are attributable to exposure to these air pollutants. Hourly data was obtained from 2011-2013 from three air quality monitoring stations on PEI for both $PM_{2.5}$ and O_3. Monitoring stations are located in Wellington, in Prince County (western PEI); Charlottetown, in Queens County (central PEI); and in South Hampton, Kings County (eastern PEI) – see Figure 21.

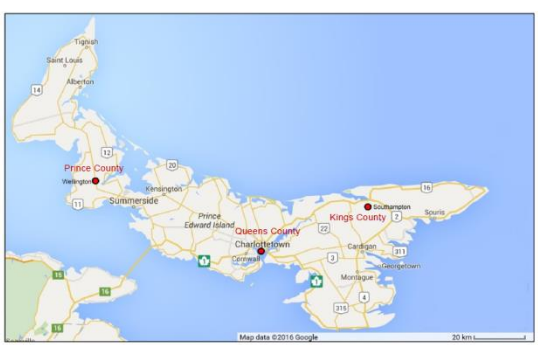


Figure 21: PEI Air Monitoring Stations

Each monitoring station is located away from significant sources of pollution such as the District Energy System on Riverside Drive in Charlottetown. The air monitoring station in the capital is sited in a residential area away from any major roadway.

Total population by county and for the capital city of Charlottetown is estimated for 2017 with some approximation. 2016 census population data (not official estimates) plus official provincial population figures for July 1, 2017 are combined to estimate population by county. For Charlottetown, census population data from 2011 and 2016 along with official population numbers from the province suggests city population may be growing slightly quicker than PEI's overall. This is accounted for. The total 2017 population estimates for each location and mean $PM_{2.5}$ in micrograms per cubic meter ($\mu g/m^3$) is provided in Table 37.

Table 37: Prince Edward Island Population and Average $PM_{2.5}$

Location	Population Estimates, 2017	Mean $PM_{2.5}$, 2011-2013 ($\mu g/m^3$)
Prince County	46,519	5.7
Queens County	87,248	6.3
Kings County	18,254	5.0
TOTALS	152,021	N/A
Charlottetown	38,450	6.3

Time-varying $PM_{2.5}$ and O_3 concentrations are applied to populations for each of the counties and for the City of Charlottetown. A health effects equation is used to calculate premature mortality estimates from exposure to these pollutants. The approach taken is similar to that in other peer-reviewed literature,[99, 100] the latter reference looked at all ages.

Health effect rates (y) due to pollutants for each location are determined from:

$$y = y_0 \sum_i \left\{ P_i \sum_t (1 - \exp[-\beta \times \max(x_{i,t} - x_{th}, 0)]) \right\}$$

Where $x_{i,t}$ is the concentration in location i at time t, x_{th} is the threshold concentration below which no health effect occurs, β is the fractional increase in risk per unit x, y_o is the baseline health effect rate, and P_i is the location population.

High, medium, and low estimates of premature air pollution mortality rates for each county and Charlottetown are estimated by combining $PM_{2.5}$ and O_3 data over 2011-2013 with high, medium, and low relative risk coefficients and population sets.[101] To be conservative and ensure air pollution death rates are not over-calculated, down-weighted relative risk coefficients are used for concentrations of $PM_{2.5}$ <8 $\mu g/m^3$ (see reference[102]) although there is no safe threshold to $PM_{2.5}$. Concentrations of only a few $\mu g/m^3$ have been shown deleterious to human health. One highly cited study found for every 5 $\mu g/m^3$ of $PM_{2.5}$ there was an increased risk of lung cancer by 18%.[103] This alone suggested results obtained here may be conservative. The low concentration threshold for health risks from O_3 exposure is 35 ppbv.

Social costs of air pollution mortality and non-mortality are calculated based on the value of life assigned by the United States of America's Environmental Protection Agency in 2010 of $9.1 million U.S. dollars (2009 USD).[104] This is brought forward to current dollars accounting only for inflation. A 1:1

relationship is assumed between USD and CAD, similar to the period from early 2009 to late 2014. Mortality costs estimates are based on a value of about $10.46 million CAD.

For non-mortality costs, such as morbidity costs that do not result in death, U.S. EPA values were recently estimated at 7% of mortality costs.[105] However, other studies in the economics literature indicate considerably higher non-mortality costs. A comprehensive analysis of air pollution damages at every air quality monitor in the U.S found that the morbidity cost of air pollution (mainly chronic illness from exposure to particulate matter) might be as high as 25% to 30% of the mortality costs.[106] A central estimate for non-mortality costs of about 16% is obtained by averaging the 7% and 25% values. Mortality plus non-mortality costs were calculated as approximately $12.14 million per premature death due to air pollution. Parameters used for the health effects equation are shown in Table 38.

Table 38: Additional $PM_{2.5}$ Health Effects Equation Parameters

	High	Mid	Low
Baseline Mortality Rate [(a)]	0.00906	0.00906	0.00906
Minimum safe $PM_{2.5}$ threshold ($\mu g/m^3$)	0	0	0
$PM_{2.5}$ mortality risk, high concentrations(>8 $\mu g/m^3$)	0.008	0.004	0.001
$PM_{2.5}$ mortality risk, low concentrations (<8 $\mu g/m^3$)	0.002	0.001	0.00025
Minimum safe O_3 threshold	35	35	35
O_3 mortality risk per 1 ppbv increase above threshold	0.0006	0.0004	0.0002

a) Annual baseline mortality rate for PEI is 906/100,000 people.

Results

Table 39 shows estimates of air pollution deaths attributable to $PM_{2.5}$ plus O_3 on PEI and for Charlottetown. Table 40 shows the estimates of economic damages caused by air pollution from loss of life and morbidity costs. Tables 41 and 42 show results obtained from calculations for both $PM_{2.5}$ and O_3 separately. Results were rounded.

Table 39: Air pollution deaths from $PM_{2.5}$ and O_3 on Prince Edward Island

	High	Mid	Low
Prince County	9	5	1
Queens County	23	12	3
Kings County	4	2	1
Total Annual Air Pollution Mortality on PEI	36	19	5
Total Annual Air Pollution Mortality in Charlottetown	14	7	2

Table 40: Air pollution mortality plus non-mortality costs by on PEI ($M-CAD/Year)

	High	Mid	Low
Prince County	$109	$61	$12
Queens County	$279	$146	$36
Kings County	$49	$24	$12
Total Annual Air Pollution Mortality & Morbidity Costs of PEI	$437	$231	$61
Annual Air Pollution Mortality & Non-Mortality Costs of Charlottetown	$170	$85	$24

Table 41: $PM_{2.5}$–related chronic premature mortality estimates for PEI

	High	Mid	Low
Prince County	9	5	1
Queens County	22	11	3
Kings County	4	2	1
Total Annual $PM_{2.5}$-Related Premature Mortality on PEI	35	18	5
Total Annual $PM_{2.5}$-Related Premature Mortality in Charlottetown	14	7	2

Table 42: O_3-related premature deaths for PEI

	High	Mid	Low
Prince County	0	0	0
Queens County	1	1	0
Kings County	0	0	0
Total Annual O_3-Related Premature Mortality on PEI	1	1	0
Total Annual O_3-Related Premature Mortality in Charlottetown	0	0	0

PEI's total air pollution mortality is estimated as 19 (5-36) deaths per year. Premature mortality due to air pollution in Charlottetown is estimated at 7 (2-14) deaths annually. Provincially the social cost of air pollution, including mortality and non-mortality costs such as illness costs that do not result in death; are estimated to be $231 million/year ($61-$437 million/year). The economic damage costs of air pollution for Charlottetown are estimated at $85 million/year ($24-$170 million/year).

Discussion

Results may be representative for counties, the capital city, and PEI overall given local air quality monitoring data and literature on exposure to $PM_{2.5}$, O_3, and dose-response relationships. A recent study found ambient population-weighted $PM_{2.5}$ in Canada is about 7 µg/m^3 compared to 6.0 µg/m^3 in PEI. That study estimated the annual deaths attributable to $PM_{2.5}$ exposure in Canada are 7,100.[107] Canada's population for the study year of 2015 was 35,804,000 with quarterly estimates for the year being averaged.[108] This means the death rate attributable $PM_{2.5}$ in Canada for the year is nearly 20 per 100,000 people. Results in this study indicate about 12 deaths/year are attributable to $PM_{2.5}$ per 100,000 people in PEI.

The same study found 690 annual deaths are attributable to O_3, a death rate of nearly 2 deaths per 100,000 in Canada. This compares to results here of less than 1 death per 100,000 people in PEI.

Another recent study found 14,400 (4,000-27,200) annual deaths are attributable to $PM_{2.5}$ and O_3 in Canada[109] as compared to 7,800 deaths a year in the above comparison of Canada to PEI air pollution deaths. In the study which estimated the higher air pollution death toll in Canada, its low- and high-end estimates capture results from the comparison study of Canada to PEI shown above, and results from the Canadian Medical Association's earlier air pollution study. Thus, the results obtained in this study on air pollution mortalities for PEI and Charlottetown, appear reasonable and conservative.

The value of life assigned to Canadians should at least equal the precedent set in the U.S. The statistical value of a human life should arguably be treated more equally, with less regard to the monetary economic circumstances of an individual or population set. The value of life is unquestionably significant. Lives are being lost prematurely due to air pollution on PEI. This should be given far more weighting relative to CMA (2008) and other studies. Some institutions and recent reports continue in assigning too little value to the lives being lost from air pollution. Value of life assigned here is on the order of about half of the values for life which have been estimated in numerous studies in the economics literature.

Conclusions

This paper offers a range of estimates based on real data and existing literature to account for uncertainty and found exposure to fine particles ($PM_{2.5}$) and ground-level ozone (O_3) may be responsible for approximately 19 premature deaths annually across PEI including 7 deaths per year in Charlottetown.

It is sensible to attribute greater value to the lives of Islanders being lost prematurely due to air pollution. Social costs from deaths and illnesses that do not result in death are estimated to be roughly $231 million/year across PEI including $85 million/year in Charlottetown.

Policies to ensure cleaner air have merit, such as significantly improved funding for energy efficiency programs. Energy efficiency programs and energy conservation measures ought to be crafted to enable a more rapid transition to high penetrations of non-emitting energy sources like wind, solar, and other clean renewable energy sources that could provide PEI's energy services for electricity, heating, cooling, and transportation. With the exception of hydrogen fuel, combustion cannot reduce both greenhouse gases and air pollutants to near zero over their lifecycle. Given the economic damages of air pollution in terms of lives lost, morbidity, and the societal costs, energy policies should place more emphasis on having a greatly lessened role, near-term, for both fossil- and bio-fuel combustion. This includes biomass, biofuels like ethanol, biodiesel, aviation fuel derived from bio-feedstocks, etc. Cleaner alternatives are viable.

Accelerated transition to more efficient energy usage and clean renewable energy sources non-emitting by nature is beneficial. Air quality will improve with a more rapid transition to clean energy, thus the quality of life for Islanders will be enhanced; protecting our public's health from unnecessary pollution.

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