Baseline Energy Study for Ottawa 2015

Including Supply Origin, Fuel Type, Use by Sector, GHG Impacts and Cost

Presented to:

The City of Ottawa
110 Laurier Ave W
Ottawa, ON K1P 1J1

In relation to
The City of Ottawa Energy Evolution Program

By:

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October 17, 2017

ABOUT THIS REPORT

City of Ottawa Energy Evolution Program

On July 8, 2015, Ottawa City Council approved the development of a Renewable Energy Strategy as part of the 2015-2018 City Strategic Plan. This initiative has been developed into a program entitled Energy Evolution – Ottawa's Renewable Energy Strategy. A main goal of Energy Evolution is to develop a baseline analysis of energy supply and demand within the City of Ottawa and assess options, in collaboration with community partners, for all such partners to advance energy conservation, energy efficiency and renewable energy generation within their respective areas of control and influence. The Energy Evolution program has interacted closely with community stakeholders from local utilities, the federal government and other government institutions, the development sector, academia, the non-profit sector, and the private sector at large. Leidos Canada was engaged by the City to support analysis in the energy supply domain, including research reports and facilitation of discussion with stakeholders.

The Purpose of this Report

This and other "Pathway Study" documents are focused technical notes describing how the specific energy technology may develop in Ottawa. The document considered the overall technical potential for implementation, and then further considered the constraints (economic, regulatory, etc.) that are likely to reduce uptake. It **s**uggests opportunities to influence uptake rates and catalyst projects that may be attractive to consider further. Results of the Pathway Studies are intended to be used along with the Baseline Study of energy data towards an overall assessment of future energy strategies within the City of Ottawa Energy Evolution program.

A draft form of this Pathway Study was circulated to key stakeholders and experts in the topic during the summer of 2017. Meetings were also undertaken during this period, where these representatives contributed their insights and ideas towards the development of leading project opportunities in relation to the topic of the Pathway.

Other documents in this series are:

Pathway Study on Wind Power in Ottawa
Pathway Study on Waterpower in Ottawa
Pathway Study on Solar Power in Ottawa
Pathway Study on Biogas Power and Energy in Ottawa
Pathway Study on District Energy Systems in Ottawa
Pathway Study on Heat Pump Technology in Ottawa

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Key Units

TJ — Terajoules is a measure of energy, base unit of joules, and used here in the context of total energy delivered over one year. As a simplistic example, a wind turbine producing on average 1.5 MW of power for 100 hours will deliver 150 MWh of energy, which can be converted in to units of joules as 0.54 TJ.

kt CO_2eq — kilotonnes of carbon dioxide (CO_2) and other equivalent greenhouse gases, which is the common unit for quantifying the greenhouse gas emissions related to a process.

2015 $ — Money spent, in 2015 Canadian dollars, by consumers on the purchase of supply “fuels” via energy bills, and where “fuels” includes electricity.

Baseline Energy Study for Ottawa 2015

EXECUTIVE SUMMARY

This report undertakes an analysis of major forms of energy in the City of Ottawa. It provides an overview and understanding of what energy types are used, the quantities that are used, where the energy comes from, and how it is used by different sectors of the community. The report also examines the greenhouse gas (GHG) and monetary costs of the energy use. A Baseline Energy Study is an important first step in the work of community energy planning. It can be combined with scenarios for future energy use to examine the potential future energy supply mix, and to consider where the most impactful opportunities to influence energy use reside. The analysis can be compared against future targets, such as greenhouse gas reductions, renewable energy increases, and local resiliency of energy supply.

The input data for the analysis in this report comes from the local distributors of energy (Enbridge, Hydro One, and Hydro Ottawa), Statistics Canada and other government entities collected data, independent market analysis data.

The study has included analyses for natural gas, electricity, motor gasoline, heating oil, propane, and diesel. It did not include biomass or other bio-fuels, solid wastes, or waste energy, though it is recommended that future work does integrate this information. The aim of the project was to provide, as efficiently as possible, an overall analysis or big picture of energy use in Ottawa. Certain assumptions have been made, as are further detailed in the report. The overall uncertainty of the main values is estimated to be less than 10%. It does not include GHG emissions other than through the direct use of the above fuels, as is the same approach used in the National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada.

Overall Values for 2015

- 114,200 TJ of energy were used in the City of Ottawa, including all sectors.
- 5,200 kt CO_2eq were emitted in relation to this energy use. This does not contain GHG emissions due to other processes such as solid waste and industrial processing.

- $3,000 million was spent by residents, companies and institutions to purchase this energy.

The Energy Use by Sector

- The energy supply is used by the residential sector, the industrial, commercial, institutional (ICI) sector, and the transportation sector in the following relative amounts: 34, 39, and 27%, respectively.

Fuel Origin and Type

- The region generates 5% of its total energy needs locally, in the form of renewable electricity energy from waterpower, solar and biogas generation.
- The remaining 95% of its energy needs are imported from outside the region, including all fossil fuels as well as electricity from the Ontario grid suppliers.

Energy, GHG and Cost Contribution per Fuel Type

The three major forms of energy are electricity, natural gas (NG), and gasoline, with small contributions by oil, propane and diesel. The relative percentages of energy, GHG and costs of the fuel types are summarized in Table 1. Most notable, is that the amount of energy provided by NG is 40% more than that provided by electricity, but the GHG impact of the NG is approximately more than four times that of electricity. Columns D and E of Table 1 provide the GHG and cost impacts of the fuels per unit of energy. These values further support these comments.

Table 1 - Summary of relative contributions and costs of the six major fuel types in use in Ottawa in 2015.

	A	B	C	D	E
	Energy (% of total)	GHGs (% of total)	Cost (% of total)	GHG impact per unit of energy (kt CO_2eq/TJ)	Cost per unit of energy ($/TJ)
Natural gas	39	42	18	0.050	0.012
Electricity	28	9	45	0.014	0.042
Gasoline	26	38	29	0.066	0.030
Propane	3	4	4	0.061	0.034
Oil	3	5	3	0.075	0.029
Diesel	1	2	1	0.071	0.028

Based on these numbers, it is clear that fuel switching from NG or gasoline to electricity (provided by the current Ontario mix or a cleaner mix of generation technologies) will have GHG reduction advantages, but it may cost more unless the efficiency of the electrical system is higher than that of the fossil fuel system. As detailed in Pathway Studies that have been undertaken on a series of renewable energy technologies, this is indeed the case in some instances.

SECTION 1 – INTRODUCTION

On July 8, 2015, Ottawa City Council approved the development of a Renewable Energy Strategy as part of the 2015-2018 City Strategic Plan. This initiative has been entitled Energy Evolution – Pathways to a Renewable Energy Future (OttEE).

The goal of the OttEE is the assessment of community aspects of energy and greenhouse gases, with an aim of (a) evaluating energy use data from local utilities to provide a baseline analysis of energy use in the city; (b) engaging with a broad set of stakeholders, and (c) developing a list of opportunities to influence energy consumption, generation and GHG emissions across the entire City.

This document provides a baseline analysis of energy use in Ottawa in the year 2015. It is an aggregation of all substantive forms and sources of energy used in the City of Ottawa, as consumed by residences, businesses, institutions, and other entities across all facets of life and business.

In addition to analysing the energy use, the report also examines the greenhouse gas (GHG) emissions that are associated with the energy use, and the cost of that energy, or the total price paid by all the consumers in Ottawa for the energy. The units of this analysis are terajoules of energy (TJ), kilotonnes of carbon dioxide equivalent gases, (kt CO_2eq), and cost in millions of dollars ($M). These values are all annual values for the year 2015. These are very large units, in comparison to the energy used by a single household – the sidebar provides some general information on these units of energy[1].

To aid in the understanding of where and how the energy is used, the data is evaluated in terms of the following subcategorizations:

- by sector of consumer (residential; institutional, commercial, industrial (ICI), and transportation);
- by supply type (electricity, natural gas, heating oil, propane, diesel, gasoline); and
- by supply origin (local or imported into Ottawa).

This analysis is based on a bottom-up analysis of major forms of energy use as provided by utilities and other sellers of fuels; it is possible that certain minor uses of energy may not be included in the datasets obtained. The analysis has required the use of some approximations (such as for minor energy supplies) and cross-inference of usage and cost values from one utility rate class to another. Furthermore, non-identical correlations between user types and utilities' account classes mean that user categorizations may have minor inconsistencies. Approximations and assumptions are reasonable for this type of analysis and are in keeping with industry practices; Leidos estimates an accuracy of 10% on major values, unless otherwise noted.

Study Boundaries

This report includes the assessment of natural gas, electricity, motor gasoline, heating oil, propane, and diesel. It does not include energy from biomass or other bio-fuels, solid wastes, or waste energy – these should be included in future efforts for a more comprehensive assessment of energy supply options, but were outside the scope of this project.

UNITS OF ENERGY

Energy is measured in units known as Joules (J). Because a Joule is a relatively small amount of energy, energy consumption is often discussed in terms of gigajoules (1 x 10^9 J or 1,000,000,000 J), denoted by GJ, and terajoules (1 x 10^{12} J or 1,000,000,000,000 J), denoted by TJ. To help put things in perspective:

- 1 GJ is equal to slightly more than 2 propane cylinders like the ones used on most gas BBQs.
- The energy content of a 30 litre tank of gasoline is about 1 GJ.
- 1 TJ is equal to slightly more than 2,200 propane cylinders.
- 1 railway tanker carrying propane contains about 113,000 L of propane, which is about 3 TJ of energy.
- 1 GJ of energy is equal to 277 kilowatt-hours (kWh).
- In one year, the average household in Ontario uses:
  - 30 GJ of electricity, and
  - 93 GJ of natural gas, and
  - 62 GJ of gasoline;

Text and data adapted from Statistics Canada[1].

The report does not include GHG emissions other than through the direct use of the above fuels. It also does not include emissions from municipal solid waste, wastewater, and agriculture, which are covered in the City's greenhouse gas inventory report.

Several smaller exclusions and certain assumptions have been required, as are further detailed in the report. The overall uncertainty of the main values is estimated to be less than 10%. The analysis is specific to the year 2015.

SECTION 2 – ANALYSIS OF ENERGY

Energy Supply Data by Fuel Type

Energy consumption data was collected from utilities and other related organizations that manage or monitor energy supply data. The majority of the data was originally collected by City staff from local energy suppliers, while Leidos undertook a review of these inputs for completeness, pursued further clarifications, and assembled the data into the subcategories. The data consisted of:

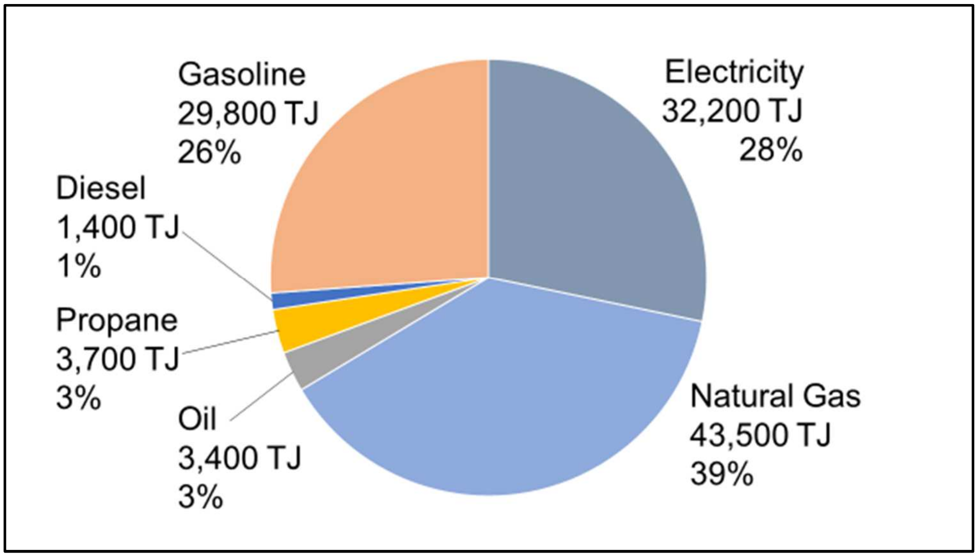
- **Electricity consumption** from Hydro Ottawa Limited (HOL) and Hydro One Networks Incorporated (HONI).
- **Natural gas consumption** from Enbridge Gas.
- **Retail gasoline and diesel consumption** from Kent Group Ltd.
- **Propane and heating oil consumption** from Navigant Fuels Technical Report of Ontario fuels consumption.

For each supply type, data was converted from its raw units into a common energy unit of TJ. Details of the raw units and the conversion factors are contained in *Appendix 1 – Additional Details of the Raw Energy Data*.

The use of biofuels (biodiesel, renewable natural gas, bioethanol, etc.) and biomass was not in the scope of the report, but as a whole was expected to be very small in 2015.

The total of all energy used in 2015 was found to be 114,000 TJ. The breakdown of energy supply into the six types of fuels is illustrated in Figure 1. The largest source of energy in Ottawa is natural gas, followed by electricity and then gasoline. Heating oil, propane, and diesel were found to provide only minor quantities of energy.

Figure 1 – Ottawa's 2015 energy use by supply type.



Energy Use by Sector

The energy use is subdivided into three main categories, as described here along with the assumptions that were required:

Residential

- All residential consumers, ranging from single detached households to multi-unit apartment complexes are assumed to be covered in the "residential" class of accounts of HOL and HONI.
- While Enbridge accounts do differentiate between residential and larger apartment buildings, these values have been combined in this report.

Industrial, Commercial, Institutional (ICI)

- All account classes relating to commercial, industrial, institutional and large user accounts are combined into one broad category for analysis. This category also includes metered energy use at agricultural facilities.

Transportation

- Transportation energy use was assessed through the quantity of gasoline and diesel fuels purchased at public pumps. Data available from Kent Marketing was for retail sales of gasoline and diesel fuel. Bulk purchases, including for fleets, is not currently included, but is recommended to be added in the future. A preliminary analysis from Canada-wide data[2] suggests that bulk purchases may add another 5 to 10%

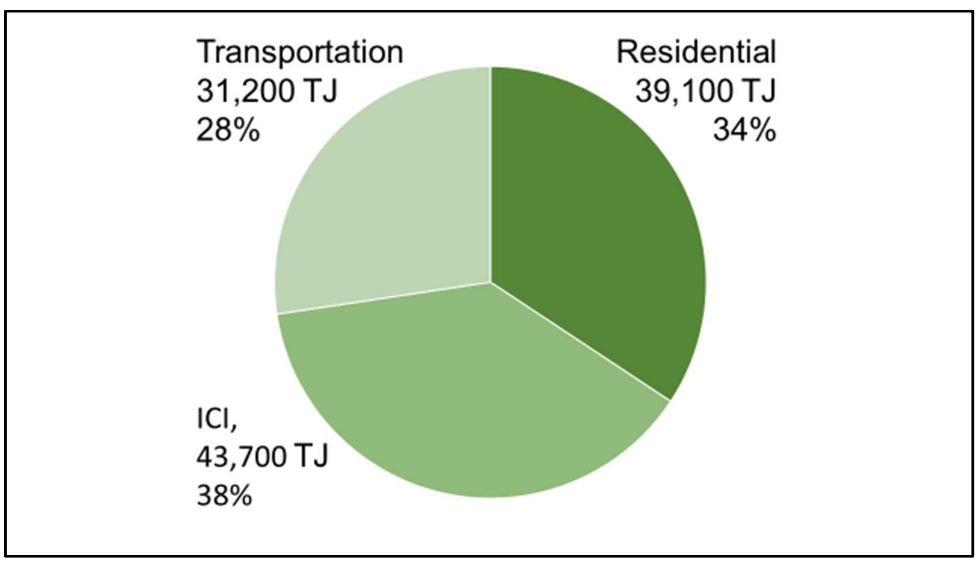
volumetric use of fuels within transportation, but are not sufficiently well understood to include within the report.

- An assumption was made that all gasoline and diesel sales were for the purposes of transportation, though it is likely that alternate uses, such as diesel generators for construction and special events, would constitute some percentage.
- Presently, no propane, natural gas, or fuel oil sales were assigned to transportation, though a small percentage would likely be used for vehicle fleets; such a division could be examined in future efforts.
- Alternate fuels for transportation (such as biodiesel, electricity and hydrogen) are not included, but considered to be very minor in 2015.
- Aviation and other fuels used in long distance transportation were not included in the analysis, as is common.

Within electricity consumption there was a collection of other account classes relating to street lighting, miscellaneous unmetered loads (traffic lights, signaling, etc.), and consumption accounts for electricity use at FIT and microFIT generation facilities. The total consumption for this category was very small, equal to 0.2% of the total, and is not further tracked in the analysis.

The breakdown of energy use by user type is illustrated in Figure 2. It roughly breaks down into thirds, with ICI being the largest consumer at slightly more than one third of the energy consumption, followed by residential, and then transportation.

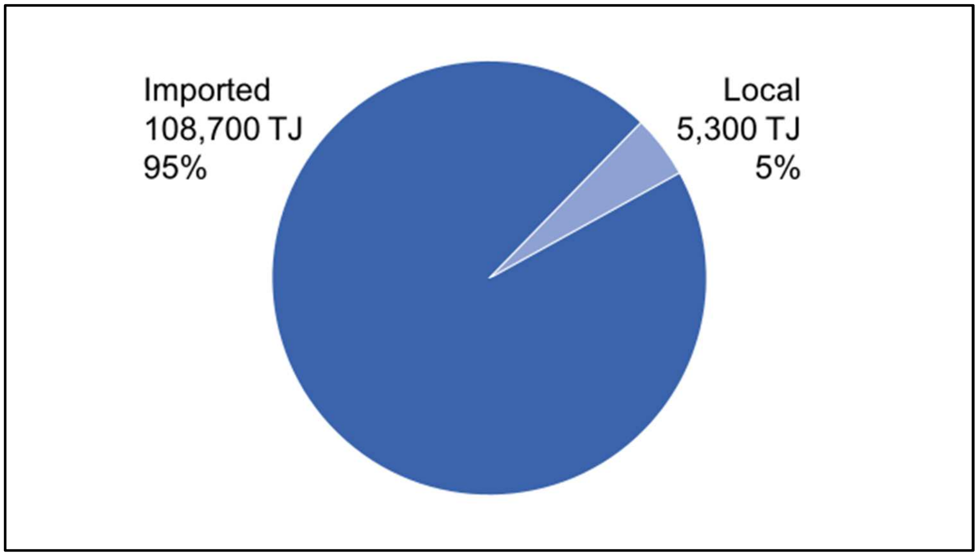
Figure 2 – Ottawa's 2015 energy use by sector.



Energy Supply by Origin

Energy supply was subdivided into whether it was produced within the boundaries of the City of Ottawa or if it was imported from elsewhere. It was assumed that all fossil fuels were imported from outside of Ottawa. Electricity is categorized in a split manner, where most electricity is considered to be *imported* from the Ontario grid, but local sources of electricity were identified and considered to be local supply, as further explained below. It is clear from Figure 3 that nearly all the energy is imported into the Ottawa region, with only 5% being generated locally.

Figure 3 – Ottawa's 2015 energy supply by origin.



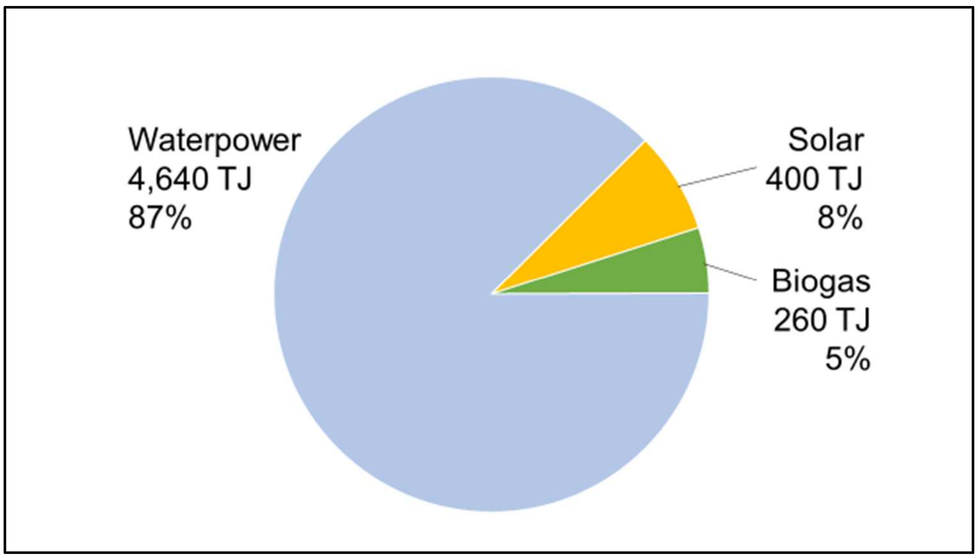
Local Renewable Electricity Supply

All renewable energy (RE) *electricity* generators in existence in 2015 are connected to the electrical grid, and as such are part of the Ontario electricity supply mix, but we have opted to separate them out into a "local" supply category. We have defined this category to represent *all* RE generators within the boundaries of the City of Ottawa, encompassing facilities of all sizes, from residential to large-scale. HOL and HONI provided data for the sums of capacity for each technology type that are connected to their distribution grids. Added to this are large-scale waterpower and solar which are connected to the provincial transmission system. Additional details are contained in *Appendix 2 – Additional Details on Renewable Energy Supply*.

It is debatable whether on-site, behind-the-meter generation should be included in local generation, as it already has an effect as a reduced electricity volume provided by the utilities. In 2015, this situation only applied to a small number of generators (< 100 TJ); they are *not included* in the generation total quoted herein. As the quantity of co-generation and net-metered solar generation grows, it may be desirable to use a more complex approach that recognizes this local generation within the analysis.

Figure 4 provides a breakdown by RE generation type. At 87% of the overall energy supply, waterpower is dominant at present, due to multiple facilities on the Ottawa River. Electricity generation by solar and biogas are the two other notable local supplies, at 8% and 5% respectively. Wind was considered, but there was no quantity of generation within the boundaries of Ottawa. As mentioned previously, biomass has not been included in this study, but likely does provide a small percentage of energy used in direct combustion for heat.

Figure 4 – Ottawa's 2015 renewable energy supply mix.



With the majority of waterpower potential already fully developed, in the future the mix of renewable energy in Ottawa will have higher proportions of non-waterpower RE generation. It is anticipated that solar has the largest growth potential, while biogas, biomass and waste heat capture also have substantial potential for growth. These opportunities are further discussed in RE Pathway Studies.

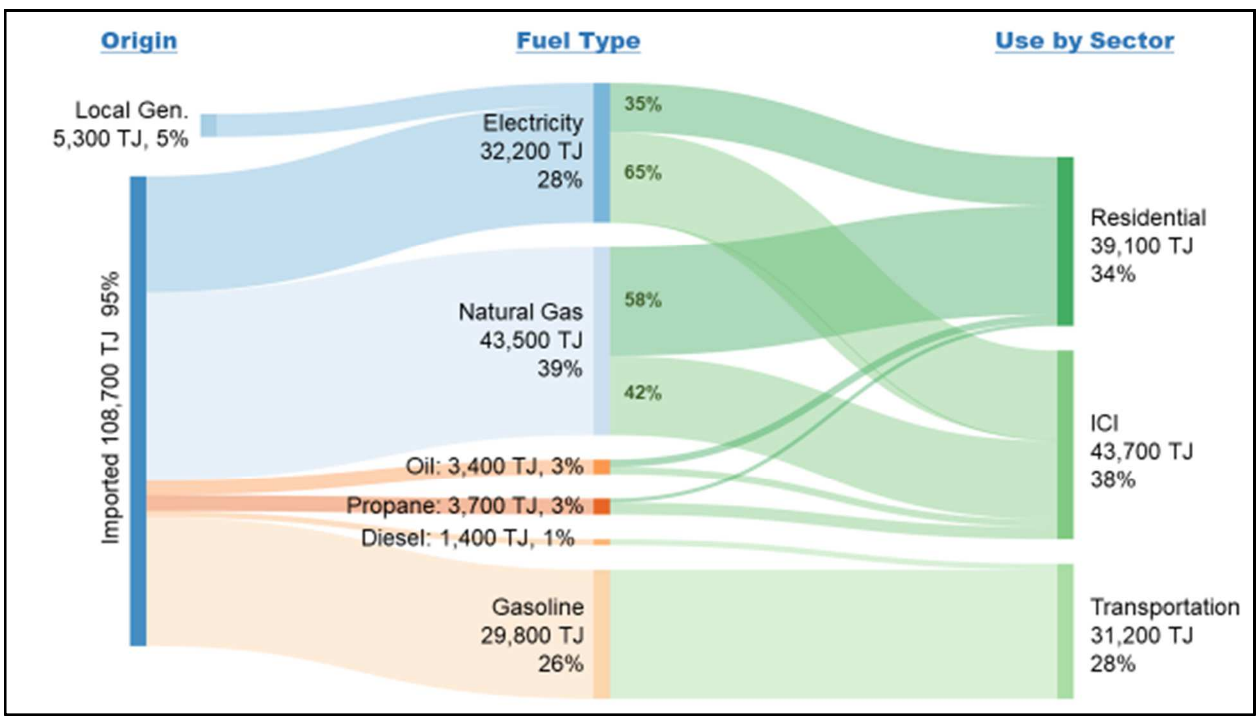
Combined Baseline Energy Analysis in a Sankey Diagram

It is illustrative to combine all three of the above subcategory analyses into interlinked energy flows by using a "Sankey" diagram, as shown in Figure 5. In this diagram, the thickness of each flow line and the height of each bar represent the quantity of energy in that path. On the left-hand side of the diagram, the origin of the energy is provided, which again shows that 5% of the energy supply is local electricity generation, while all remaining energy is imported. The central section of the diagram illustrates how the energy supply breaks down by fuel type. Finally, moving to the right-hand side, these fuel types flow to their users as follows:

- electricity flows to both the residential and ICI sectors, with 35% of electricity used by residential and 65% used by ICI.
- natural gas flows to both the residential and ICI sectors, with 58% of natural gas used by residential and 42% used by ICI.
- oil and propane are minor forms of energy supply to both the residential and ICI sectors.
- gasoline, and to a small extent diesel, support the transportation sector.

It is worth reiterating that certain minor forms of energy supply and energy use (such as propane, other fuels for transportation, and biomass for heating) were not in the scope of the present analysis.

Figure 5– A Sankey diagram showing the flow of energy from origin into a categorization by fuel type and then use by sector. The diagram was created using SankeyMATIC.



SECTION 3 – ANALYSIS OF GHG EMISSIONS

The combustion of fossil fuels results in the release of carbon dioxide and other gases which are greenhouse gases that contribute to climate change. These emissions are quantified in terms of weight of carbon dioxide (CO_2) emitted into the atmosphere. The global warming potential of certain gases, such as methane, are substantially higher than carbon dioxide on a per weight basis, but standardized weighting factors are used to convert their emissions into the common unit of kilotonnes of CO_2 equivalent (kt CO_2eq). The quantities of GHG emissions for a given type of fuel use are reasonably consistent and well established. In this analysis, we have used emissions factors and global warming potential values from the Canadian National Inventory Report 1990-2014 for all of the fossil fuels[3]. At the time of the analysis, the 2015 report was not available, but emissions factors of fossil fuels are not expected to change significantly between the years 2014 and 2015. Electricity, when generated by the combustion of fossil fuels, also has a GHG impact. In Ontario, the phase out of coal generation was completed in 2014, while generation based on NG is an on-going portion of the supply mix. We have used the 2015 value for the average GHG emission factor for the Ontario grid from the Independent Electricity System Operator ("IESO")[4]. Details of the emission factors used are contained in *Appendix 3 – Greenhouse Gas Emission Factors*.

As the percentage of local RE grows, a more detailed calculation of the GHG emissions of the local supply may be worthwhile, considering the transmission loss avoidance and possibly also the particular type of provincial generation that is displaced by the local generation (e.g. if use of a natural gas peaker plant is avoided due to local RE generation) rather than the average supply mix value. Also, uptake of local NG combustion for combined heat and power, where electricity is produced locally and the waste heat is collected and used advantageously, is a net GHG emission reduction opportunity if it displaces centralized NG peaker plants, but not if it displaces low-carbon electricity.

With regards to fossil fuels, it should further be noted that these emission factors consider only emissions from the local combustion of the fuels themselves. Full life-cycle emissions (including raw material extraction, refining, shipping, operations, etc.) are not included, as is typical in such analyses.

The total of all GHG emissions from the above sources in Ottawa in 2015 was calculated to be 5,200 kt CO_2eq. Figure 6 shows the GHG emissions breakdown by fuel type and Figure 7 shows a breakdown by use sector.

Figure 6 – Ottawa's 2015 GHG emissions by fuel type.

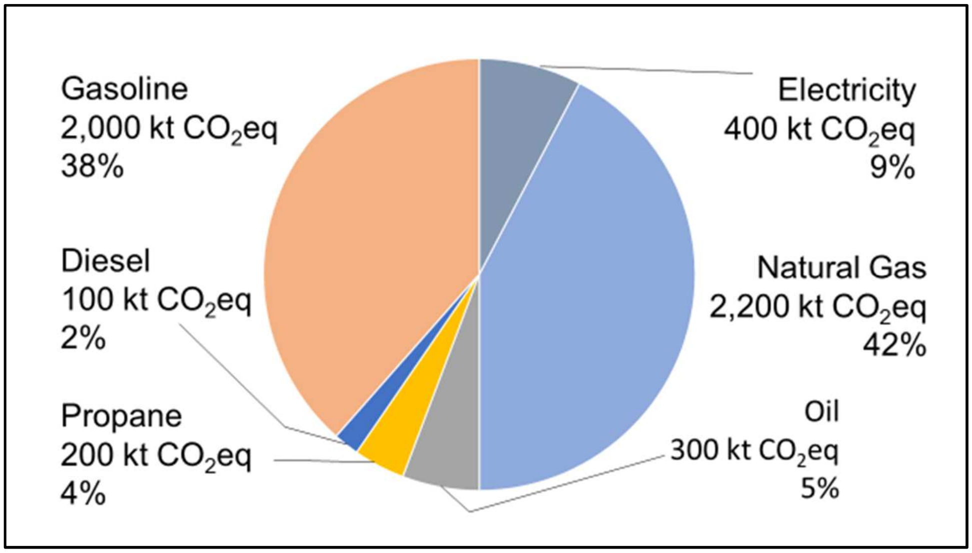
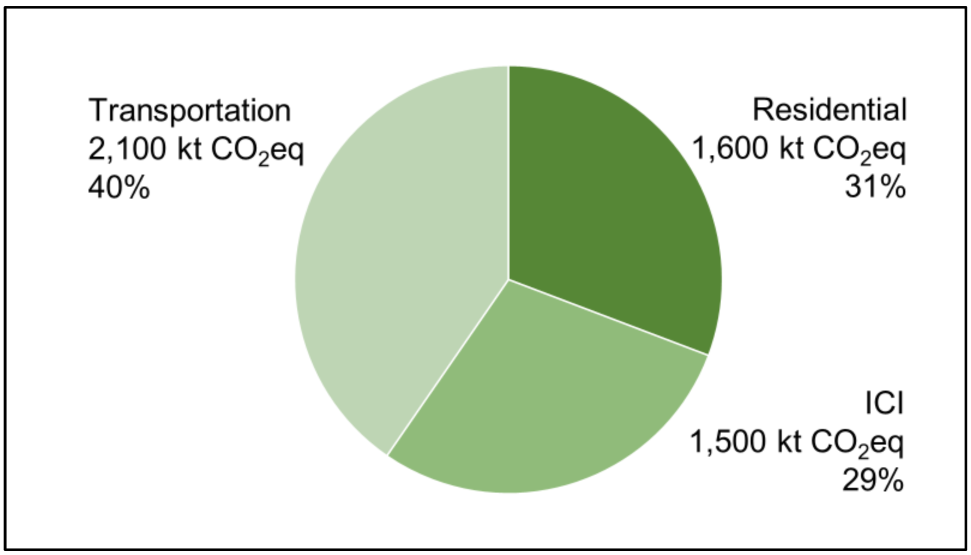


Figure 7 – Ottawa's 2015 GHG emissions by sector of energy user.

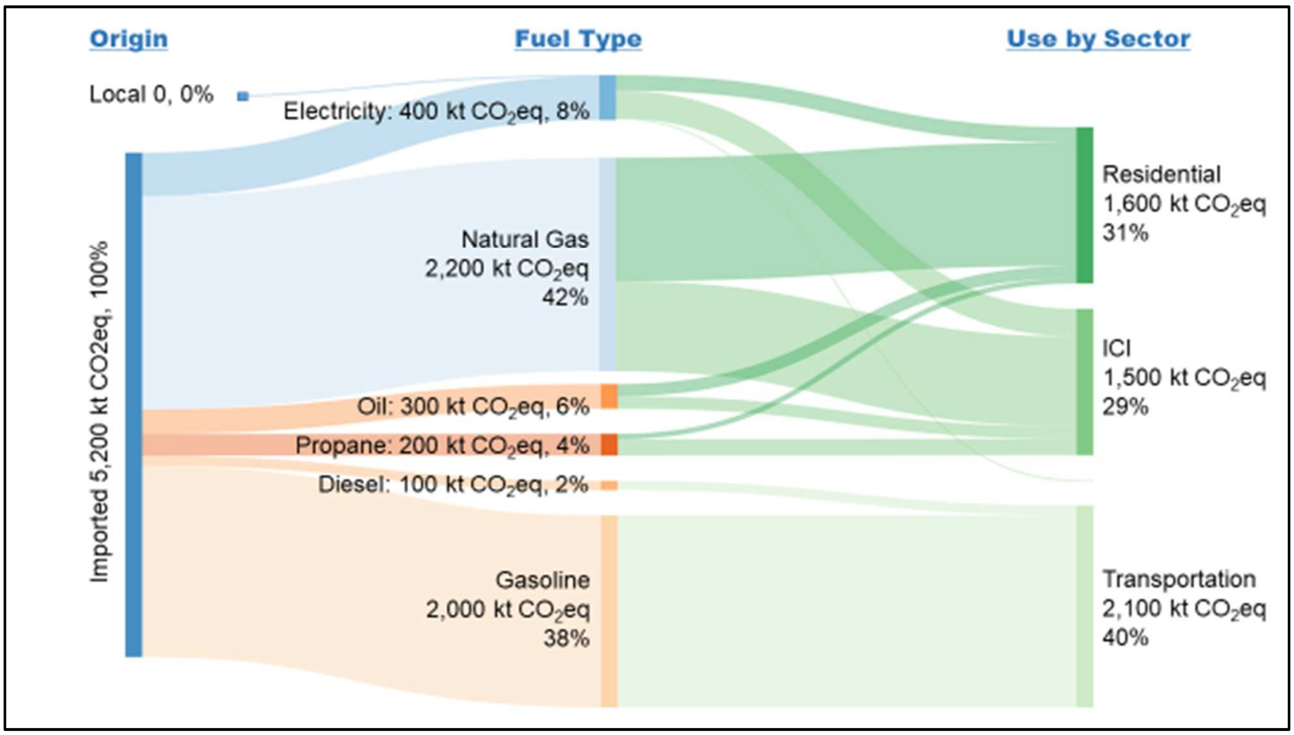


It can be observed that natural gas emissions represent close to half of the total GHG emissions, which is a larger portion than the proportion of energy it provides (as was shown in Figure 1). Electricity exhibits the opposite – it contributes a smaller portion of GHG emissions than it does of energy supply due to the relatively low emission intensity of the Ontario grid mix. The GHG emissions per unit of energy are summarized in Table 2. A Sankey diagram of the GHG emissions is provided in Figure 8. Larger flow lines represent larger contributions of GHGs, and thus it is noticeable how small the electricity line is.

Table 2 - Summary of the GHG impact by fuel type.

	Percentage of Energy (%)	Percentage of GHG emissions (%)	GHG impact per unit of energy (kt CO_2eq/TJ)
Natural gas	39	42	0.050
Electricity	28	9	0.014
Gasoline	26	38	0.066
Propane	3	4	0.061
Oil	3	5	0.075
Diesel	1	2	0.071

Figure 8 - GHG emissions in relation to energy use in Ottawa in 2015.



SECTION 4 – ANALYSIS OF ENERGY COSTS

Cost of energy was calculated using detailed information of rate structures and account types specific to 2015.

Costs for natural gas were derived with consideration of the monthly consumption data and the variability in market rates, and with details for four types of account classes. Similarly, electricity costs were evaluated using the specific rates and account classes for HONI and HOL. Prices for gasoline, diesel and oil were derived from average quarterly retail prices from Ontario Energy Reports[5] and other sources[6]. The details are further explained in *Appendix 4 – Methodology for Cost Calculations*.

The HST (at 13%) is added to the cost totals. Certain institutional "large users" may pay a lower tax rate, but this was not factored in.

<u>The total of all energy costs in Ottawa was $3,000 million (in 2015 dollars)</u>. Figure 9 shows a breakdown of the cost by fuel type and Figure 10 shows the breakdown of energy cost by sector. Electricity is the largest contributor to cost at 45% of all costs, while gasoline is second at 30%. So, although electrification in Ontario is a sound GHG emissions reduction solution, such a transition could be constrained by the cost of electricity. However, recent provincial policies have resulted in reduced electricity costs for 2017 compared to these 2015 values. Local electricity generation at cost competitive rates may also help to mitigate cost increases and increased grid capacity requirements. Also, many electrically powered devices operate with much higher efficiencies than their fossil fuel counterparts - good examples are heat pumps and electric vehicles.

Figure 9 - Ottawa's 2015 energy costs, by fuel type.

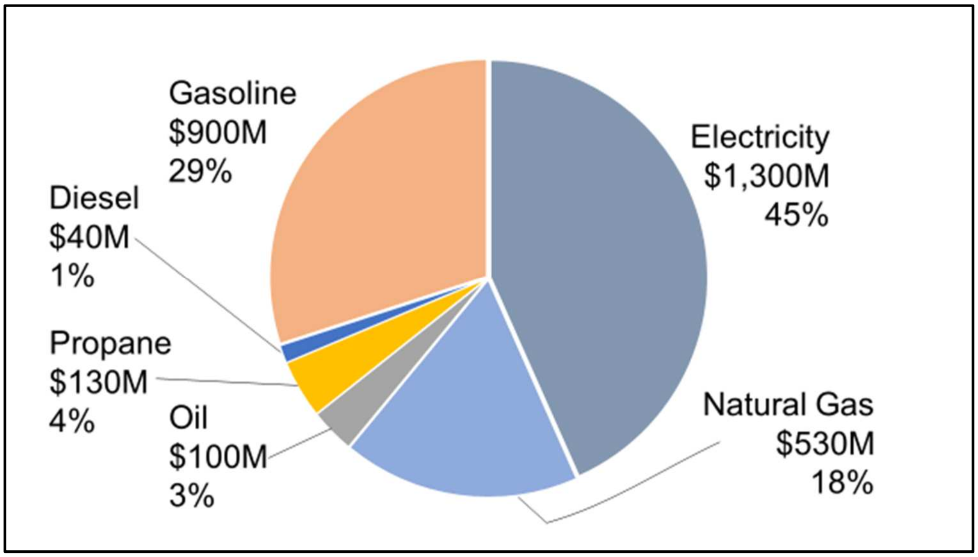
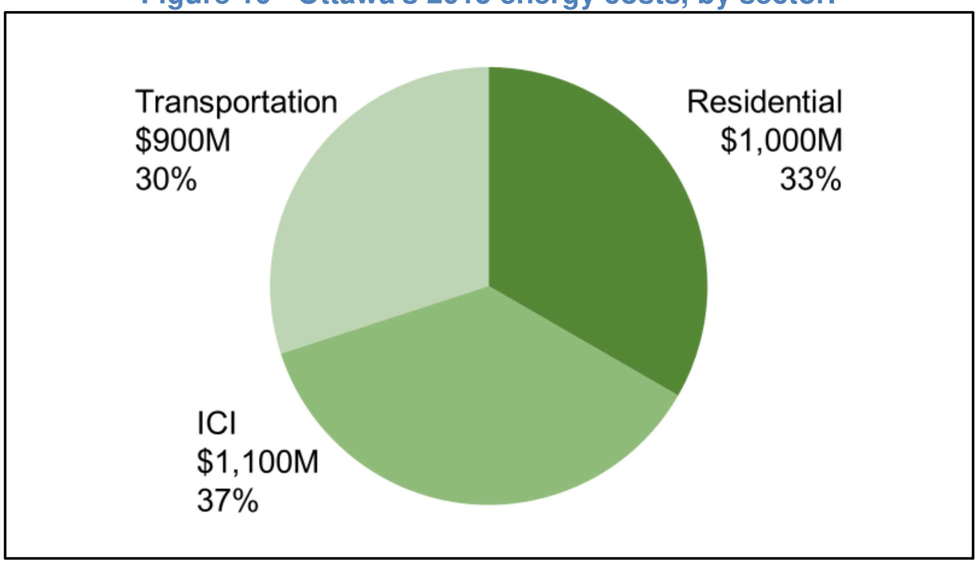


Figure 10 - Ottawa's 2015 energy costs, by sector.



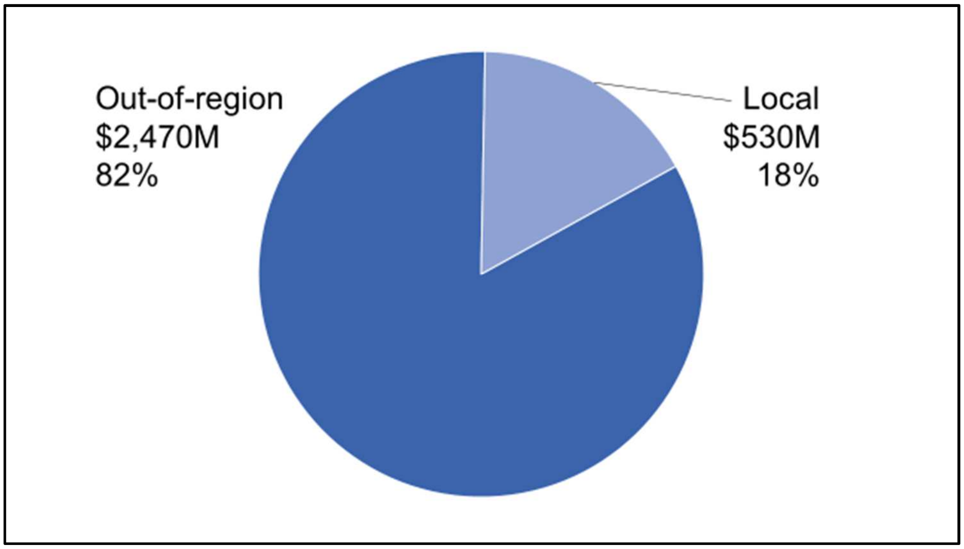
It can be observed that natural gas emissions represent a smaller portion of total energy costs than it did for energy supply, as was shown in Figure 1, while electricity exhibits a larger portion of costs than it did for energy supply. The exact values of the relative portions and the cost per unit of energy are further detailed in Table 3. The higher cost of electricity per unit of energy has the potential to dissuade fuel switching from fossil fuels, but the efficiency gains, where less energy input is required for the same service of electrical process, counter the higher costs, as is discussed in some of the Pathway Studies.

Table 3 – Summary of the energy costs by fuel type.

	Percentage of Energy (%)	**Percentage of total energy costs (%)**	**Cost per unit of energy ($M/TJ)**
Natural gas	39	18	0.012
Electricity	28	45	0.042
Gasoline	26	29	0.030
Propane	3	4	0.034
Oil	3	3	0.029
Diesel	1	1	0.028

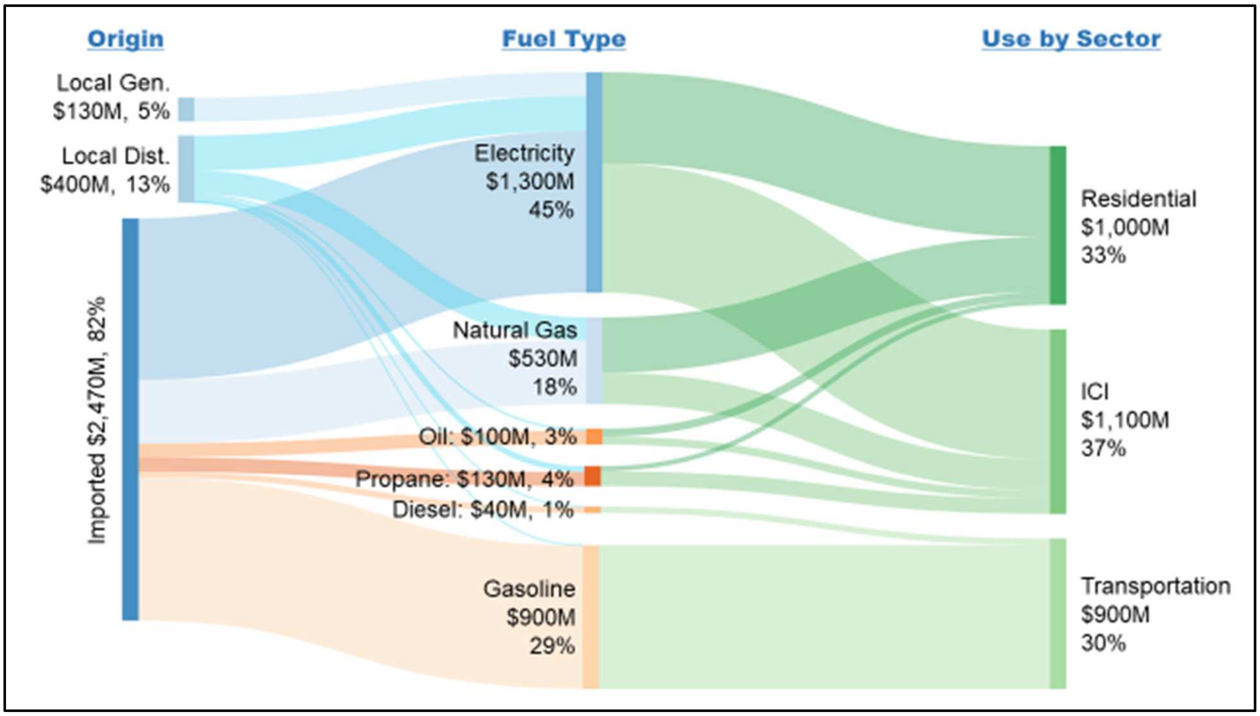
Figure 11 provides an analysis of where this money goes, in that some of these costs become revenues to local companies, whereas the remainder is revenues to non-Ottawa entities. Money that stays in the local economy was found to be 18% of the total, and this relates to the distribution of the fuels (13%) and local RE generation (5%). With respect to the latter, a value equal to the commodity price of electricity was assigned, irrespective of the contracted power purchase agreement prices of the projects. A more detailed accounting approach to this assignment could be undertaken in the future.

Figure 11 - Ottawa's 2015 energy supply cost by whether the money goes to local entities or leaves the region.



A Sankey diagram is provided in Figure 12, which shows the flow of costs. In this Sankey, a new category of local distribution costs is added as a node.

Figure 12 - Sankey diagram of the costs of energy in Ottawa 2015.



It is worth mentioning that the rate structures of energy bills, and those of electricity in particular, have been subject to considerable change, including due to the following recent policy changes:

- The debt retirement charge on residential bills ended on Dec. 31, 2016, and for commercial bills it will end on April 1, 2018.
- The Ontario Clean Energy Benefit rebate, valued at 10% of total electricity charges on most accounts ended Dec. 31, 2015.
- The provincial portion of the HST, at 8% of the total bill, was removed in Jan. 1, 2017.
- A further reduction of electricity prices of 13% for residential and small business users was implemented May 1, 2017 with a subsequent small reduction in July
- Many more accounts became eligible for the Global Adjustment “Class A” billing category July 1, 2017. This is a cost savings opportunity for many accounts.

Furthermore, starting in 2017, Ontario’s cap and trade carbon pricing has added approximately 7% to the cost of natural gas and 5% to the cost of gasoline, while electricity costs will have minimal price increases, due to the low percentage of fossil fuel based generation in the electricity supply mix.

SECTION 5 - CONCLUSIONS

This analysis has developed an understanding of the baseline energy supply and its associated GHG emissions and costs for the City of Ottawa in 2015. The analysis found the following major results:

- The annual energy use in Ottawa was 114,200 TJ.
- Only 5% was sourced locally, which was renewable generation of electricity from waterpower, solar and biogas. Presently waterpower is the largest contributor, at 87%, but growth is anticipated to be in solar and bio-energy.
- The remaining 95% of the energy supply is imported as Ontario grid electricity and fossil fuels (natural gas, gasoline, heating oil, propane, and diesel fuel).
- ICI is the largest user of energy, at 38%, followed by residential at 34% and transportation at 28%.
- The GHG emissions associated with this energy use was 5,200 kt CO_2eq. Natural gas use is the largest contributor of GHGs, while electricity has a low GHG emission per unit of energy.
- The cost for the purchase of this energy was $3,000 million in 2015 dollars. Of this, 83% of that money left the region as revenue paid to entities outside of Ottawa, while 18% was collected as revenue to local companies. This 18% includes the value of the locally generated energy (approximately 5%) and the distribution services (approximately 13% of the total costs).

The analysis is a snapshot in time for 2015. Technological, market and policy decisions may be influenced by new approaches that affect the energy supply type and GHG emissions, though the embedded momentum of existing infrastructure means that change takes time. However, the cost of energy can be influenced substantially and instantly by both policy and market conditions, and thus creates a degree of volatility in energy economics.

Next Steps

Evaluation of the potential in Ottawa for new clean energy approaches, or Pathway Studies, have been separately developed. These provide information on the potential sustainable energy technologies, including scenarios for conservative moderate and aggressive uptake. They also consider opportunities that can advance their uptake. The output of Pathway Studies can be combined with this Baseline Study to develop an aggregated evaluation of future energy use, energy generation, and GHG emissions.

APPENDIX 1 – ADDITIONAL DETAILS OF THE RAW ENERGY DATA

Table 4 - Details of the energy data received, and the factors used to convert into TJ.

Sources	Data	Raw Data Format	Conversion Factors into TJ
Hydro Ottawa Limited (HOL) and Hydro One Networks Incorporated (HONI)	Electricity consumption	Kilowatt hours (kWh) consumed in 2015 per account category	3.6×10^{-6} TJ/kWh
Enbridge Gas	Natural gas consumption	Cubic meters (m^3) consumption in 2015 per account category	37.7×10^{-6} TJ/m^3 taken from Enbridge documentation[7]
Kent Group Ltd.[(a)]	Retail gasoline and diesel consumption	Liters (L) consumed in 2015 per fuel grade	34.8×10^{-6} TJ/L for regular unleaded[8], 39.5×10^{-6} TJ/L for premium plus grade[9], and interpolated values for premium and midgrade. 39×10^{-6} TJ/L for diesel
Hydro Ottawa Limited (HOL) and Hydro One Networks Incorporated (HONI)	Renewable energy generation	Kilowatt AC (kW) capacity total connected in 2015 per technology type, and per major size categories	CF x 8760 x 10^{-6} TJ/kW where CF is an estimated technology specific capacity factor (see Table 2).
Navigant Fuels Technical Report of Ontario fuels consumption	Propane and Heating Oil consumption	TJ of energy consumed by user type and fuel in 2015	This data needed to be converted from Ontario values into Ottawa specific values, and this was done by using the ratio of population and employees in Ottawa relative to Ontario: population ratios were used to estimate residential consumption, while employment ratios were used for the commercial sector.

[(a)] The Kent Group data only includes retail pump sales, and thus omits bulk sales including to vehicle fleets. See Transportation section for more discussion.

APPENDIX 2 – ADDITIONAL DETAILS ON RENEWABLE ENERGY SUPPLY

For local RE generation, data was provided in units of total power capacity connected to the grid (for each type of RE technology solar, wind, water and biogas), as listed in Table 5. The actual energy generation of a facility is not always the maximum rated value, in particular for resources like solar and wind that vary on a continuous basis. The capacity factor describes the *average* power output over an entire year relative to the facility's power rating. Thus, to determine the annual energy generation of the facilities in Ottawa from their net power rating (of each type), Leidos developed estimates for the average capacity factor of each fuel type, as listed in Table 6.

Table 5 - Total of RE power generation capacity on the two distribution grids within Ottawa, in 2015.

<table>
<tr><th></th><th>HOL grid
(MW_{AC})</th><th>HONI grid
(MW_{AC})</th><th>Totals
(MW_{AC})</th></tr>
<tr><td>Distributed solar</td><td>6.3</td><td>7.8</td><td rowspan="2">78</td></tr>
<tr><td>Large-scale solar</td><td>20</td><td>43.8</td></tr>
<tr><td>Biogas</td><td>6.9</td><td>3.4</td><td>10</td></tr>
<tr><td>Waterpower</td><td>17.2</td><td>171 (a)</td><td>188</td></tr>
<tr><td>Totals</td><td>50</td><td>226</td><td>276</td></tr>
<tr><td colspan="4">(a) This value includes several large waterpower and solar facilities that were identified as being within the City of Ottawa, and which are further discussed in the respective Pathway Studies. Likely these are connected directly to the transmission system.</td></tr>
</table>

Table 6 – Estimated capacity factors for renewable energy generators in Ottawa.

Technology	Capacity Factor	Comment
Biogas	0.80	Estimated.
Waterpower	0.78	Derived from data from Ottawa-specific waterpower facilities, as further explained in Waterpower Pathway[10].
Solar	0.16	Value for typical 2010-2015 facility for the Ottawa solar resource, based on Leidos' experience in the analysis of hundreds of systems across Ontario, including Ottawa.
Wind	0.22	This is a rough estimate for a low grade wind resource around Ottawa. The value varies substantially with the wind resource at each project location.

APPENDIX 3 – GREENHOUSE GAS EMISSION FACTORS

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Table 7 - Estimated emission factors by fuel type, from the Canadian National Inventory Report[3].

Supply Type	Use Category	CO_2 Emission Factor	CH_4 Emission Factor	N_2O Emission Factor	Combined CO_2eq Emission Factor
Natural Gas	All	1888 g/m^3	0.037 g/m^3	0.035 g/m^3	1899 g/m^3
Gasoline	Transportation	2316 g/L	0.1 g/L	0.02 g/L	2324 g/L
Diesel	Transportation	2690 g/L	0.085 g/L	0.16 g/L	2740 g/L
Propane	Residential & ICI	1515 g/L	0.027 g/L	0.108 g/L	1548 g/L
Fuel Oil	Residential	2753 g/L	0.026 g/L	0.031 g/L	2763 g/L
Fuel Oil	ICI	2753 g/L	0.006 g/L	0.006 g/L	2755 g/L

The calculation of a carbon dioxide equivalence (CO_2eq) is based on using the global warming potential of methane (CH_4) and nitrous oxide (N_2O) as given in Table 8, into an equivalent carbon dioxide (CO_2) value and then combining the emission factor for the three compounds to enable working with a single unit of kt CO_2eq.

Table 8- Global warming potential of significant compounds.

	CO_2	CH_4	N_2O
Global Warming Potential	1	25	298

In addition to the above conversion factors, certain additional assumptions were used:

- Emissions were assumed to be equal for all grades of gasoline.
- Emissions for diesel were based on light-duty diesel trucks (uncontrolled), though any selected truck type provided similar net results of CO_2eq.

For electricity, the analysis used an emissions intensity of 4.98E-05 t/kWh for the Ontario grid, as was taken from the IESO Ontario Planning Outlook[4], which is derived considering the relative proportion of all the types of generators contributing to the overall Ontario supply mix. All local renewable generation provides electricity onto this grid through power purchase agreements, and as such their emissions are included within the value. Additional costs due to transmission losses from point of centralized generation to Ottawa are not a clearly defined magnitude, and have not been included in the present analysis.

APPENDIX 4 – METHODOLOGY FOR COST CALCULATIONS

Electricity Costs

Detailed rates were taken from published Ontario Energy Board (OEB) "rate orders" for each of HOL[11] and HONI[12]. These rate orders include distribution, transmission and regulatory aspects of the cost of electricity consisting of up to twelve different types of charges, which are further differentiated for each account class of the utility (9 for HOL and 13 for HONI). For commercial accounts with demand > 50kW, the rate structures include charges based on peak demand of the account holder, in units of $/kW. Values for peak demand per account class were obtained from documentation associated with OEB rate filings for HOL[13] and HONI[14]. The HONI data was Ontario-wide values (not Ottawa-specific), but the average demand/customer was assumed to be reasonably indicative of Ottawa use. The HONI data also did not include demand values for its "large users" account class, so an inference from HOL demand per kWh in this class was used.

The commodity (electricity) can be charged as time of use (TOU), tiered, or as the spot market prices (hourly Ontario energy price, HOEP plus global adjustment (GA) charges). Values for TOU and tiered are taken from on-line records of the OEB[15], both types of regulated price plans are designed to result in similar electricity costs to typical consumers[16]. We considered it a reasonable approximation to assign one type of commodity billing to an entire rate class. For Class A accounts that pay non-regulated rates, annual average values for HOEP and GA were taken from the OEB Ontario Energy Report Q4, 2015.[17]

Three government related charges also appeared on electricity bills in 2015:

- The debt retirement charge (DRC) fee for residential and commercial bills is collected towards offsetting debt relating to the former Ontario Hydro. Note that this charge ended Dec. 31, 2016 for residential bills, and will end for commercial bills on April 1, 2018.
- The Ontario Clean Energy Benefit (CERB) rebate, valued at 10% of total electricity charges on most accounts (this rebate ended Dec. 31, 2015).
- The HST at 13% of the total bill.

These last two charges were assumed to be the same for all rate classes, except for Class A, where no CERB was applied.

Natural Gas Costs

Costs for natural gas were derived with consideration of the monthly consumption data and the variability in market rates, and with details for four types of account classes. There are six types of charges on an Enbridge bill for natural gas service: gas commodity, delivery to the property by Enbridge, transportation from source to Enbridge distribution system, site restoration clearance, price adjustment charges, and monthly account fees. All but the last are charged as $\$/m^3$ rates.

- Monthly rates for gas commodity and delivery for 2015 were obtained from Enbridge for all account classes and multiplied by monthly consumption per class, also provided by Enbridge.
- A uniform transportation rate for all rate classes was confirmed in OEB rate orders.[11] The rates for price adjustment and site restoration clearance were derived from available residential bills and assumed to apply to all account classes.
- Monthly account fees were taken as $20 for residential and $70 for commercial classes (obtained on-line[18]), and the latter was assumed to apply to all industrial clients as well.

Gasoline and Diesel Costs

Average quarterly retail prices for regular gasoline and diesel in Ottawa in 2015 were obtained from Ontario Energy Reports[17], while rates for mid and premium grade gasoline, propane and oil were scaled from these values using price ratios derived from other sources[6].

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1 Statistics Canada, “Table 3-2 Household energy use, by fuel type and by province, 2011 — Average energy use”, http://www.statcan.gc.ca/pub/11-526-s/2013002/t004-eng.htm; and archived content at http://www.statcan.gc.ca/pub/11-526-s/2010001/part-partie1-eng.htm

2 Analysis used data from Statistics Canada CanSIM on-line tool, Table 134-0004. When examining Ontario “motor gasoline” data, the difference between “Domestic sales” and “Retail sales of motor gasoline” in 2015 was approximately 8%, which is thought to be primarily representative of fleet sales, though may also include other commercial sales. However it is also considered that Ottawa likely has larger fleet sales than most other markets given the large number of government fleets in operation.

3 Environment and Climate Change Canada, “National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada 1990–2014 Canada’s Submission to the United Nations Framework Convention on Climate Change”, 2016; Tables A6-1 to A6-4.

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5 Ontario Energy Report Q4 2015 - October - December 2015, http://www.ontarioenergyreport.ca/pdfs/5806_IESO_OntarioEnergyReportQ42016_OilGas_EN_FA.pdf

6 City of London Energy Cost 2014 analysis spreadsheet, as provided in confidence via City of Ottawa staff.

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17 Ontario Energy Report Q4 2015 – Oct-Dec 2015 Electricity (Commodity Cost – Class A), http://www.ontarioenergyreport.ca/pdfs/5806_IESO_OntarioEnergyReportQ42016_Electricity_EN_FA.pdf

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