UNDERTAKING JT-2.3

Reference:

Sponsors-1.1-Energy Probe-11(d)

Undertaking:

To respond to interrogatory Energy Probe 11D

Response:

Please see attached Hydro Ottawa's Interrogatory Responses to Pollution Probe in the OEB proceeding EB-2019-0261 (Attachment 1). Discussions on the City of Ottawa's Energy Evolution plan includes the following references:

PP-4(g);

PP-4(h);

PP-9(a);

PP-9(b);

PP-9(c);

Attachment to PP-11(A), Ottawa Sub-Region 2020 IRRP;

PP-12(c).

To provide further assistance, the City of Ottawa has contacted Hydro Ottawa and Hydro Ottawa has provided the following responses:

a) Hydro Ottawa commented on their active engagement in Energy Evolution in the interrogatory responses to EB-2019-0261 (see particularly page 5 of 5 of IRR PP-4)
b) Hydro Ottawa staff commented on the "Electricity Resource Strategy" prior to its inclusion in the Energy Evolution plan which was submitted to Council and unanimously approved by Ottawa City Council in October 2020
c) The City of Ottawa has had ongoing discussions with Hydro Ottawa about Energy Evolution since it was unanimously approved by Ottawa City Council. Hydro Ottawa made a commitment to be net zero by 2030 (link); a commitment which exceeds the requirements of the Energy Evolution 100% scenario model.

`

UNDERTAKING JT-2.4(A)

Reference:

Environmental Defense Compendium Panel 2 Excel Spreadsheet

Undertaking:

To advise if there are there any errors in the spreadsheet and if these electricity demand scenarios are consistent with Energy Evolution.

Response:

We have examined the referenced spreadsheet and found no errors. The electricity demand for heating in scenario 2 of the spreadsheet is consistent with Energy Evolution.

The electrical energy demand for heating in scenario 1, while plausible, is not included in the Energy Evolution 100% GHG reduction model and we therefore can not comment on it specifically. It may be included in a re-run of the model which the City of Ottawa is considering doing by the end of 2025.

UNDERTAKING JT-2.4(B)

Undertaking:

To make best efforts to provide natural gas usage for the City of Ottawa; if not, to indicate why not.

Response:

Please see the gas consumption tables below:

Corporate

Natural Gas Annual Consumption (m^3)					
2012	2016	2017	2018	2019	2020
16,312,735.23	21,814,076	19,664,402	21,020,442	21,866,292	19,941,908

Community

Natural Gas Annual Consumption (m^3)					
2012	2016	2017	2018	2019	2020
1,066,849,275	1,073,215,386	1,106,509,140	1,211,294,708	1,237,638,128	1,114,756,573

UNDERTAKING JT-2.5

Reference:

Transcript p. 50

Undertaking:

To file the document referred to in the interrogatory response.

Response:

Please see attached Data Methods and Assumptions Manual for Energy Evolution (Attachment 2).

UNDERTAKING JT-2.6

Undertaking:

To provide an estimate of natural gas usage with respect to the relevant period, and provide any assumptions or calculations used to derive that natural gas usage.

Response:

The remaining fossil natural gas in the 100% reduction model in 2050 generates 40 kilotons of carbon dioxide equivalent emissions. The consumption of such remaining fossil natural gas is related to longer duration gas contracts which may not have expired by 2050.

The Data Methods and Assumptions Manual (attached as Attachment 2) states that carbon dioxide equivalent emissions from the consumption of each gigajoule (GJ) of fossil natural gas is 49 kg.

The calculation is therefore 40,000,000 kg of emissions divided by 49 kg of carbon dioxide equivalent per GJ of gas consumed to give 816,326 GJ of fossil natural gas consumption in 2050.

UNDERTAKING JT-2.7

Reference:

I.M.2.1.STAFF.21

Undertaking:

In relation to Attachment 1, Staff 21, to confirm the correctness of the addresses that are shown.

Response:

By cross-referencing the City of Ottawa's property reports, we have identified the following errors and omissions in the address list provided.

a) The Bingham Hill Comfort Station has an address in Bowmanville Ontario. This address should not be included in the list because this facility is very small and is associated with another facility.
b) The Don Gamble St. Laurent Complex is located at 525 Côté.
c) There is no street address shown for the Montreal Rd EMS. It should be 200 Montreal Road.
d) The OC Transpo south garage is not located on Colonnade Rd. It is on the property parcel at 1500 St Laurent Blvd. which includes the administrative building. Therefore "OC Transpo South Garage * Colonnade Road" should not be included in the list.
e) There is no address for "Vanier Garage *OC Transpo Vanier Garage". The City of Ottawa refers to this location as "Vanier Garage/ Office/ Police" with the address of:
   252 McArthur Ave. K1L 6P4
f) Village Green Park Chalet should not be included in the list because it is very small and may not have gas service.

UNDERTAKING JT-2.8

Reference:

2.1-STAFF-5(b)

Undertaking:

To provide a documentary source to confirm data on reductions in gas use and GHG remissions at the Cliff Street Heating Plant referred to in IR Staff 5B.

Response:

We have contacted Energy Service Acquisition Program at Public Services and Procurement Canada for clarifications regarding the changes at the Cliff Street plant relative to this undertaking. The representative from The Energy Services Acquisition program provided the following information.

The conversion of the system from operating on steam to low temperature hot water is scheduled for completion by 2025. The work is on schedule and on budget and will result in some reduction of gas consumption with the exact reduction amount possibly offset by expansion of the system to more federal buildings.

The supply of electrically heated water is still the plan for the downtown district energy system supplied by Cliff Street as described in the evidence submitted by the City of Ottawa in EB-2020-0293 proceedings. A soon to be announced ministerial announcement will provide more information and clarification.

Furthermore, the use of ground source heat pumps for the area served by Cliff Street is under study with a determination of feasibility expected later in 2022

It would be the pleasure of City of Ottawa to continue to assist with inquiries about developments related to the Cliff Street plant

ATTACHMENT 1

INTERROGATORY RESPONSE - PP-4

4

EXHIBIT REFERENCE

Exhibit 1, Tab 1, Schedule 4, UPDATED

SUBJECT AREA: Distribution System Plan

Reference: "By way of this Application, Hydro Ottawa is informing the OEB of minor modification to the project' con truction chedule Wherea the original chedule had contemplated an in-service date of November 2021, this date has subsequently been revised to Q2 2022 "

Reference [EB 2019 0077 Deci ion and Order] A a re ult of the South Nepean Leave to Construct approval in 2019 (estimated project costs for Hydro Ottawa of $50.1 million), Hydro Ottawa indicated that it e pect to ee a ignificant improvement in their upply reliability According to Hydro Ottawa this will also support greater deployment of renewable resources, a the South Nepean MTS tran former have been pecifically de igned to accommodate injection of renewable energy into the local area's transmission system.

Questions:

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

g) Please provide details on what activities Hydro Ottawa plans to undertake over thi IR period to promote and encourage the additional di tributed/renewable energy resources noted above.

h) Plea e provide detail on all coordination and communication activitie Hydro Ottawa has conducted to promote greater deployment of renewable resources, including those in alignment with the City of Ottawa energy and emissions plan.

RESPONSE:

[redacted]

[redacted]

[redacted]

g) Hydro Ottawa plans to undertake the following activities over the course of its five-year Custom IR period to promote and encourage the deployment of additional distributed energy resources ("DERs"), as well as renewable resources:

- Continue to participate in the City of Ottawa's "Energy Evolution" initiative, as plans and projects are more concretely defined, and identify areas with greater capacity for uptake of DER (i.e. South Nepean);[1]
- Focus on advancing the capability to connect DERs in the course of the utility's renewal and modernization activities and building platforms to support control and monitoring of DERs connected to the distribution system; and
- Engage with and advise customers who are interested in renewable and DER resources, with an eye towards collaboratively developing and deploying solutions.

h) Coordination and communication activities that Hydro Ottawa has conducted to promote greater deployment of renewable resources are as follows:

- Hydro Ottawa continues to participate in industry groups to foster an enhanced understanding of the impacts of renewable resources on the distribution grid (e.g. Hydro One Networks Working DER group, and the Centre for Energy Advancement through Technological Innovation's ("CEATI") Smart Grid, Protection & Control, Distribution Line Asset Management, and Station Equipment Asset Management groups);
- Through Smart Grid projects such as MiGen, the utility is investing to explore tools and market models that support transactive future marketplace, with the aim of supporting the system and customer needs;
- Hydro Ottawa continues to participate in the IESO-led Regional Planning

[1] For additional information on Hydro Ottawa's involvement in Energy Evolution, please see the response to interrogatory ED 11

process, which evaluates different alternatives to address needs in the Ottawa area, including deployment of renewable resources;

- Through numerous forums and channels, the utility seeks to encourage customer uptake of renewable energy and to signal openness to collaborating with customers on the deployment of renewable energy solutions (e.g. Key Account forums and page on corporate website providing information on net metering);
- The utility has sought to lead by example through the deployment of solar energy installations at its own facilities (please see UPDATED Attachment 2-1-1(A): New Administrative Office and Operations Facilities for details); and
- Hydro Ottawa has remained actively engaged in the Energy Evolution initiative since its inception and has taken the strategy's goals into consideration in the development of its Distribution System Plan ("DSP"). Where appropriate, the DSP highlights planned actions and expenditures that are complementary to Energy Evolutions' objectives. For example, the expansion of station capacity can support increased accommodation of renewable energy projects through such measures as the installation of transformers which are designed to enable reverse-flow capabilities. For additional information on the utility's involvement in Energy Evolution, please see the response to interrogatory ED-11.

INTERROGATORY RESPONSE - PP-9

9

EXHIBIT REFERENCE

Exhibit 1, Tab 1, Schedule 9, UPDATED

SUBJECT AREA: Business Plan

Reference: Updated Hydro Ottawa Business Plan 2021-2025

Questions:

a) Please provide specific details on any cost savings or capital efficiencies Hydro Ottawa plan to achieve over the Cu tom IR period through coordination with the City of Ottawa on activity related to Energy Evolution, the City of Ottawa's Energy and Emi ion Plan (including project , cu tomer outreach, ocial media, DER planning, CDM, etc.). Please indicate the estimated costs savings to Ratepayers associated with the e effort by year

b) Plea e confirm if Hydro Ottawa ha compared it Cu tom IR period load foreca t against the City of Ottawa's forecast for its Energy Evolution plan. If yes, please identify any area where the e foreca t vary and the driver (e g EV , DER, CDM, cu tomer growth, load growth, etc.).

c) The City of Ottawa Official Plan is under development for the period starting 2021 and will upport Energy Evolution goal and outcome Plea e provide detail on Hydro Ottawa's intended coordination efforts over the Custom IR period related to Energy Evolution (including growth in DER, renewable , microgrid , CDM, and climate resilience planning).

[redacted]

[redacted]

[redacted]

RESPONSE:

a) As noted in the response to interrogatory OEB-68, the full scope and implementation plan for the City of Ottawa's "Energy Evolution" initiative has not yet been finalized. Key inputs that remain pending at the time of writing include a final energy and emissions model, financial and affordability analysis of the model, descriptions of the proposed projects, and an action plan. These items are set to be submitted to Ottawa City Council for approval later this year, along with the final policy design report on Energy Evolution.

As a result, there are currently no capital or operational investments or projects in Hydro Ottawa's 2021-2025 Custom IR rate plan that are being driven or defined by Energy Evolution. Hydro Ottawa will continue to engage in the implementation of Energy Evolution and will collaborate with the City of Ottawa and other stakeholders on potential opportunities and projects that are planned under the scope of the initiative.

b) No, Hydro Ottawa has not compared its load forecast for the 2021-2025 rate term against the City of Ottawa's forecasts under Energy Evolution. As noted in the response to part (a) above, the modelling and forecasting components of Energy Evolution have not yet been finalized.

c) Please see the response to interrogatory ED-11 for a detailed overview of Hydro Ottawa's engagement to date in Energy Evolution. Hydro Ottawa is committed to providing ongoing engagement and support for the initiative, consistent with its robust level of involvement to date.

[redacted]

[redacted]

[redacted]

[redacted]

[1] The type of GHG emissions measured were Scope 1 emissions, meaning they were direct emissions from sources that were owned or controlled by the utility

INTERROGATORY RESPONSE - PP-11

11

EXHIBIT REFERENCE

Exhibit 2, Tab 4, Schedule 3, UPDATED

SUBJECT AREA: Distribution System Plan

Questions:

a) Please file a copy of the most recent Integrated Regional Resource Plan (IRRP) for the Ottawa area sub-region.

[redacted]

[redacted]

[redacted]

RESPONSE:

a) Plea e ee Attachment PP 11(A) Ottawa Sub Region 2020 IRRP

[redacted]

Ottawa Sub-Region:

Integrated Regional Resource Plan

Part of the Greater Ottawa Regional Planning Region

March 4, 2020

Connecting Today.
Powering Tomorrow.

Integrated Regional Resource Plan

Ottawa Sub-Region

This Integrated Regional Resource Plan (IRRP) was prepared by the Independent Electricity System Operator (IESO) pursuant to the terms of its Ontario Energy Board license, EI-2013-0066.

The IESO prepared the IRRP on behalf of the Ottawa Sub-Region Working Group (Working Group), which included the following members:

- Independent Electricity System Operator
- Hydro Ottawa Limited
- Hydro One Networks Inc. (Distribution)
- Hydro One Networks Inc. (Transmission)

The Working Group developed a plan that considers the potential for long-term electricity demand growth and varying supply conditions in the Ottawa Sub-Region, and maintains the flexibility to accommodate changes to key conditions over time.

[redacted]

[redacted]

[redacted]

[redacted]

7.7 SUMMARY OF RECOMMENDED ACTIONS AND NEXT STEPS

Table 7-6, below, summarizes the specific recommendations that should be implemented immediately to address the most imminent electricity supply needs in the Ottawa area.

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

The Working Group has also identified the following additional planning activities to address ongoing regional planning needs.

Targeted Need or Area	Action	Timeframe
Across the Sub-Region	Monitor the City of Ottawa's Energy Evolution mandate and explore the potential for alignment between integrated regional planning and the Energy Evolution mandate.	Throughout the next regional planning cycle
Regional 115 kV System	Develop a long-term plan for the 115 kV transmission system. This study will include an assessment of the potential for non-wires alternatives to manage demand growth at heavily loaded stations supplied by the 115 kV system while maintaining demand on the overall 115 kV transmission system within the capability of the existing 230/115 kV transformers.	2020
Across the Sub-Region	Monitor demand growth and the status of major development proposals on an annual basis. The next regional planning cycle is scheduled to begin in 2023, however it could be triggered sooner if the Working Group identifies a material need.	Annually

[redacted] [redacted]

[redacted]

[redacted]

[redacted]

8.3 ENGAGE EARLY AND OFTEN

Leveraging relationships built during the previous planning cycle, the IESO held preliminary discussions to help inform the engagement approach during this second planning cycle – starting with the Scoping Assessment Outcome Report.

Early communication and engagement activities began with invitations to all subscribers and targeted communities to learn about and provide comments on the draft Greater Ottawa Scoping Assessment Outcome Report before it was finalized. This scoping assessment identified the need for an IRRP specifically for the Ottawa Sub-Region, and included Terms of Reference to guide development of the plan. Following a window for comments to be submitted by interested parties, the final Scoping Assessment Outcome Report was published in September 2018. No comments were received during this feedback period.

Outreach then began with targeted communities to inform early discussions for the development of the IRRP including the IESO's approach to engagement. In response to the input received through these initial discussions, the IESO undertook direct outreach and

[15] http://www.ieso.ca/en/Sector-Participants/Engagement-Initiatives/Engagements/Integrated-Regional-Resource-Plan-Ottawa-Area-Sub-Region

engagement with municipal councilors in targeted areas of need in the City of Ottawa. The launch of a broader engagement initiative followed with an invitation to subscribers to ensure that all interested parties were made aware of this opportunity for input.

Two public webinars were held at major junctures during IRRP development to give interested parties an opportunity to hear about its progress and provide comments on key components. Both webinars received strong participation with cross-representation of stakeholders and community representatives attending the webinar, and submitting written feedback during a 14-day comment period.

The first webinar sought input on the electricity demand forecast and needs in the Ottawa area and potential solutions to be examined. Several comments were received during the feedback window that touched on the following major themes:

- Non-wires solutions
- Land use
- GHG reduction
- Cost effectiveness
- Feasibility of generation

As a final step in the engagement initiative, a second public webinar was held to seek input on the analysis of options and draft IRRP recommendations. Feedback received during the written comment period were related to the major themes below:

- Options analysis: delivery models
- Options analysis: non-wires alternatives
- Alignment with local initiatives
- Engagement

Based on the discussion in the webinar and written feedback received, it is clear that there is a strong interest and need for ongoing monitoring of capacity and local demand growth and continued discussion and engagement with communities and stakeholders. While there is strong community interest in non-wires alternatives, the near-term nature of the needs will require other solutions to be in place in order to ensure a continued reliable electricity supply to support rapid local growth. Furthermore, other factors and initiatives that may have an impact on local electricity needs will continue to evolve post IRRP, such as projects arising from the City of Ottawa's Energy Evolution. To that end, ongoing discussions will continue through the

IESO's Eastern Ontario Regional Electricity Network to keep interested parties engaged on local developments, priorities and planning initiatives.

All background information, including engagement presentations, recorded webinars, detailed feedback submissions, and responses to comments received, are available on the IESO's Integrated Regional Resource Plan engagement web page.

8.4 OUTREACH WITH MUNICIPALITIES

As the City of Ottawa was a key stakeholder in the development of this IRRP, the IESO held a number of meetings with City representatives, to exchange information on municipal planning and electricity planning processes, as well as the City's community energy transition strategy, called Energy Evolution. Meetings began in August 2018 at the outset of this planning project and continued in April, August and October 2019. These meetings were held with municipal representatives in the climate change resiliency and planning areas, as well as with some City Councilors to build awareness and provide opportunities to raise concerns that might arise from their constituents. No concerns were raised. The potential for future alignment between Energy Evolution and regional planning was also a topic of discussion with municipal representatives. In addition to helping to inform the City's electricity needs, these meetings also provided opportunities to strengthen relationships to enable ongoing dialogue beyond this IRRP process.

INTERROGATORY RESPONSE - PP-12

12

EXHIBIT REFERENCE

Exhibit 1, Tab 1, Schedule 4, UPDATED

SUBJECT AREA: CDM

Questions:

[redacted]

[redacted]

c) Please confirm that Hydro Ottawa will develop and execute its CDM activities in coordination with the City of Ottawa' Energy Evolution plan, which include complimentary goals to reduce energy costs and emissions for consumers in the City of Ottawa

[redacted]

RESPONSE:

[redacted]

c) Hydro Ottawa is collaborating with the City of Ottawa on its “Energy Evolution” initiative and will consult with the City on any future CDM activities. For more information, please see the response to interrogatory ED-11.

[redacted]

ATTACHMENT 2

CITY OF OTTAWA

COMMUNITY ENERGY TRANSITION PLAN 2018

Data, Methods & Assumptions Manual

PREPARED BY:

SSG SUSTAINABILITY SOLUTIONS GROUP

whatIf?

Contents

Summary

The Data, Methods and Assumptions (DMA) manual has been created for the City of Ottawa to illustrate the modeling approach used to provide energy and emissions benchmarks and projections. The DMA will also provide a summary of the data and assumptions being used as the foundation for the energy and emissions modeling. This allows for the elements of the modelling to be fully transparent, as well as lay a foundation for the scope of data required for future modelling efforts that the City can build upon.

Accounting and Reporting Principles

The Global Protocol for Community-Wide GHGs (GPC) is based on the following principles in order to represent a fair and true account of emissions:

- Relevance: The reported GHG emissions shall appropriately reflect emissions occurring as a result of activities and consumption within the Town boundary. The inventory will also serve the decision-making needs of the Town, taking into consideration relevant local, subnational, and national regulations. Relevance applies when selecting data sources, and determining and prioritizing data collection improvements.
- Completeness: All emissions sources within the inventory boundary shall be accounted for. Any exclusions of sources shall be justified and explained.
- Consistency: Emissions calculations shall be consistent in approach, boundary, and methodology.
- Transparency: Activity data, emissions sources, emissions factors and accounting methodologies require adequate documentation and disclosure to enable verification.
- Accuracy: The calculation of GHG emissions should not systematically overstate or understate actual GHG emissions. Accuracy should be sufficient enough to give decision makers and the public reasonable assurance of the integrity of the reported information. Uncertainties in the quantification process should be reduced to the extent possible and practical.

Assessment Boundary

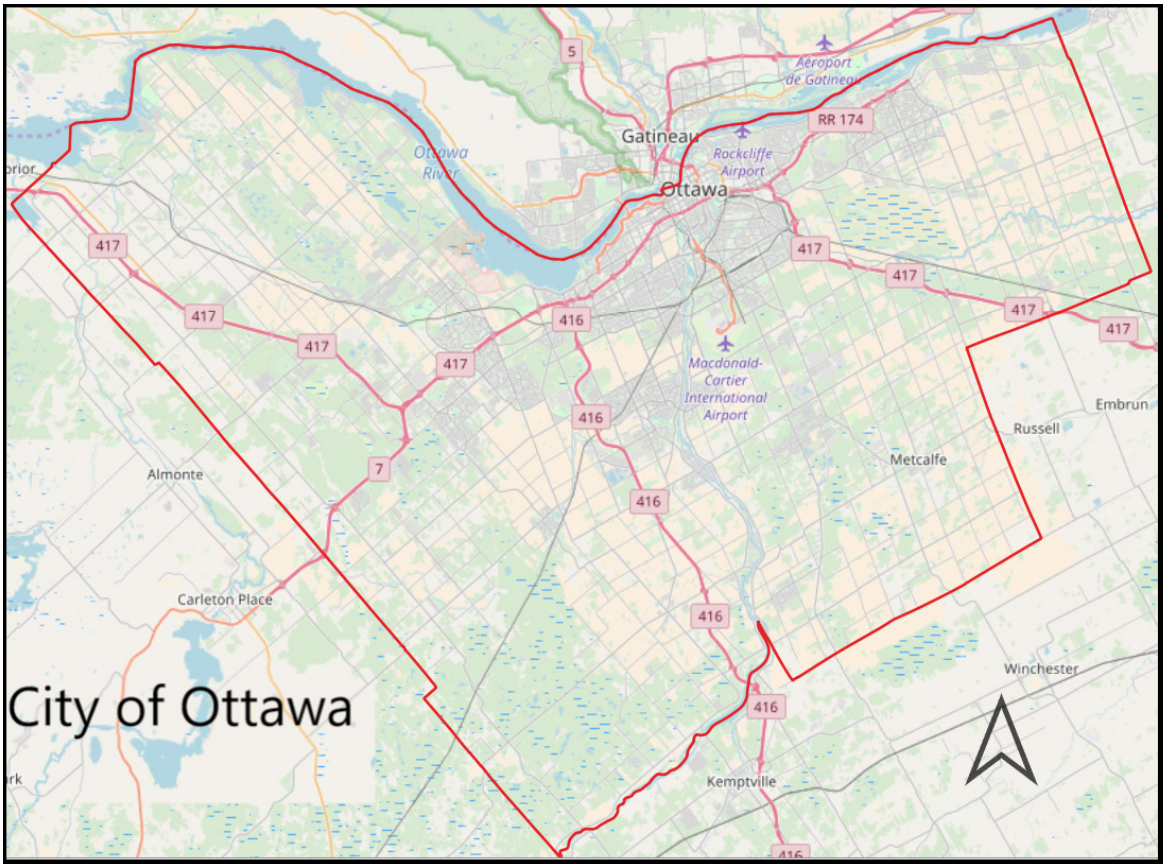

Figure 1. Municipal Boundary of Ottawa.

Assessment Time Frame

The energy and emissions modelling for this project considers the time frame of 2016 (baseline year) to 2050 (target year). The 2016 census is used to establish the baseline year, which is also based on as much observed data as possible in order to provide an accurate and consistent information snapshot.

Assessment Scope

The inventory will include Scopes 1 and 2, and some aspects of Scope 3. Refer to Appendix 1 for a list of GHG emission sources by Scope that are included.

Table 1. GPC scope definitions.

Scope	Definition
1	All GHG emissions from sources located within the Town boundary.
2	All GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the Town boundary.
3	All other GHG emissions that occur outside the Town boundary as a result of activities taking place within the Town boundary.

Emissions Factors

Table 2. Emissions Factors for Ottawa Baseline and Future Scenarios.

Category	Description	Comment
Natural gas	49 kg CO2e/GJ	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Tables A6-1 and A6-2, Emission Factors for Natural Gas.
Electricity	2016: CO2: 28.9 g/kWh CH4: 0.007 g/kWh N2O: 0.001 g/kWh 2050: CO2: 37.4 g/kWh CH4: 0.009 g/kWh N2O: 0.001 g/kWh	National Energy Board. (2016). Canada's Energy Future 2016. Government of Canada. Retrieved from https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016pt/nrgyftrs_rprt-2016-eng.pdf
Gasoline	g/L CO2: 2316 CH4: 0.32 N2O: 0.66	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Diesel	g/L CO2: 2690.00 CH4: 0.07 N2O: 0.21	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Fuel oil	Residential g/L CO2: 2560 CH4: 0.026 N2O: 0.006 Commercial g/L CO2: 2753 CH4: 0.026 N2O: 0.031 Industrial g/L CO2: 2753 CH4: 0.006 N2O: 0.031	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–4 Emission Factors for Refined Petroleum Products

Category	Description	Comment
Propane	g/L Transport CO2: 1515.00 CH4: 0.64 N2O: 0.03 Residential CO2: 1515.00 CH4 : 0.027 N2O: 0.108 All other sectors CO2: 1515.00 CH4: 0.024 N2O: 0.108	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–3 Emission Factors for Natural Gas Liquids Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Waste	Landfill emissions are calculated from first order decay of degradable organic carbon deposited in landfill. Derived emission factor in 2016 = 0.015 kg CH4/ tonne solid waste (assuming 70% recovery of landfill methane); 0.050 kg CH4/tonne solid waste not accounting for recovery.	Landfill emissions: IPCC Guidelines Vol 5. Ch 3, Equation 3.1
Wastewater	CH4: 0.48 kg CH4/kg BOD N2O: 3.2 g / (person * year) from advanced treatment 0.005 g /g N from wastewater discharge	CH4 wastewater: IPCC Guidelines Vol 5. Ch 6, Tables 6.2 and 6.3; MCF value for anaerobic digester N2O from advanced treatment: IPCC Guidelines Vol 5. Ch 6, Box 6.1 N2O from wastewater discharge: IPCC Guidelines Vol 5. Ch 6, Section 6.3.1.2

Modelling Tool

The modelling for the 2016 baseline year and BAP scenario out to 2050 were completed using CityInSight, an integrated energy, emissions and finance model developed by Sustainability Solutions Group (SSG) and whatIf? Technologies Inc. (whatIf?). It is an integrated, multi-fuel, multi-sector, spatially-disaggregated energy systems, emissions and finance model for cities. The model enables bottom-up accounting for energy supply and demand, including renewable resources, conventional fuels, energy consuming technology stocks (e.g. vehicles, appliances, dwellings, buildings) and all intermediate energy flows (e.g. electricity and heat).

Table 3. Characteristics of CityInSight.

Characteristic	Rationale
Integrated	CityInSight is designed to model and account for all sectors that relate to energy and emissions at a city scale while capturing the relationships between sectors. The demand for energy services is modelled independently of the fuels and technologies that provide the energy services. This decoupling enables exploration of fuel switching scenarios. Physically feasible scenarios are established when energy demand and supply are balanced.
Scenario-based	Once calibrated with historical data, CityInSight enables the creation of scenarios to explore different possible futures. Each scenario can consist of either one or a combination of policies, actions and strategies. Historical calibration ensures that scenario projections are rooted in observed data.
Spatial	The configuration of the built environment determines the ability of people to walk and cycle to their destinations, accessibility to transit, feasibility of district energy and other aspects. CityInSight therefore includes a full spatial dimension that can include as many zones - the smallest areas of geographic analysis - as are deemed appropriate. The spatial component to the model can be integrated with City GIS systems, land-use projections and transportation modelling.
GHG reporting framework	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC Protocol).
Economic impacts	CityInSight has the ability to incorporate a financial analysis of costs related to energy (expenditures on energy) and emissions (carbon pricing, social cost of carbon), as well as operating and capital costs for policies, strategies and actions. It supports the generation of marginal abatement curves to illustrate the cost and/or savings of policies, strategies and actions.

Energy and GHG emissions are derived from a series of connected stock and flow models, evolving on the basis of current and future geographic and technology decisions/assumptions (e.g. EV penetration rates). The model accounts for physical flows (i.e. energy use, new vehicles by technology, vehicle kilometres travelled) as determined by stocks (buildings, vehicles, heating equipment, etc).

CityInSight incorporates and adapts concepts from the system dynamics approach to complex systems analysis. For any given year within its time horizon, CityInSight traces the flows and transformations of energy from sources through energy currencies (e.g. gasoline, electricity, hydrogen) to end uses (e.g. personal vehicle use, space heating) to energy costs and to GHG emissions. An energy balance is achieved by accounting for efficiencies, conservation rates, trade, and losses at each stage in the journey from source to end use.

Model Structure

The major components of the model, and the first level of modelled relationships (influences), are represented by the blue arrows in Figure 2. Additional relationships may be modelled by modifying inputs and assumptions, specified directly by users, or in an automated fashion by code or scripts running "on top of" the base model structure. Feedback relationships are also possible, such as increasing the adoption rate of non-emitting vehicles in order to meet a particular GHG emissions constraint.

The model is spatially explicit. All buildings and transportation activities are tracked within a discrete number of geographic zones, or zone system, specific to the city. This enables consideration of the impact of land-use patterns and urban form on energy use and emissions production from a baseline year to future points in the study horizon. CityInSight's GIS outputs can be integrated with city mapping and GIS systems.

Stocks and flows

For any given year, various factors shape the picture of energy and emissions flows, including: the population and the energy services it requires; non-residential buildings; energy production and trade; the deployed technologies which deliver energy services (service technologies); and the deployed technologies which transform energy sources to energy carriers (harvesting technologies). The model makes an explicit mathematical relationship between these factors - some contextual and some part of the energy consuming or producing infrastructure - and the energy flow picture.

Some factors are modelled as stocks - counts of similar things, classified by various properties. For example, population is modelled as a stock of people classified by age and gender. Population change over time is projected by accounting for: the natural aging process, inflows (births, immigration) and outflows (deaths, emigration). The fleet of personal use vehicles, an example of a service technology, is modelled as a stock of vehicles classified by size, engine type and model year - with a similarly-classified fuel consumption intensity. As with population, projecting change in the vehicle stock involves aging vehicles and accounting for major inflows (new vehicle sales) and major outflows (vehicle discards). This stock-turnover approach is applied to other service technologies (e.g. furnaces, water heaters) and also harvesting technologies (e.g. electricity generating capacity).

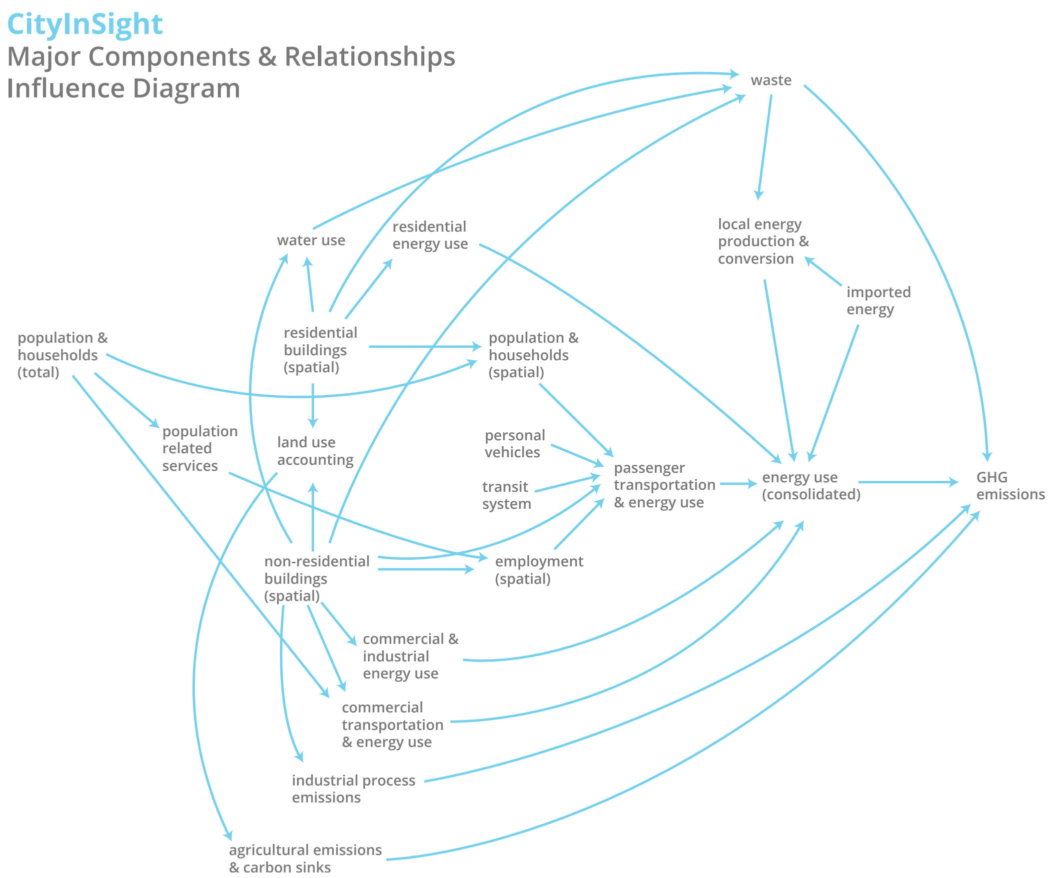

Figure 2. Representation of CityInSight's structure.

Sub-models

Population and demographics

City-wide population is modelled using the standard population cohort-survival method, disaggregated by single year of age and gender. It accounts for various components of change: births, deaths, immigration and emigration. The age structured population is important for analysis of demographic trends, generational differences and implications for shifting energy use patterns. Population in CityInSight drives residential waste generation and generates demand for community services such as education and health care.

Residential buildings

Residential buildings are spatially located and classified using a detailed set of 30+ building archetypes capturing footprint, height and type (single, double, row, apt. high, apt. low), in addition to year of construction. This archetype classification enables a "box" model of buildings to estimate building surface area and the thermal conduction through the building walls. Coupled with thermal envelope performance and degree-days the model calculates space conditioning energy demand independent of any particular space heating or cooling technology and fuel.

Energy service demand then drives stock levels of key service technologies (heating systems, air conditioners, water heaters). These stocks are modelled with a stock-turnover approach capturing equipment age, retirements, and additions - exposing opportunities for efficiency gains and fuel switching, but also simulating the rate limits to new technology adoption and the effects of lock in.

Residential building archetypes are also characterized by number of contained dwelling units, allowing the model to capture the energy effects of shared walls as well as the urban form and transportation implications of population density.

In addition to energy service demand, residential buildings produce demand for water and generate wastewater.

Non-residential buildings

Non-residential buildings are spatially located and classified by a detailed use/purpose-based set of 50+ archetypes, and the floorspace of these non-residential building archetypes can vary by location. Non-residential floorspace produces waste and demand for energy and water, and also provides an anchor point for locating employment of various types.

Spatial population and employment

City-wide population is made spatial by assignment to dwellings, using assumptions about persons-per-unit by dwelling type. Spatial employment is projected via two separate mechanisms: population-related services and employment, which is assigned to corresponding building floorspace (e.g. teachers to school floorspace); and floorspace-driven employment (e.g. retail employees per square metre).

Passenger Transportation

The model includes a spatially explicit passenger transportation sub-model that responds to or accounts for changes in land use, transit infrastructure, vehicle technology, travel behavior and other factors. Trips are divided into four types (home-work, home-school, home-other, and non-home-based), each produced and attracted by different combinations of spatial drivers (population, employment, classrooms, non-residential floorspace).

Trips are distributed - that is, trip volumes are specified for each zone of origin and zone of destination pair. For each origin-destination pair trips are shared over walk/bike (for trips within the walkable distance threshold), public transit (for trips whose origin and destination are serviced by transit) and automobile. Following the mode share step, along with a network-based distance matrix, a projection of total personal vehicles kilometres travelled (VKT) is produced. The energy use and emissions associated with personal vehicles is calculated by assigning VKT to a stock-turnover personal vehicle model. All internal and external passenger trips are accounted for and available for reporting according to various geographic conventions.

Waste

Households and non-residential buildings generate solid waste and wastewater, and the model traces various pathways to disposal, compost and sludge including those which capture energy from incineration and recovered gas. Emissions accounting is performed throughout the waste sub-model, which follows the recommended methodology for solid waste and wastewater emissions calculations in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.[1] Landfill methane emissions calculations in CityInSight use the First Order Decay (FOD) method in which models the release of methane through the decomposition of organic carbon over time. Emissions from biological treatment processes such as composting and anaerobic digestion are calculated from emissions factors applied to the amount of waste treated and a methane recovery rate. Methane emissions from wastewater are calculated from emissions factors applied to the biochemical oxygen demand (BOD) in the wastewater influent. Nitrous oxide emissions from wastewater come from process emissions within the treatment plant and indirect emissions from the wastewater effluent. Process emissions are calculated from a population-based emission factor and the population served. Indirect emissions are calculated from the estimated nitrogen concentration in the wastewater effluent.

Energy flow and local energy production

Energy produced from local, primary sources (e.g. solar, wind) is modelled alongside energy converted from imported fuels (e.g. electricity generation, district energy, CHP). As with the transportation sub-model, the district energy supply model has an explicit spatial dimension and represents areas - collections of zones - served by district energy networks.

Finance and employment

Energy related financial flows and employment impacts—while not shown explicitly in Figure 2—are captured through an additional layer of model logic. Calculated financial flows include the capital, operating and maintenance cost of energy consuming stocks and energy producing stocks, including fuel costs. Employment related to the construction of new buildings, retrofit activities and energy infrastructure is modelled.

1 Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). (2006). IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme,Published: IGES, Japan.

Modelling Process

1. Data request & collection

A detailed data request was compiled and issued to the City of Ottawa. Data was collected from various sources by the City, SSG and whatIf?. Assumptions were identified to supplement any gaps in observed data. The data and assumptions were applied in modelling per the process described below.

2. Setting up the model

Zone system

The modelling tool (CityInSight) is spatially explicit, that is, population, employment and residential and non-residential floorspace, which drives stationary energy demand, are allocated and tracked spatially within the model's zone system. The passenger transportation sub-model, which drives transportation energy demand, also operates within the same zone system.

The City of Ottawa uses a pre-existing transportation zone system extensively for planning projections and analysis. The population, employment and floorspace projections, as well as baseline and projected transportation modelling results, were completed and provided by the City of Ottawa at the transportation zone level. As such, the transportation zone system for the City of Ottawa was adopted as CityInSight's zone system, the primary spatial unit of analysis.

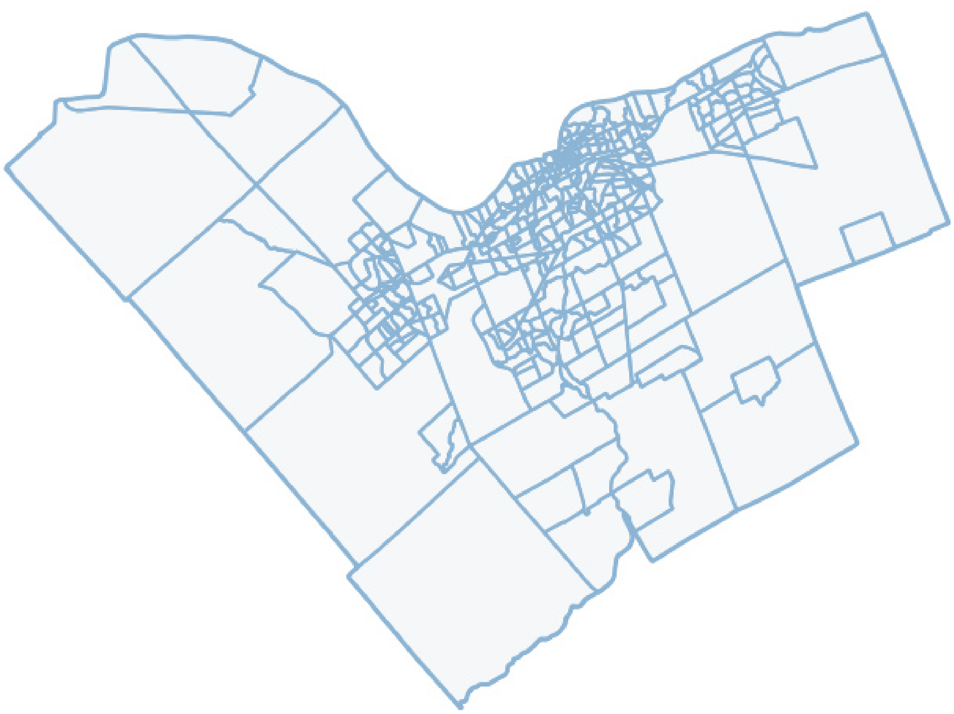

Figure 3. Transportation zones for City of Ottawa (2011).

Buildings

Buildings data, including building type, building footprint area, number of storeys, total floorspace area, number of units, and year built was sourced from the City of Ottawa's Municipal Property Assessment Corporation (MPAC) data for 2016. Using the spatial attributes of the MPAC data, buildings were allocated to specific zones, based on the zone system for the City of Ottawa.

Subsequently, buildings were classified using a detailed set of buildings archetypes; 30+ archetypes for residential, and 50+ archetypes for non-residential (see Appendix 2). These archetypes capture footprint, height and type (eg. single family home, semi-attached home etc.), enabling the creation of a “box” model of buildings, and an estimation of surface area for all buildings.

Residential buildings

The model multiplies the residential building surface area by an estimated thermal conductance (heat flow per unit surface area per degree day) and the number of degree days to derive the energy transferred out of the building during winter months and into the building during summer summer months. The energy transferred through the building envelope, the solar gain through the building windows, and the heat gains from equipment inside the building constitute the space conditioning load to be provided by the heat systems and the air conditioning. The initial thermal conductance estimate is a provincial average by dwelling type from the Canadian Energy System Simulator (CanESS). This initial estimate is adjusted through the calibration process as the modelled energy consumption in the residential sector is forced to track on observed residential fuel consumption in the baseline year.

Non-residential buildings

For non-residential buildings, the model calculates the space conditioning load as it does for residential buildings with one distinction, the thermal conductance parameter for non-residential buildings is based on floor space area instead of surface area. CanESS provides the initial estimate of the non-residential thermal conductance by building sector. This estimate is then adjusted to match the space heating energy use intensity for building types in the Ontario Broader Public Sector data set.

Starting values for output energy intensities and equipment efficiencies for other residential and non-residential end uses are also provincial averages from CanESS. All parameter estimates are further adjusted during the calibration process. The calibration target for non-residential building energy use is the observed commercial and industrial fuel consumption in the baseline year.

Using assumptions for thermal envelope performance for each building type, the model calculates total energy demand for all buildings, independent of any space heating or cooling technology and fuel.

Population and employment

Population and employment data was sourced directly from the City, and spatially allocated to residential (population) and non-residential (employment) buildings. Population and employment is allocated spatially primarily to enable indicators to be derived from the model, such as emissions per household, and to drive the BAP energy and emissions projections (buildings, transportation, waste).

Population for 2016 was spatially allocated to residential buildings using initial assumptions about persons-per-unit (PPU) by dwelling type. These initial PPUs are then adjusted so that total population in the model (which is driven by the number of residential units by type multiplied by PPU by type) matches the total population from census data.

Employment for 2016 was spatially allocated to non-residential buildings using initial assumptions for two main categories: population-related services and employment, allocated to corresponding building floorspace (e.g. teachers to school floorspace); and floorspace-driven employment (e.g. retail employees per square metre). Similarly to population, these initial ratios are adjusted within the model so that the total employment derived by the model matches total employment from census data.

Transportation

The model includes a spatially explicit passenger transportation sub-model that responds to changes in land use, transit infrastructure, vehicle technology, travel behavior change and other factors. Trips are divided into four types (home-work, home-school, home-other, and non-home-based), each produced and attracted by different combination of spatial drivers (population, employment, classrooms, non-residential floorspace). Trips volumes are distributed as pairs for each zone of origin and zone of destination. For each origin-destination pair, trips are shared over walk/bike (for trips within the walkable distance threshold), public transit (for trips whose origin and destination are serviced by transit) and automobile. Total personal vehicles kilometres travelled (VKT) is produced when modelling mode shares and distances. The energy use and emissions associated with personal vehicles is calculated by assigning VKT to model of personal vehicle ownership. The City of Ottawa Transportation Planning group provided several data sets to support the calibration of the transportation sub-model:

- 2011 Ottawa travel survey data - provided initial trip mode shares by origin/destination pair and trip purpose
- 2011 TRANS model results - provided initial trip distribution by trip purpose over origin/destination pairs
- 2011 origin/destination network distance matrix
- MTO vehicle registration data

The GPC induced activity approach is used to account for emissions. All internal trips (trips within Ottawa's boundary) are accounted for, as well as half of the trips that terminate or originate within the Town's boundary. This approach allows Ottawa to better understand its impact on the peripheries and the region. Figure 4 shows sample trips within a municipality.

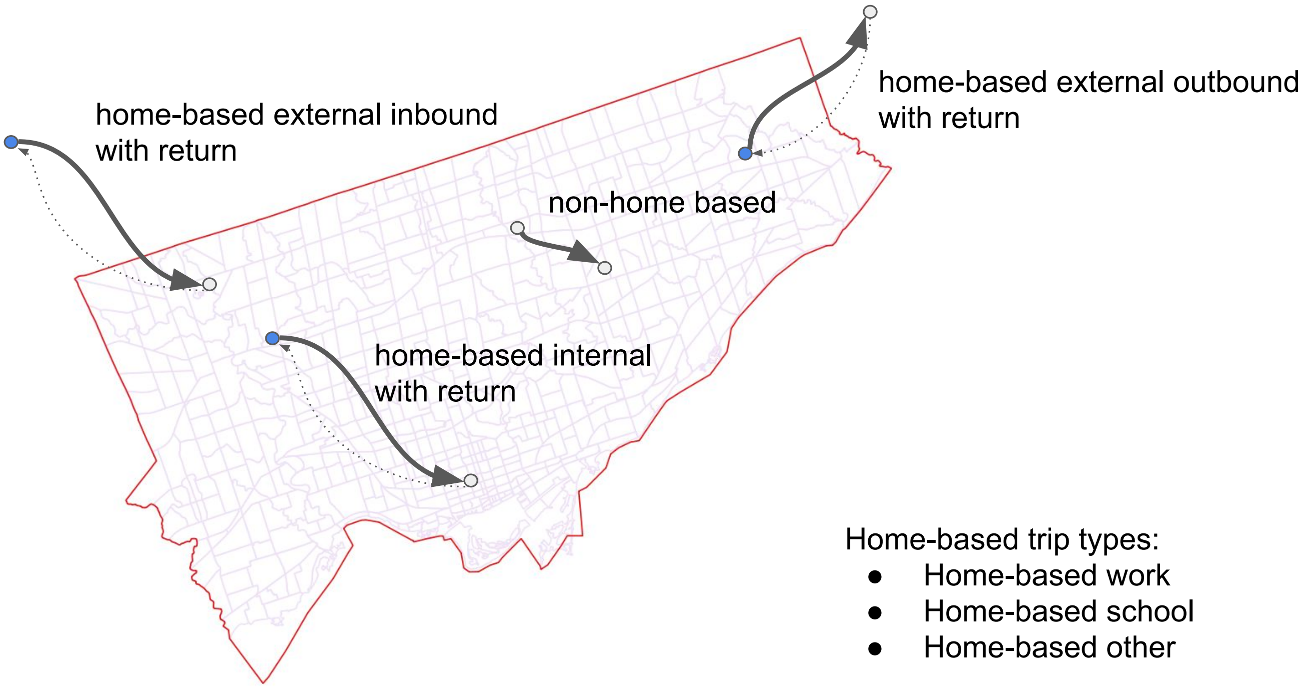

Figure 4. Conceptual diagram of trip categories.

Waste

Solid waste stream composition and routing data (landfill, composting, recycling) was sourced from the City of Ottawa reports for the years 2012, 2015, and 2016 for the Trail Road Waste Facility. The base carbon content in the landfill was estimated based on waste production data going back to 1971. 1971-2012 waste inputs into landfills is sourced from the Ottawa LandGEM model. 2013-2015 waste inputs into landfills is estimated from the 2016 per capita waste generation and Ottawa population in 2013-2015 for residential wase, the 2016 ICI waste per unit floor space and pre-2016 non-residential floor space for ICI waste. Total methane emissions were estimated using the first order decay model, with the methane generation constant and methane correction factor set to default, as recommended by and based on values from IPCC Guidelines for landfill emissions. Data on methane removed via recovery/flaring was sourced from data provided by The City of Ottawa, and Ottawa Research and Forecasting Centre for R.O. Pickard Environment Centre (Wastewater)

Model Calibration

Buildings calibration

Total buildings energy demand, derived from the buildings box model, was then calibrated against 2016 observed utility data for electricity and natural gas, provided by Ottawa Hydro / Hydro One, and Enbridge Gas respectively. In the calibration process, fuel shares are adjusted to meet the ratio of electricity to natural gas energy use in a given sector. Then the thermal conductance for residential building space conditioning and output energy use intensities for non-residential buildings and non-space conditioning residential end uses are adjusted until the model estimate of electricity and natural gas use matches the observed data.

Transportation calibration

Unlike utility-reported stationary energy consumption totals (e.g. electricity, natural gas) transportation fuel sales data is not a preferred control total for municipal transportation activity and energy analysis, due to the uncertainty of estimating point of fuel consumption based on retail point of fuel purchase. Therefore, calibration of the passenger transportation model was anchored with the household survey informing the spatial travel demand model and the results compared for reasonableness against indicators such as average annual VKT per vehicle. For medium-heavy duty commercial vehicle transportation, the diesel fuel sales for Ottawa were used as a control total - along with an assumed retail/non-retail ratio - due to the absence of other data sources for local commercial transportation activity.

The modelled stock of personal vehicles (by size, fuel type, efficiency, vintage) was informed by CANSIM and Natural Resources Canada's Demand and Policy Analysis Division. The total number of personal use and corporate vehicles is proportional to the projected number of households in the BAP.

The transit vehicle fleet, and its respective VKT and fuel consumption was modelled on data provided by Ottawa 's transit provider, OC Transpo.

Scenario Analysis

Creating a Baseline Scenario

After completion of model calibration, a baseline energy and emissions profile is generated for 2016.

Business-as-planned Scenario

The business-as-planned (BAP) scenario is a projection over the time period from 2017 to 2050. It is designed to illustrate the anticipated energy use and greenhouse gas emissions for the City of Ottawa if no additional policies, actions or strategies to address energy and emissions are implemented between 2017-2050, other than those currently underway or planned.

Note that a scenario, as it is applied in this context, is an internally consistent view of what the future might turn out to be—not a forecast, but one possible future outcome. As such, the BAP scenario projection is one of many possible views of the future; in this case, one that assumes that no additional policies, actions or strategies to address energy and emissions, other than those currently underway or planned, are implemented between 2017-2050.

The BAP process

The BAP scenario was established through developing assumptions as follows:

- Incorporating existing quantitative projections directly into the model when available. This included:
    a. From the City:
        - Population and employment projections by zone;
    b. From other technical sources:
        - Ontario building code and new building energy performance standards
        - Electricity grid emissions factor
        - Climate projections for heating/cooling degree days
        - Vehicle efficiency standards
        - Electric vehicle uptake projections
- Where quantitative projections were not carried through to 2050 (eg. completed to 2031), the projected trend was extrapolated to 2050.
- Where specific quantitative projections were not available, projections were derived using proxy or related data, and continuing with the existing trend; this included:
    - Building floorspace projections, derived using the population and employment projections and allocating new dwellings based on existing persons per unit (for residential), and floorspace (m2) per employee/job (for non-residential space).
    - Waste projections, derived using population projections and applying existing waste productions rates (tonnes waste/person).

The BAP methodology and assumptions for the major model components are summarized. Further details and sources of data can be found in BAP data & assumptions.

Population, employment and buildings

The BAP energy and emissions profile was generated through:

» Applying the population and employment projections into the future, provided by the City;

» Identifying new residential floorspace (households/dwellings) to house the projected population; this is derived by allocating new dwellings based on the existing persons per unit;

» Identifying new non-residential floorspace to accommodate projected employment; this is derived by allocating new non-residential floorspace according to gross floor area per employee/job.

» New residential and non-residential floorspace is spatially allocated according to existing and projected growth/land-use plans.

Buildings performance

New construction: No policy for new construction was found when reviewing City of Ottawa policies and data, however building efficiencies are anticipated to increase with future technologies. Modelling for all new construction assumes a 10% improvement every 5 years.

Existing buildings: The efficiency of the existing building stock was assumed to remain unchanged; efficiency was held constant from 2016-2050.

Climate projections

To account for the influence of projected climate change, energy use was adjusted according to the number of heating and cooling degree days. Projections are created using "Statistically Downscaled Climate Scenarios," developed by the Pacific Climate Impacts Consortium and applied to the Ottawa Region . (Figure 5).

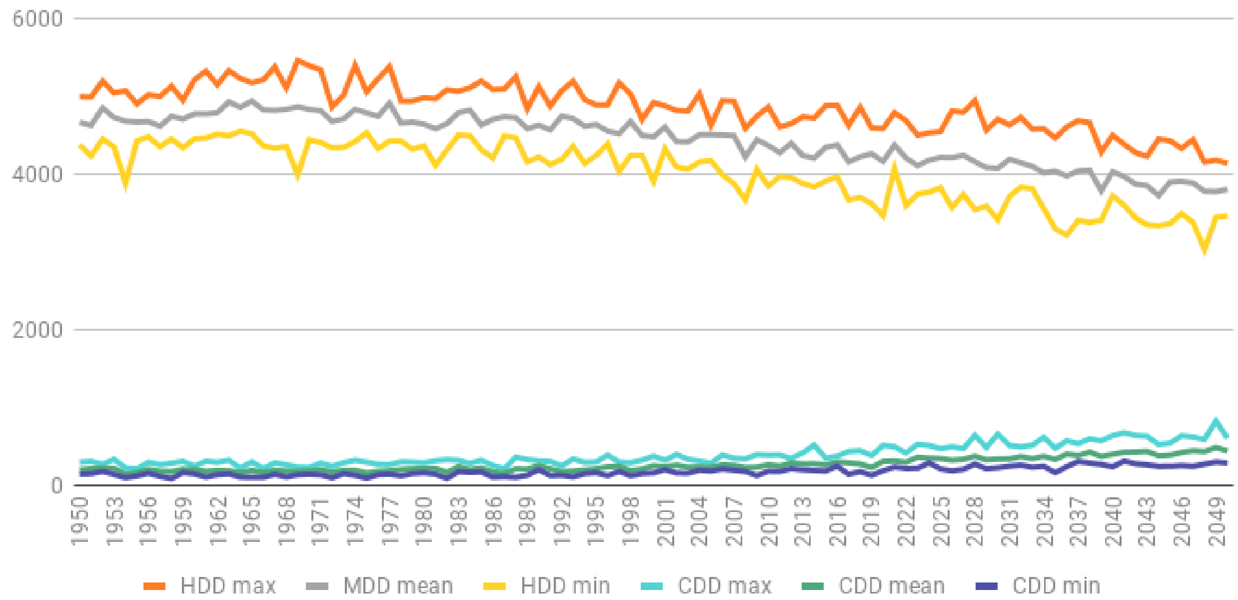

Figure 5. Projected heating and cooling degree days, 2011-2050.

The projection indicates a decrease in heating degree days (HDD), and an increase in cooling degree days (CDD) as the climate continues to warm towards 2050. A decrease in the number of heating degree days (the number of degrees that a day's average temperature is below 18o Celsius, at which buildings need to be heated) results in a reduction in the amount of energy required for space heating. This increase is partially offset by an increase in the number of cooling days (the temperature at which buildings start to use air conditioning for cooling), which results in an increase in energy use.

Grid emissions

For the BAP scenario, the electricity generation input variables were set on the basis of a combination of NEB's Energy Future 2016 projected electricity generation capacity for Ontario, and IESO capacity factors that specify the planned deployment of that capacity. This scenario assumes: the Pickering generation units are decommissioned between 2022 and 2024, while refurbishments of the remaining nuclear facilities mostly occurs in the 2020s; wind, solar and natural gas increases in capacity from 2016 to 2025; from 2016 onwards there is a slight increase in carbon intensity as nuclear loses some of its share; and, post 2035 fossil fuel based electricity generation (natural gas) is maintained at 2035 levels, and all increases in capacity, required due to increases in demand, is non-fossil fuel based, resulting in a constant carbon intensity post 2035 (Figure 6). The resulting Ontario grid carbon intensity closely aligns with the emission and generation projection of Outlook B presented in the 2016 IESO Ontario Planning Outlook (OPO).

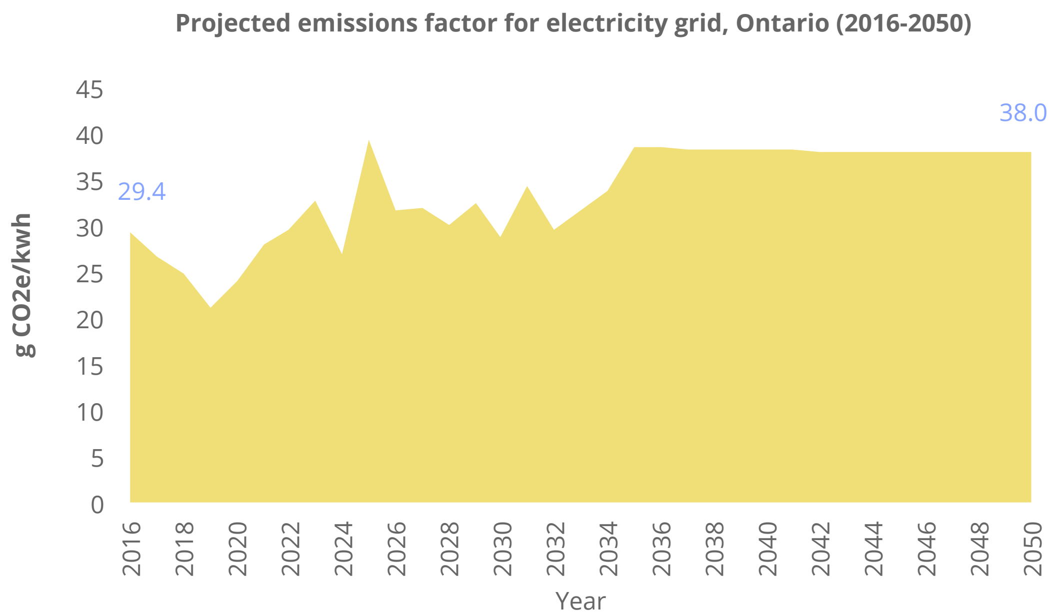

Figure 6. Projected emissions factor for Ontario's electricity grid, 2016-2050.

Transportation

Transportation projections for vehicle stocks, distance travelled, and fuel consumption are derived from calibrated baseline model parameters, BAP household projections, BAP buildings projections, and explicit assumptions about the introduction of electric vehicles and changes to vehicle fuel efficiency standards.

For vehicle stocks, the BAP assumes the introduction of electric vehicles. Original projections in the Ontario Climate Plan (2017) are not considered as programs to encourage EV use are currently on hold by the Ontario government. For modelling purposes, an assumption of 2-3% of market share by 2040 is used and held constant to 2050, mirroring other provinces without robust EV policies & programs as shown in the Canada's Electric Vehicle Policy Report Card (2016. Axsen, Goldberg, Melton (Simon Fraser University)). The total number of personal use and corporate vehicles is proportional to the projected number of households in the BAP.

Vehicle distances travelled projections are driven by buildings projections. The number and location of dwellings and non-residential buildings over time in the BAP drive the total number of internal and external person trips. Person trips are converted to vehicle trips using the baseline vehicle occupancy. Vehicle distance travelled is calculated from vehicle trips using the baseline distances between zones and average external trip distances.

Vehicle fuel consumption rates in the BAP are set to reflect the implementation of the U.S. Corporate Average Fuel Economy (CAFE) fuel standard for light duty vehicles and phase 1 and phase 2 of EPA HDV fuel standards for medium and heavy duty vehicles.

Waste

Emissions projections for waste are derived using projected population growth and existing rates of waste produced per capita. For 2016, solid waste diversion was calculated at 47% in line with Ontario Rates; this rate was held constant to 2050 and applied to additional waste generated over the period. The projection assumes no reduction in the rates of per capita waste production and no improvement in treatment facilities.

Financial

Energy cost intensities were derived from two sources: National Energy Board Energy Futures 2016 projections- reference case (electricity, natural gas, fuel oil, gasoline and diesel oil); and, a Fuels Technical Report prepared for the Government of Ontario (propane). The National Energy Board projections extend until 2040; these were extrapolated to 2050. The energy cost intensities are applied to energy consumption by fuel, derived by the model as described above, to determine total annual energy and per household costs.

Table 4. Energy costs projections, 2016 & 2050.

Energy costs ($/MJ)		2016	2050	% +/- (2016-2050)
Residential	Natural_Gas	$0.009	$0.010	17%
Residential	Electricity	$0.042	$0.048	14%
Residential	FuelOil	$0.029	$0.037	28%
Commercial	Natural_Gas	$0.006	$0.008	23%
Commercial	Electricity	$0.035	$0.042	20%
Commercial	FuelOil	$0.025	$0.034	33%
Commercial	Propane	$0.015	$0.018	26%
Industrial	Natural_Gas	$0.006	$0.007	27%
Industrial	Electricity	$0.032	$0.039	20%
Industrial	Diesel	$0.016	$0.024	54%
Industrial	FuelOil	$0.016	$0.024	54%
Industrial	Propane	$0.019	$0.027	41%
Vehicles	Natural_Gas	$0.009	$0.010	17%
Vehicles	Electricity	$0.042	$0.048	14%
Vehicles	Gasoline	$0.036	$0.049	36%
Vehicles	Diesel	$0.035	$0.048	39%

BAP Data and Assumptions

Data/Assumption		Source	Summary approach/methodology
DEMOGRAPHICS			
Population & employment			
Population & employment	Population: 969,318 (2016) 1,200,449 (2031) 1,509,358 (2050) Employment: 565,955 (2016) 750,727 (2031) 954,765 (2050)	2016 census data City of Ottawa; population & employment projections for 2023 and 2031 by zone. 2023 and 2031 TZ Projection Revised May 2016 .xlsx	Population and employment projections by zone to 2050 are applied and spatially allocated in the model. 2016 population number includes estimated census undercount. Post 2031 projections and spatial allocation were not available from the City. The population and employment trends for 2023-2031 are extrapolated to get totals for 2050. Spatial allocation of post 2031 population and employment are distributed according to similar patterns of growth exhibited between 2023-2031.

Data/Assumption		Source	Summary approach/methodology
BUILDINGS			
New buildings growth			
Building growth projections	Job density and vacancy rate assumptions Vacancy adjusted (sqft/job) Commercial 327 (8.9% weighted avg of 10.5% office and 4.2% retail) Industrial 853 (6.6%) Institutional 400 Base (sqft/job) Commercial 300 Industrial 800 Institutional 400	City of Ottawa Research and Forecasting	Buildings floorspace (res & non-res) by zone to 2050 was derived using population and employment projections provided by the City. New residential floorspace is derived by allocating new dwellings based on the existing persons per unit. New dwellings by type are allocated to zones: - if zone already has dwellings, the existing dwelling type share is used for new builds - if zone does not have dwellings, existing dwelling type share from nearby zones is used for new builds - if population in a zone is projected to decrease, dwellings are removed - Greenfield vs. infill designation is based on the Neptis Foundation GIS data New non-residential floorspace is derived by allocating the floorspace according to gross floor area per employee/job. New non-residential floorspace by type is allocated to zones - if zone already has employment, the existing employment sector shares are used along gross floor area per employee - if zone does not have employment, the employment shares from nearby zones are used along with gross floor area per employee - if employment in a zone decreases, non-residential buildings are removed

Data/Assumption		Source	Summary approach/methodology
New buildings energy performance			
Residential	New construction 10% more efficient every 5 years starting in 2018.	Adapted from Report by Environmental Commissioner of Ontario. Conservation: Let's Get Serious 2015-2016	The Let's Get Serious report forecasts a building energy performance of 13% every 5 years. For the purpose of the Ottawa BAP Scenario, a slightly more conservative 10% energy improvement every 5 years is used.
Multi-residential	New construction 10% more efficient every 5 years starting in 2018.		
Commercial & Institutional	New construction 10% more efficient every 5 years starting in 2018.		
Industrial	New construction 10% more efficient every 5 years starting in 2018.		
Existing buildings energy performance			
Residential	Existing building stock efficiency unchanged; efficiency held constant from 2016-2050.		Baseline efficiencies for each building type are derived in the model through calibration with observed data; for existing buildings, no improvements in efficiency are applied.
Multi-residential			
Commercial & Institutional			
Industrial			
End use			
Space heating	Fuel shares for end use unchanged; held from 2016-2050.	Canadian Energy Systems Analysis Research. Canadian Energy System Simulator. http://www.cesarnet.ca/research/caness-model	Within the model, the starting point for fuel shares by end use is an Ontario average value for the given building type, which comes from CanESS. From there, the fuel shares are calibrated to track on observed natural gas and electricity use. Once calibrated, end use shares are held constant through the BAP.
Water heating			
Space cooling			

Data/Assumption		Source	Summary approach/methodology
Projected climate impacts			
Heating & cooling degree days	Heating degree days (HDD) decrease and cooling degree days (CDD) increase from 2016-2050.	Statistically Downscaled Climate Scenarios (2018). Pacific Climate Impacts Consortium. https://www.pacificclimate.org/data/statistically-downscaled-climate-scenarios	Average HDD and CDD values across all models for Ottawa in the RCP4.5 scenario is used
Grid electricity emissions			
Grid electricity emissions factor	2016: 50.8 gCO_2e/kWh 2050: 76.4 gCO_2e/kwh 2016: CO_2: 28.9 g/kWh CH_4: 0.007 g/kWh N_2O: 0.001 g/kWh 2050: CO_2: 37.4 g/kWh CH_4: 0.009 g/kWh N_2O: 0.001 g/kWh IESO ONT Planning Outlook: 2016: 32.06 gCO_2e/kWh 2035: 35.81 gCO_2e/kwh	National Energy Board. (2016). Canada's Energy Future 2016. Government of Canada. Retrieved from https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016pt/nrgyftrs_rprt-2016-eng.pdf 2016 Ontario Planning Outlook - IESO http://www.ieso.ca/sector-participants/planning-and-forecasting/ontario-planning-outlook	Electricity generation input variables are sourced from CanESS and are set on the basis of a combination of NEB's Energy Future 2016 projected electricity generation capacity for Ontario, and IESO capacity factors that specify the planned deployment of that capacity. IESO emissions factors are derived from forecast emissions from Outlook B divided by forecasted demand (which appears to be total generation) for Outlook B. See Grid Emissions Factors sheet for comparison of two sources. If IESO forecast are used, variation in 2036-2050 from CanESS data will be applied to 2035 IESO to extend forecast. Also, splits between CO_2,CH_4,and N_2O from CanESS will be used.

Data/Assumption		Source	Summary approach/methodology
ENERGY GENERATION			
Local energy generation			
Solar PV	2016 solar generation: 700 GWh	Historical solar PV generation provided by Hydro One and Hydro Ottawa	Generation was derived assuming solar capacity is available 8760 hr/year and using a capacity factor of 0.15, which was based on the assumed solar capacity factor in the Ottawa 2012 Energy and Emissions report, page 13. Solar capacity in 2016 is held constant to 2050.
District Energy	2016 DE thermal supply: 872 (TJ) 2016 DE cooling supply: 435 TJ	Reported rates from University of Ottawa DE system, and 4 Federal Systems within the city	Existing DE capacity in 2016 is held constant through 2050

Data/Assumption		Source	Summary approach/methodology
TRANSPORTATION			
Transit			
Expansion of transit	Transit mode shares by O-D zones in 2011 & 2031 model data; mode shares constant post 2031	Ottawa transportation model data for 2011 and 2031	It is assumed the modelled 2031 trips by mode reflects planned transit expansion
Electric vehicle transit fleet	Transit fleet is electrified by 2050.	Transit fleet is electrified as vehicles come to end of life beginning in 2030.	
Active			
Cycling & walking infrastructure	Active mode shares by O-D zones in 2011 & 2031 model data; mode shares constant post 2031	Ottawa transportation model data for 2011 and 2031	It is assumed the modelled 2031 trips by mode reflects planned cycling and pedestrian infrastructure expansion
Private & commercial vehicles			
Vehicle kilometers travelled	No data from City or other transportation agencies. Derived by the model.		VKT projections are driven by buildings projections. The number and location of dwellings and non-residential buildings over time in the BAP drive the total number of internal and external person trips. Person trips are converted to vehicle trips using the baseline vehicle occupancy. VKT is calculated from vehicle trips using the baseline distances between zones and average external trip distances.
Vehicle fuel efficiencies	Vehicle fuel consumption rates reflect the implementation of the U.S. Corporate Average Fuel Economy (CAFE) Fuel Standard for Light-Duty Vehicles, and Phase 1 and Phase 2 of EPA HDV Fuel Standards for Medium- and Heavy-Duty Vehicles.	EPA. (2012). EPA and NHTSA set standards to reduce GHGs and improve fuel economy for model years 2017-2025 cars and light trucks. https://www3.epa.gov/otaq/climate/documents/420f12050.pdf http://www.nhtsa.gov/fuel-economy	Fuel efficiency standards are applied to all new vehicle stocks starting in 2016.
Vehicle share	Personal vehicle stock share changes, commercial stock does not, between 2016-2050.	CANSIM and Natural Resources Canada's Demand and Policy Analysis Division.	The total number of personal use and corporate vehicles is proportional to the projected number of households in the BAP.
Electric vehicles	2-3% of Market Share in 2040	Canada's Electric Vehicle Policy Report Card 2016. Axsen, Goldberg, Melton (Simon Fraser University)	The BAP will use a similar market share to other provinces who lack distinct policy to support EV (prairies) as established by the Canada's Electric Vehicle Policy Report Card 2016.

Data/Assumption		Source	Summary approach/methodology
WASTE			
Waste generation	Existing per capita waste generation rates unchanged.	City of Ottawa Reports prepared by Dillon Consulting for TRAIL waste facility Ontario Rates provided by Resource Productivity & Recovery Authority (2015 Rates) https://www.rpra.ca/wp-content/uploads/2015-Waste-Diversion-Rates.pdf	Waste generation per capita held constant form 2016-2050.
Waste diversion	Existing waste diversion rates unchanged.		Waste diversion rates held constant form 2016-2050.
Waste treatment	Existing waste treatment processes unchanged.		No change in waste treatment processes assumed 2016-2050.
Wastewater	Existing waste treatment processes unchanged.	City of Ottawa, Ottawa research and Forecasting	No change in wastewater treatment processes assumed 2016-2050.

FINANCIAL			
Energy costs	Energy intensity costs by fuel increase incrementally between 2016-2050 per projections.	National Energy Board. (2016). Canada's Energy Future 2016. Government of Canada. Retrieved from https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016pt/nrgyftrs_rprt-2016-eng.pdf Government of Ontario. (2016). Fuels Technical Report. https://www.ontario.ca/document/fuels-technical-report	NEB projections extend until 2040; extrapolated to 2050. Energy cost intensities are applied to energy consumption by fuel, derived by the model, to determine total annual energy and per household costs.

Pathways Analysis: Policies, Actions and Strategies

Throughout the CityInSight accounting framework there are input variables - for user assumptions and projections - which collectively comprise an interface to controlling the physical trajectory of the urban energy system and resultant emissions. Different settings for these inputs can be interpreted as alternative behaviours of various actors or institutions in the energy system (e.g. households, various levels of government, industry, etc). This interface can be directly set or controlled by the model user, to create "what if" type scenarios. The modelling platform upon which CityInSight is built allows for a "higher layer" of logic to operate at this physical-behavioural interface, in effect enabling a flexible mix-and-match approach to behavioral models which connect to the same constraining physical model. CityInSight is able to explore a wide variety of policies, actions and strategies. The resolution of CityInSight enables the user to apply scenarios to specific neighbourhoods, technologies, building or vehicle types or eras, and configurations of the built environment.

Methodology

1. Develop and order a list of potential actions developed during the Pathway Studies (Phase 1 and 2) and evaluated from the perspective of staff and consultant experience.

2. Identify the technological potential of each action (or group of actions) to reduce energy and emissions by quantifying actions:
   » If the action or strategy specifically incorporates a projection or target; or,
   » If there is a stated intention or goal, review best practices and literature to quantify the goal;
   » Identify any actions that are either overlapping and/or include dependencies on other actions;

3. Translate the actions into quantified assumptions over time;

4. Apply the assumptions to relevant sectors in the model to develop the 80% and 100% scenarios (i.e. apply the technological potential of the actions to the model);

5. Analyze results of the low carbon scenarios;

6. If the target is not achieved, Identify variables to scale up and provide a rationale for doing so;

7. Iteratively adjust variables to identify a pathway for the 80% and 100% scenarios;

8. Develop marginal abatement curve for the 80% and 100% scenarios;

9. Define criteria to evaluate low carbon scenario (i.e identify criteria for multi-criteria analysis)

10. Prioritize actions of low carbon scenario through multi-criteria analysis (along with other criteria e.g. health, prosperity, etc.);

11. Revise scenario to reflect prioritisation for final low carbon scenario, removing and scaling the level of ambition of actions according to the evaluation results.

Sensitivity Analysis

The BAP scenario illustrates the projected emissions for the City of Ottawa built upon the assumptions as described in this report. In that light, the BAP reflects what is anticipated to occur in the future if the actions/assumptions as described are implemented.

Sensitivity analysis involves the process of adjusting certain selected variables within the model in order to identify variables that have the most significant impact on the model outcomes of a scenario. It is not a process of “scenario analysis”, as the variables tested do not represent internationally consistent scenarios. The approach to sensitivity analysis is to adjust those variables that were identified as having a higher potential to “move the curve”, (ie. the factors that appear to be contributing significantly to the BAP scenario), in order to be better informed about the implications of future options.

The process used applies a judgement-based “one-at-a-time” exploration of variables within a scenario. The results should not be viewed as an evaluation of fully considered alternative futures, rather, it is an exploration revealing how a selected output (i.e. emissions) responds to changes in selected inputs (e.g. # residential units).

Variables and Results

Sensitivity analysis was applied to the BAP scenario. Several variables were identified for sensitivity analysis; the assumptions and results of each are described in Table 13, and depicted in Figures 40 & 41. The impact , expressed in GJ for energy and kt CO2e for emissions, shows the absolute difference relative to the BAP in 2050.

Discussion

For energy, changes in BAP assumptions for heating degree days (HDD) and building energy performance have the most significant impact on BAP energy consumption. Those variables with the least impact include changes in VKT and the uptake of electric vehicles.

Similarly for emissions, changes in BAP assumptions for HDD and building energy performance have the most significant impact on the BAP emissions trajectory, as does the grid electricity emissions factor. Variables with a lesser impact include changes in VKT, the uptake of electric vehicles, and changes in solid waste diversion rates.

Population and employment assumptions also play a role in both energy and emissions outcomes of the BAP; an increase in population and employment of 10% by 2050 results in a 7.5% increase in energy and 8.5% increase in emissions; a decrease of 10% in population and employment by 2050 results in a 8.9% and 8.4% decrease in energy and emissions respectively.

Notwithstanding the above however; the assumptions for heating degree days appear to be muting the impact of a growing population on energy and emissions in the BAP. For sensitivity, if it is assumed that HDD are constant over the time period (i.e. the climate does not change, and winters do not become warmer), and the population projections used in the BAP are not adjusted (as described above), the results indicate an increase in energy (+15.6%) and emissions (+18.9%); the impact of population growth becomes much more apparent.

Changes in the grid electricity emissions factor (EF) has an important influence for emissions. There is only a minor shift towards electricity in the BAP; by 2050, approximately two thirds of energy consumption remains fossil fuel based (predominantly natural gas), resulting in over 80% of emissions. As such, large changes in the grid emissions factor assumption in the BAP scenario results in somewhat minor changes in emissions; an increase and decrease of 7.1% and 6.8% respectively. However, this would not be the case for a scenario that represented a large shift towards electricity (eg. in a low carbon scenario). It will be fundamental, in that type of scenario, for the EF of new capacity to remain low, or the electrification approach will be at risk from a greenhouse gas emissions perspective.

The BAP assumes that all new construction, in all building sectors, will be 15% more efficient every 5 years starting in 2018, which is based on The Atmospheric Fund (TAF) analysis indicating that by 2017, the Ontario Building Code (OBC) will be the equivalent of the Toronto Green Standards (TGS) v2 Tier 1 with a 5-year lag. For sensitivity, the performance improvement was decreased to represent a lower achievement in performance of OBC. Results indicate that if OBC building energy performance requirements do not follow those in TGS, building energy and emissions will increase by 12.1% and 12.7% respectively (for 5% improvement), and 7.0% and 7.0% (for 10% improvement). The City should therefore not rely solely on the expected improvements in OBC to decrease energy and emissions in new buildings; the City will need to focus on adopting more aggressive energy performance requirements in the buildings sector.

Appendix 1: GPC Emissions Scope Table

Reasons for exclusions

N/A	Not Applicable, or not included in scope
ID	Insufficient Data
NR	No Relevance, or limited activities identified
Other	Reason provided in other comments

GPC ref No.	Scope	GHG Emissions Source	Inclusion	Reason for exclusion (if applicable)
I		**STATIONARY ENERGY SOURCES**		
I.1		**Residential buildings**		
I.1.1	1	Emissions from fuel combustion within the city boundary	**Yes**	
I.1.2	2	Emissions from grid-supplied energy consumed within the city boundary	**Yes**	
I.1.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	**Yes**	
I.2		**Commercial and institutional buildings/facilities**		
I.2.1	1	Emissions from fuel combustion within the city boundary	**Yes**	
I.2.2	2	Emissions from grid-supplied energy consumed within the city boundary	**Yes**	
I.2.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	**Yes**	
I.3		**Manufacturing industry and construction**		
I.3.1	1	Emissions from fuel combustion within the city boundary	**Yes**	
I.3.2	2	Emissions from grid-supplied energy consumed within the city boundary	**Yes**	
I.3.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	**Yes**	
I.4		**Energy industries**		
I.4.1	1	Emissions from energy used in power plant auxiliary operations within the city boundary	**Yes**	
I.4.2	2	Emissions from grid-supplied energy consumed in power plant auxiliary operations within the city boundary	**Yes**	
I.4.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption in power plant auxiliary operations	**Yes**	
I.4.4	1	Emissions from energy generation supplied to the grid	**Yes**	
I.5		**Agriculture, forestry and fishing activities**		
I.5.1	1	Emissions from fuel combustion within the city boundary	**Yes**	
I.5.2	2	Emissions from grid-supplied energy consumed within the city boundary	**Yes**	
I.5.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	**Yes**	
I.6		**Non-specified sources**		

GPC ref No.	Scope	GHG Emissions Source	Inclusion	Reason for exclusion (if applicable)
I.6.1	1	Emissions from fuel combustion within the city boundary	**No**	NR
I.6.2	2	Emissions from grid-supplied energy consumed within the city boundary	**No**	NR
I.6.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	**No**	NR
I.7		**Fugitive emissions from mining, processing, storage, and transportation of coal**		
I.7.1	1	Emissions from fugitive emissions within the city boundary	**No**	NR
I.8		**Fugitive emissions from oil and natural gas systems**		
I.8.1	1	Emissions from fugitive emissions within the city boundary	**Yes**	
II		**TRANSPORTATION**		
II.1		**On-road transportation**		
II.1.1	1	Emissions from fuel combustion for on-road transportation occurring within the city boundary	**Yes**	
II.1.2	2	Emissions from grid-supplied energy consumed within the city boundary for on-road transportation	**Yes**	
II.1.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	**Yes**	
II.2		**Railways**		
II.2.1	1	Emissions from fuel combustion for railway transportation occurring within the city boundary	**Other (Partial)**	
II.2.2	2	Emissions from grid-supplied energy consumed within the city boundary for railways	**Other (Partial)**	
II.2.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	**No**	NR
II.3		**Water-borne navigation**		
II.3.1	1	Emissions from fuel combustion for waterborne navigation occurring within the city boundary	**No**	N/A
II.3.2	2	Emissions from grid-supplied energy consumed within the city boundary for waterborne navigation	**No**	N/A
II.3.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	**No**	N/A
II.4		**Aviation**		
II.4.1	1	Emissions from fuel combustion for aviation occurring within the city boundary	**No**	N/A
II.4.2	2	Emissions from grid-supplied energy consumed within the city boundary for aviation	**No**	N/A

GPC ref No.	Scope	GHG Emissions Source	Inclusion	Reason for exclusion (if applicable)
II.4.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	**No**	N/A
II.5		**Off-road**		
II.5.1	1	Emissions from fuel combustion for off-road transportation occurring within the city boundary	**No**	NR
II.5.2	2	Emissions from grid-supplied energy consumed within the city boundary for off-road transportation	**No**	NR
III		**WASTE**		
III.1		**Solid waste disposal**		
III.1.1	1	Emissions from solid waste generated within the city boundary and disposed in landfills or open dumps within the city boundary	**Yes**	
III.1.2	3	Emissions from solid waste generated within the city boundary but disposed in landfills or open dumps outside the city boundary	**No**	N/A
III.1.3	1	Emissions from waste generated outside the city boundary and disposed in landfills or open dumps within the city boundary	**No**	N/A
III.2		**Biological treatment of waste**		
III.2.1	1	Emissions from solid waste generated within the city boundary that is treated biologically within the city boundary	**Yes**	
III.2.2	3	Emissions from solid waste generated within the city boundary but treated biologically outside of the city boundary	**No**	N/A
III.2.3	1	Emissions from waste generated outside the city boundary but treated biologically within the city boundary	**No**	N/A
III.3		**Incineration and open burning**		
III.3.1	1	Emissions from solid waste generated and treated within the city boundary	**No**	N/A
III.3.2	3	Emissions from solid waste generated within the city boundary but treated outside of the city boundary	**No**	N/A
III.3.3	1	Emissions from waste generated outside the city boundary but treated within the city boundary	**No**	N/A
III.4		**Wastewater treatment and discharge**		
III.4.1	1	Emissions from wastewater generated and treated within the city boundary	**Yes**	
III.4.2	3	Emissions from wastewater generated within the city boundary but treated outside of the city boundary	**No**	NR
III.4.3	1	Emissions from wastewater generated outside the city boundary	**No**	N/A
IV		**INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)**		
IV.1	1	Emissions from industrial processes occurring within the city boundary	**No**	ID

GPC ref No.	Scope	GHG Emissions Source	Inclusion	Reason for exclusion (if applicable)
IV.2	1	Emissions from product use occurring within the city boundary	**No**	ID
V		**AGRICULTURE, FORESTRY AND LAND USE (AFOLU)**		
V.1	1	Emissions from livestock within the city boundary	**No**	NR
V.2	1	Emissions from land within the city boundary	**No**	NR
V.3	1	Emissions from aggregate sources and non-CO2 emission sources on land within the city boundary	**No**	NR
VI		**OTHER SCOPE 3**		
VI.1	3	Other Scope 3	**No**	N/A

Appendix 2: Building Types

Residential Buildings (Dwellings)	Non-Residential Buildings	
Single_detached_1Storey_tiny	college_university	religious_institution
Single_detached_2Storey_tiny	school	surface_infrastructure
Single_detached_3Storey_tiny	retirement_or_nursing_home	energy_utility
Single_detached_1Storey_small	special_care_home	water_pumping_or_treatment_station
Single_detached_2Storey_small	hospital	industrial_generic
Single_detached_3Storey_small	municipal_building	food_processing_plants
Single_detached_1Storey_medium	fire_station	textile_manufacturing_plants
Single_detached_2Storey_medium	penal_institution	furniture_manufacturing_plants
Single_detached_3Storey_medium	police_station	refineries_all_types
Single_detached_1Storey_large	military_base_or_camp	chemical_manufacturing_plants
Single_detached_2Storey_large	transit_terminal_or_station	printing_and_publishing_plants
Single_detached_3Storey_large	airport	fabricated_metal_product_plants
Double_detached_1Storey_small	parking	manufacturing_plants_miscellaneous_processing_plants
Double_detached_2Storey_small	hotel_motel_inn	asphalt_manufacturing_plants
Double_detached_3Storey_small	greenhouse	concrete_manufacturing_plants
Double_detached_1Storey_large	greenspace	industrial_farm
Double_detached_2Storey_large	recreation	barn
Double_detached_3Storey_large	community_centre	
Row_house_1Storey_small	golf_course	
Row_house_2Storey_small	museums_art_gallery	
Row_house_3Storey_small	retail	
Row_house_1Storey_large	vehicle_and_heavy_equiptment_service	
Row_house_2Storey_large	warehouse_retail	
Row_house_3Storey_large	restaurant	
Apartment_1To4Storey_small	commercial_retail	
Apartment_1To4Storey_large	commercial	
Apartment_5To14Storey_small	commercial_residential	
Apartment_5To14Storey_large	retail_residential	
Apartment_15To24Storey_small	warehouse_commercial	
Apartment_15To24Storey_large	warehouse	
Apartment_25AndUpStorey_small		
Apartment_25AndUpStorey_large		
inMultiUseBldg		

SUSTAINABILITY SOLUTIONS GROUP

whatIf?