CITY OF EDMONTON

GHG Emissions and Energy Analysis for the City Plan

Briefing

FEBRUARY 4, 2020

PREPARED BY:

SSG SUSTAINABILITY SOLUTIONS GROUP

whatIf?

This analysis has been undertaken to assess the impact of the City Plan evaluation scenarios and City Plan Concept scenario on greenhouse gas (GHG) emissions. Reasonable skill, care and diligence have been exercised to assess the information acquired during the preparation of this analysis, but no guarantees or warranties are made regarding the accuracy or completeness of this information. This document, the information it contains, the information and basis on which it relies are subject to changes that are beyond the control of the authors. The information provided by others is believed to be accurate but has not been verified. The authors do not accept responsibility for the use of this analysis for any purpose other than that stated above and does not accept responsibility to any third party for the use, in whole or in part, of the contents of this document. Any use by the City of Edmonton, project partners, sub-consultants or any third party, or any reliance on or decisions based on this document, are the responsibility of the user or third party.

City Plan Background

Edmonton's City Plan has a target of doubling Edmonton's population to two million people over a number of decades. A set of evaluation scenarios and a recommended City Plan Concept scenario were prepared for the City Plan. Each scenario was assessed from the perspectives of where people will live, where people will access services, and where new jobs will be located.

The City Plan team has used modelling and analysis tools to simulate the effects of the increase in population. Modelling tools can help to understand what different choices might look like and the benefits and drawbacks associated with various land use and transportation permutations.

The approach taken to developing the City Plan Concept involved a four-step process of:

1. developing three evaluation scenarios ("City Scenarios");
2. modelling the evaluation scenarios and evaluating their outputs against a set of performance indicators;
3. extracting learnings from the evaluation scenarios to inform the development of the City Plan Concept scenario ("Preferred Scenario");
4. modelling and re-evaluating the Preferred Scenario against the indicators and updating the Preferred Scenario as needed.

This paper evaluates the Preferred Scenario and its impacts on greenhouse gas (GHG) emissions and related indicators. A report on the outcomes of the evaluation scenarios was completed under a separate cover[1].

Method

The CityInSight model was used to calculate projections of GHG emissions and energy consumption for each of the scenarios.

CityInSight uses activity data for buildings, transportation and energy generation by geographic areas in order to calculate energy consumption and GHG emissions annually until 2065. Appendix 1 describes characteristics of the CityInSight model.

For this analysis, the City Plan team provided population and employment projections and travel demand origin-destination matrices at a traffic analysis zone level as inputs into CityInSight for each scenario.

[1] City of Edmonton (prepared by SSG), *GHG Emissions and Energy Analysis for the City Plan Evaluation Scenarios Briefing*, August 2019.

In addition to the population and employment projections, SSG also incorporated the actions developed and evaluated as a component of Edmonton's Energy Transition Plan update into the Preferred Scenario analysis. In CityInsight these actions were modelled to take effect at various time horizons, with timelines reflecting an attempt to keep within the 1.5 degree budget. These actions[2] include the following assumptions:

- increasing the energy performance of new dwellings and non-residential space to net zero by 2030;
- retrofitting all pre-2017 dwellings and commercial buildings with energy savings of 50% by 2050;
- scaled fuel switching buildings to electric heat pumps;
- scaled increase in solar and wind generation;
- adding energy storage;
- electrifying transit by 2030;
- increasing walking and cycling infrastructure;
- new personal vehicle sales are 100% electric by 2030; and
- decreasing waste consumption.

Each scenario was then evaluated in terms of its impacts on buildings, transportation, energy systems and GHG emissions.

The Scenarios

Six scenarios were evaluated over the course of the project. This paper focuses on the Preferred Scenario and its impacts relative to the BAP Scenario. A more detailed analysis of the three evaluation scenarios ("City Scenarios") was undertaken and the results are provided in a separate briefing report.

Business-as-usual Scenario (BAU): The BAU Scenario is based on a projection of existing development patterns and development trends. This scenario distributes future growth in the same patterns as growth has occurred over the past 10 years. It also attempts to encompass the required infrastructure upgrades that will be required to sustain the BAU development trends.

Business-as-Planned Scenario ("BAP"): The BAP Scenario assumes growth occurs according to the City's approved and strategic land use plans, including Area Structure Plans (and associated Neighbourhood Structure Plans) contained within in the plans in effect. The BAP Scenario also contains plans for infill redevelopments such as Blatchford, Bonnie Doon, and Mill Woods Town Centre. This scenario is more ambitious in terms of growth intensification

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[2] The actions align with those evaluated in the City of Edmonton's Energy Transition Update which strives to have Edmonton's emissions align with the international target of limiting global warming to 1.5°C.

than the BAU Scenario in that more growth occurs through redevelopment in the mature and developed areas of the City.

Central City ("City I"): This scenario concentrates employment and population within a specific boundary centred mainly around current downtown and mature areas. Policies would focus on achieving a strong central core that is supported by a large concentration of population and employment within the central core boundaries. Nodes and corridors are mainly located within the central core with strategic nodes located outside the central core boundary.

Node City ("City II"): This scenario attracts more people and jobs to the central core and other intensification areas. Policies will work to ensure the city develops into a community of communities that are spatially bounded by 15 different City District boundaries. The Districts and a tiered network of activity centres (nodes) are the base structural elements of this scenario. Corridors are still present within this scenario; however, their location is more strategic in nature. Overall, they play a supportive/secondary role.

Corridor City ("City III"): This scenario redistributes population and employment throughout the city along corridors, with less concentration in nodes. There is a heavy focus on rebuilding, repurposing or reclaiming underutilized land (commercial, institutional, industrial) to distribute medium intensity development and green spaces to all parts of the city. Policies would pursue achieving more equitable and spatially distributed access to services, jobs and housing by emphasizing high density corridors. Nodes still exist within this scenario; however, as with City II, their location is more strategic, and they play a supportive/secondary role.

City Plan Concept Scenario ("Preferred"): The City Plan Concept reflects a collection of the most desirable features of the Central, Node and Corridor City evaluation scenarios. This includes a City Centre node with the highest density and mix of land uses and is well served by all modes of transportation including the convergence of many mass transit routes, cycling and walking routes. A network of nodes and corridors across the city provide areas of concentration of people and jobs, typified by public institutions, a diverse housing mix, amenities, and commercial land uses. Unless otherwise indicated, this scenario also incorporates the actions in the updated Energy Transition Strategy.

What drives Greenhouse Gas emissions?

GHG emissions are a product of human activities, including the movement of people and the use of energy to heat or cool buildings. The factors which drive GHG emissions can be characterised for a particular configuration of a city, and examples of characteristics for building and transportation systems are highlighted below.

GHG emissions from buildings are the product of:

- the floor area of the buildings;

- the energy intensity (energy use per square meter) for heating, cooling, lighting and equipment); and
- the emission factor of the fuels and electricity consumed.

For light duty vehicles, GHG emissions depend on:

- the number of trips;
- the length of the trips;
- the number of people per vehicle;
- the energy efficiency of the vehicles; and
- the emission factors of the fuels (or electricity) consumed.

Variation in one or all of these factors can either increase or decrease GHG emissions. At the most basic level, more activity, whether it is more buildings or travel, results in more GHG emissions. But other factors are also important. For example, if the City facilitates development that results in vehicle trips of increased length, energy use will increase, and if the energy source is gasoline, so will GHG emissions. However, if development occurs in such a way as to reduce the distance travelled by people, the energy required for each trip decreases and consequently so do GHG emissions. The efficiency of the vehicle also influences the energy consumed, as does the fuel source. Vehicles which are powered by electricity, which in turn can be generated from clean sources such as wind and solar, reduce GHG emissions independently of trip length.

Locking-in patterns of GHG emissions

Figure 1 illustrates the varying lengths of time that environmental implications will continue to be felt for different types of city planning decisions. Many municipal planning decisions made today will still be having environmental impacts 100 years from now and beyond. In the case of infrastructure investments and land use plans, the environmental consequences can continue for centuries. This leads to "lock-in" and a situation where past decisions limit future options and increase the costs for future decisions. In the context of community energy and emissions planning, this makes the longest-term decisions also among the most urgent.

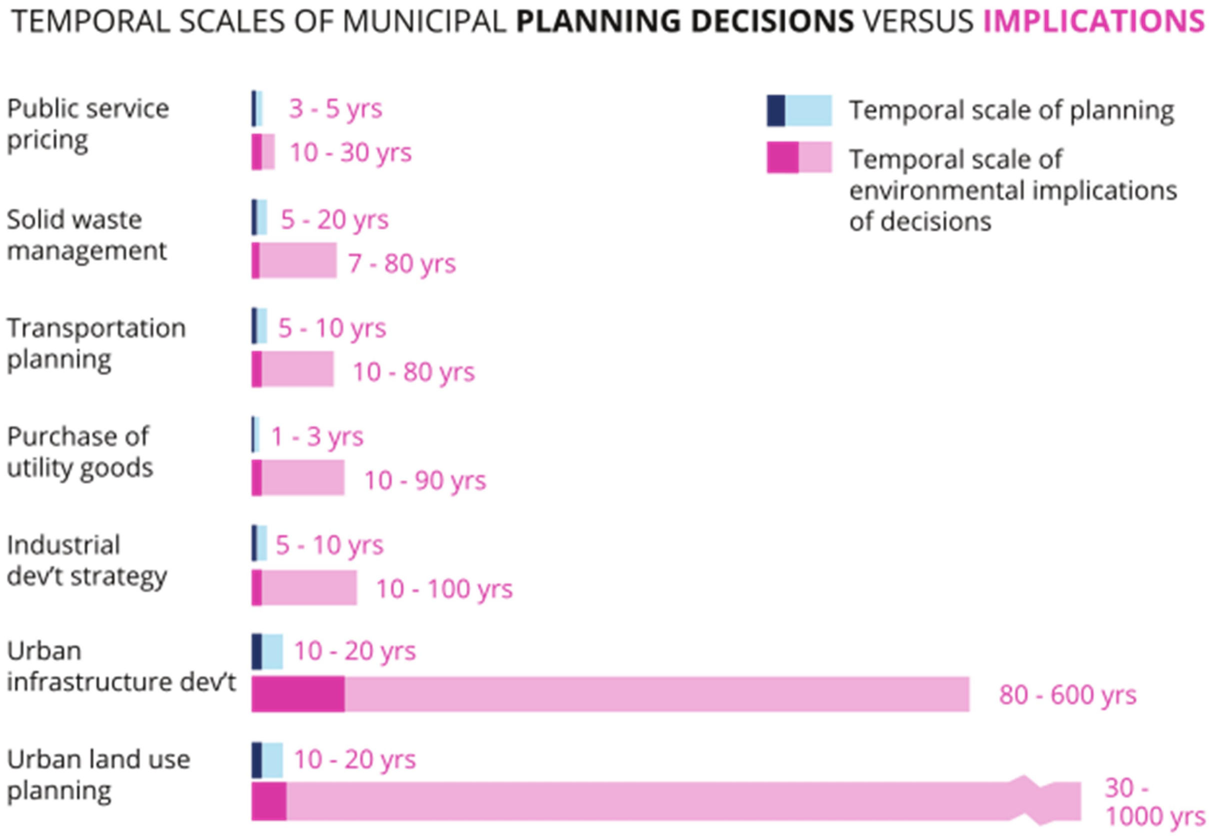

Figure 1: The temporal implications of municipal decisions.[3]

Results and Key Findings

GHG emissions in the Preferred Scenario substantially decrease between 2020 and 2045, as illustrated by the dashed blue curve in Figure 2. Other scenarios from the updated Energy Transition Strategy are also presented in this figure as comparators.[4] The 1.5-degree curve aligns with global commitments to reduce GHG emissions; it is the targeted pathway. None of the scenarios evaluated achieve this level of reduction in emissions. The Delivering on Paris+ ("DOP+"), which was developed as part of the Energy Transition Strategy Update achieves the deepest reductions in line with both the City Scenario 1 and the Preferred Scenario. The gap between the BAP Scenario and the Preferred Scenario illustrates the magnitude of the challenge.

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[3] Urban infrastructure development refers to water and wastewater distribution systems and roads, for example. Adapted from: Bai, X., McAllister, R. R., Beaty, R. M., & Taylor, B. (2010). Urban policy and governance in a global environment: complex systems, scale mismatches and public participation. *Current Opinion in Environmental Sustainability*, *2*(3), 129–135. https://doi.org/10.1016/j.cosust.2010.05.008.

[4] The scenarios in the Energy Transition Strategy were evaluated to 2050 whereas the City Plan scenarios were evaluated until 2065.

The Preferred Scenario does not go to zero emissions.

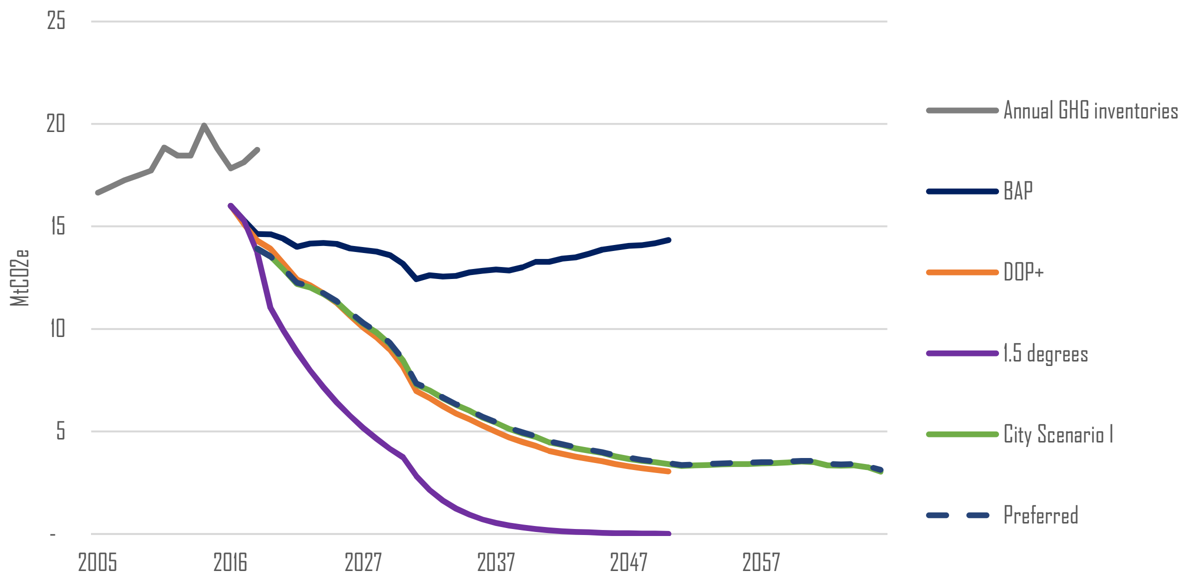

Figure 2: GHG emissions of selected City Plan scenarios relative to Energy Transition Scenarios

Table 1: Summary of GHG emissions for the BAP and Preferred Scenario

	GHG emissions in 2065	
Scenario	BAP	Preferred Scenario
2065 total (MtCO2e)	14.47	3.3
% reduction in 2065 over BAP	N/A	77%

A core insight from the recent climate analysis is the notion of the carbon budget. The global scientific community recognizes that the atmosphere can absorb only so much GHG emissions before dangerous levels of climate change occur. The global carbon budget can be distributed to cities; a calculation which gives rise to a carbon budget of 135 MtCO2e for the City of Edmonton beginning in 2020.[5]

Figure 3 indicates that the Preferred Scenario does not fall within the City's carbon budget of 135 MtCO2e; the budget is exceeded in 2033 and is nearly doubled by 2065.

[5] For more details on City of Edmonton's Carbon budget, see the Information Brief: Carbon Budget and Accounting.

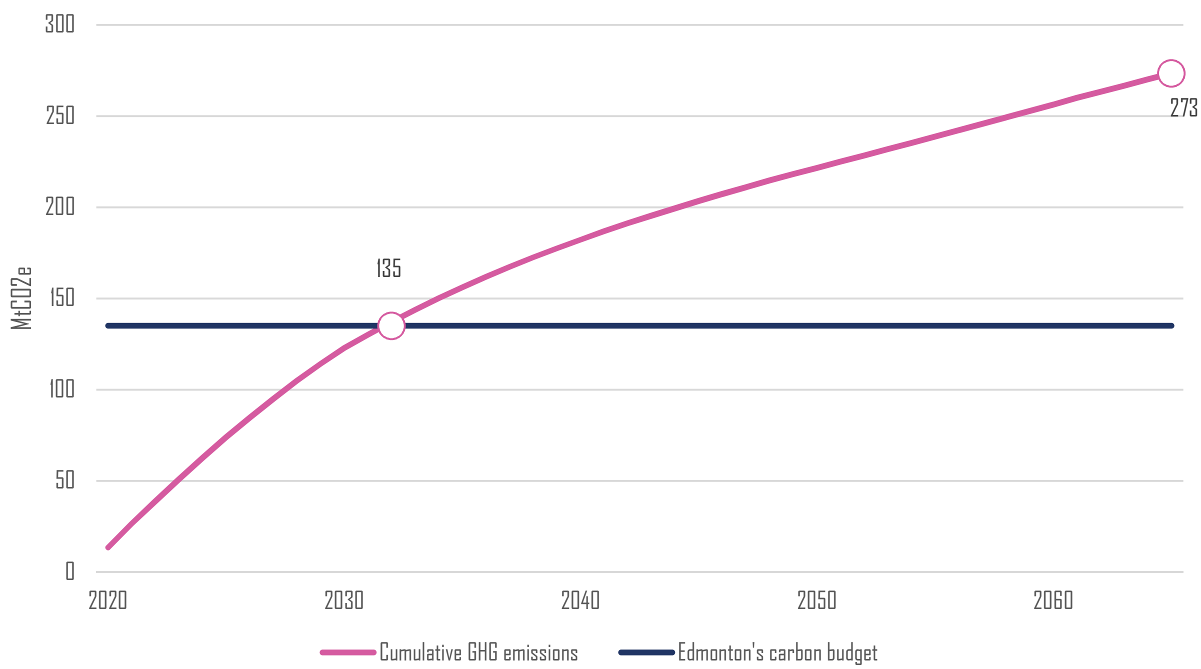

Figure 3: Cumulative GHG emissions in the Preferred Scenario relative to the Carbon Budget as at 2020

The Preferred Scenario enables staying within the carbon budget if community emissions from electricity are eliminated through offsets or renewable energy purchases by 2024.

Further analysis of the remaining GHG emissions from the Preferred Scenario post-2038 indicates that the GHG emissions result primarily from the Edmonton community's electricity use, which is a function of the electricity generation mix of the provincial grid. The share of GHG emissions in the Preferred Scenario from electricity consumption is illustrated in Figure 4.

If a community-wide program is in place to incentivize the purchase of green electricity or offsets are purchased early in the scenario, by the mid-2020s, it is possible to stay within the carbon budget. Figure 5 illustrates the impact of eliminating GHG emissions from electricity by 2024 on the GHG emissions trajectory.

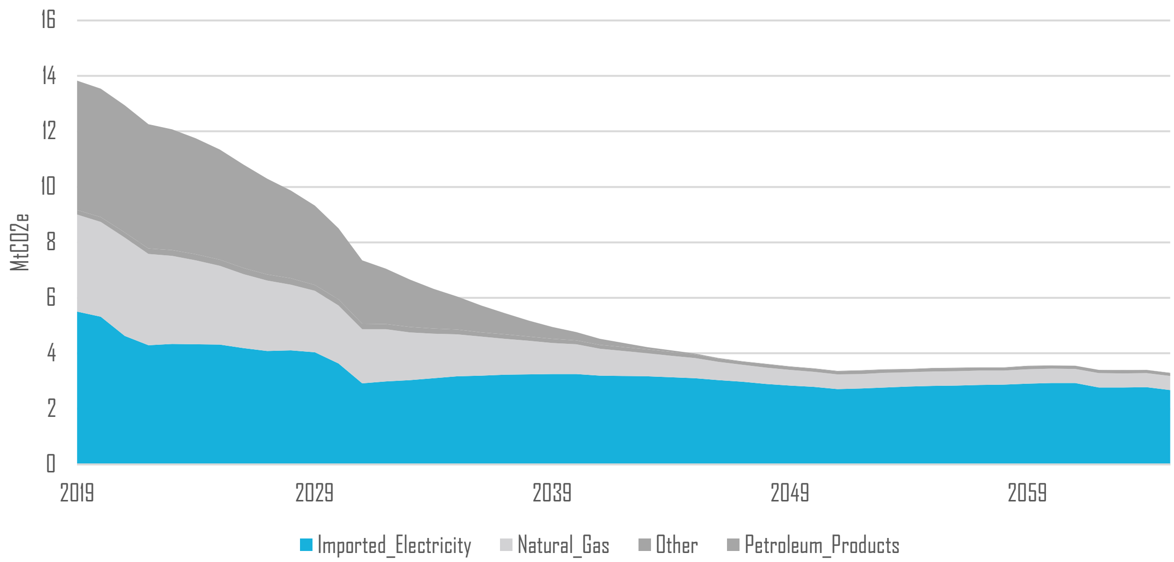

Figure 4: Emissions from electricity relative to other fuels, 2019-2065

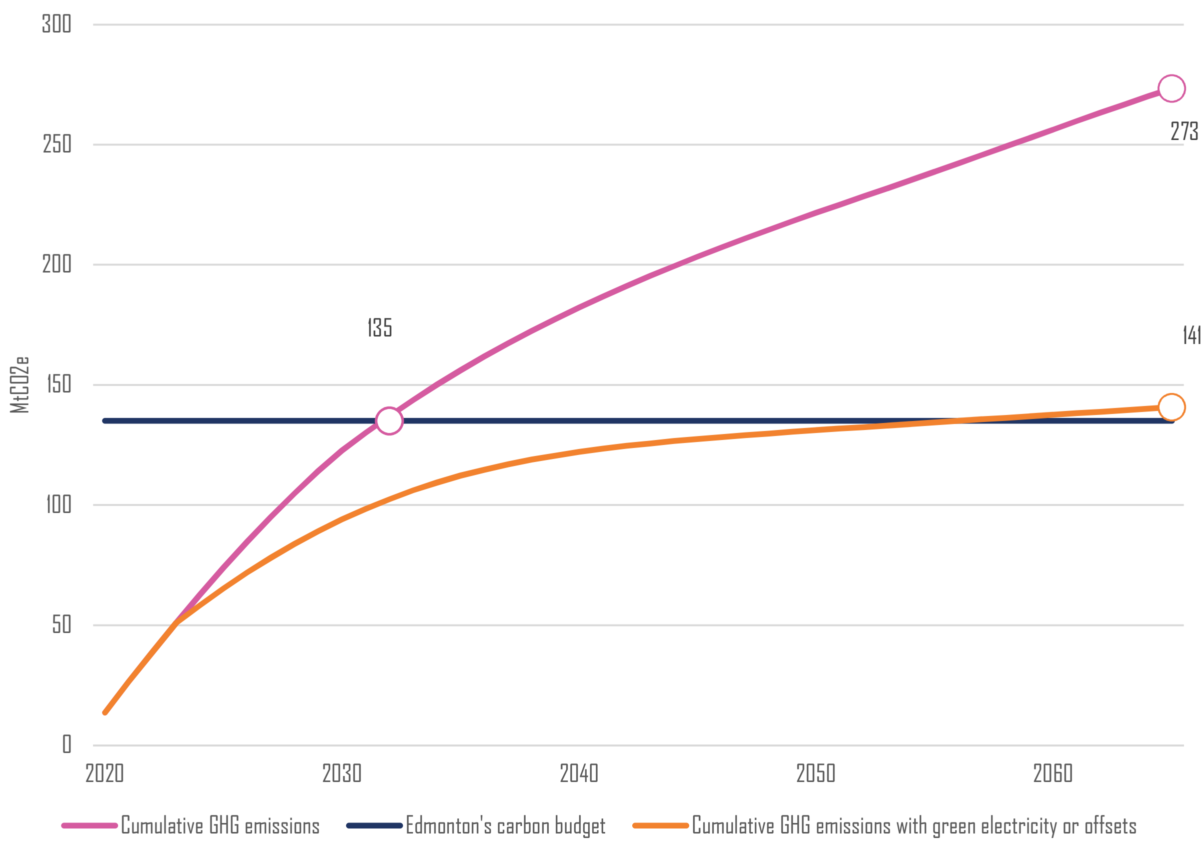

Figure 5: The impact of clean electricity or offsets on the carbon budget in the Preferred Scenario

The Preferred scenario lowers GHG emissions relative to two other City Evaluation Scenarios.

In comparison with the other three City Scenarios evaluated, the Preferred Scenario reduces emissions over City II and City III, but slightly exceeds emissions from City I.[6] While the impact is relatively small, in a carbon constrained world, every avoided tonne of GHG emissions contributes to efforts to remain within the carbon budget, particularly reductions which do not require a capital investment. Figure 6 zooms in to the last fifteen years of the period analysed to illustrate the impact.

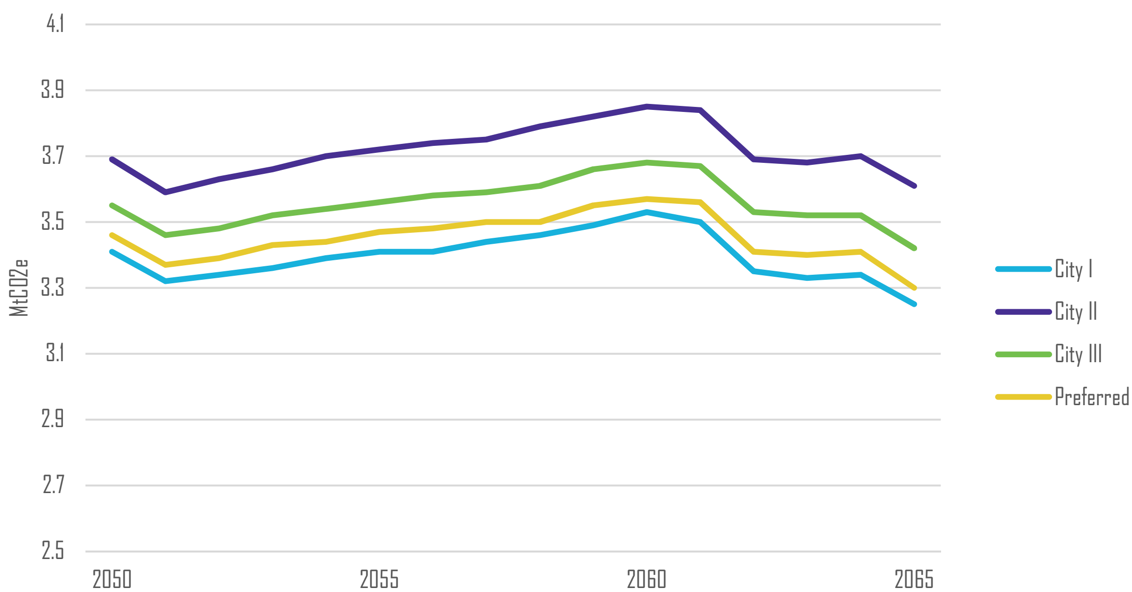

Figure 6: Zooming in on the GHG impact of the City and Preferred Scenarios

Despite an increase in population, GHG emissions decline dramatically in the Preferred Scenario.

A core insight is that the Preferred Scenario constitutes a decarbonised future. On a per capita basis, city-wide GHG emissions fall from nearly 15 tCO_2e in 2017 to 1.6 tCO_2e by 2065. There is a steady decline starting in 2020, before GHG emissions flatten out around 2050. Over this period, the vehicular transportation system and much of the heating of buildings is electrified.

GHG emissions as reported as part of Edmonton Community's GHG inventory increased from 2017 to 2018 and were higher than the modelled results for the same time period. The difference between the modelled emissions and those reported in GHG inventory in Figure 7 is

[6] Note that the Preferred Scenario was developed based on a range of considerations, of which GHG emissions was one factor.

a result in a difference in methodology. The inventory tracks sources of GHG emissions which were not modelled in this analysis including from aviation, freight trains and other sources.

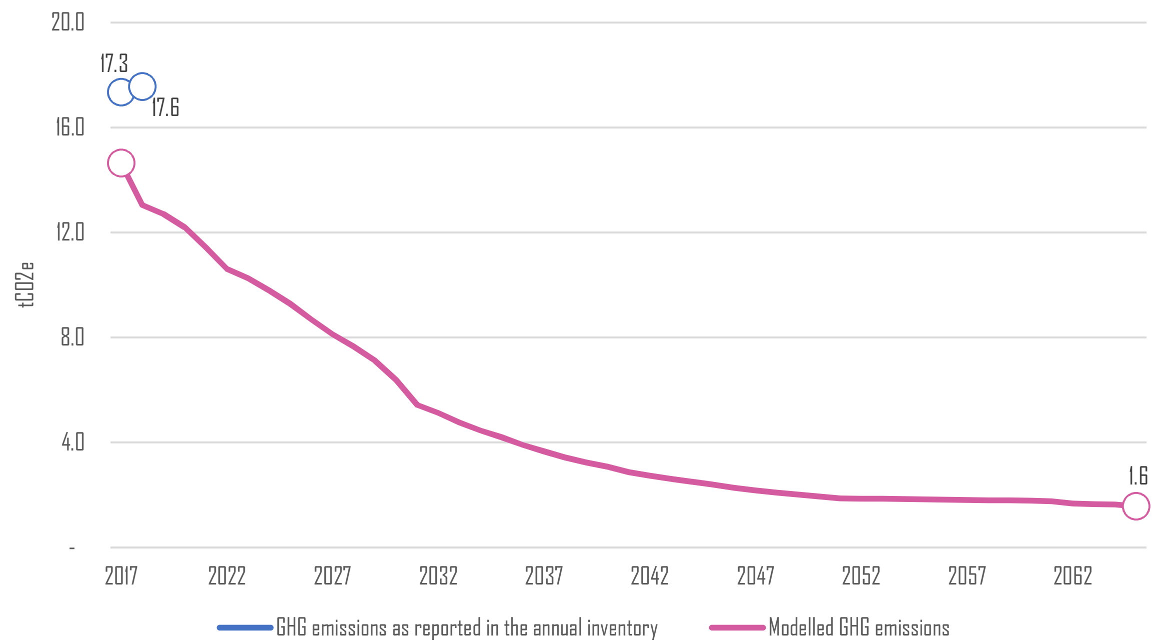

Figure 7: Per Capita GHG Emissions, Preferred Scenario

Transit use increases in the Preferred Scenario.

Transit use increases in the Preferred Scenario over the BAP Scenario as illustrated in Figure 8, where darker blue indicates a higher transit mode share. Many zones achieve transit mode shares of 20-40% by 2065, whereas in the BAP Scenario, nearly all the zones have a transit share of less than 20%.

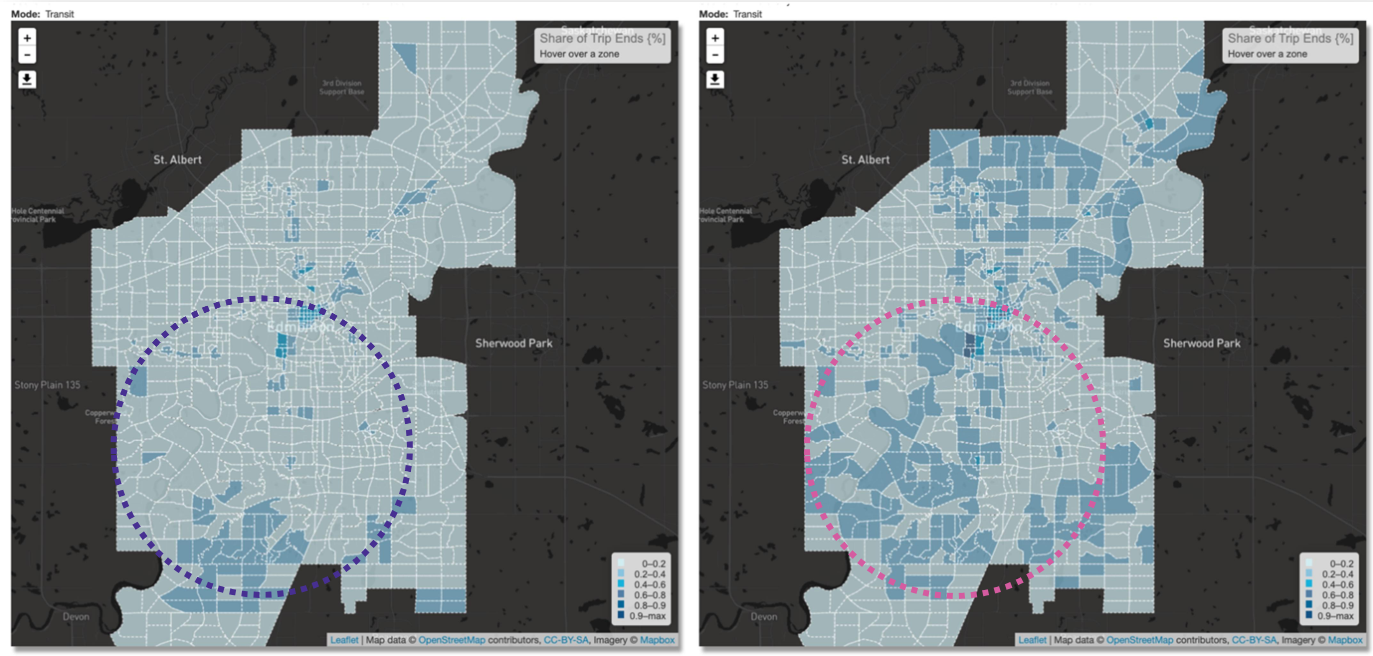

Figure 8: Transit Mode Share, BAP (left) and Preferred Scenarios, 2065 (right)

Figure 9 illustrates the impact of land-use policy alone on the Preferred Scenario transit mode share, without the actions included in the Energy Transition Strategy Update. Transit mode share increases to 20-40% in many zones in the downtown core as a result of the land-use projections. This shift away from single vehicle transportation becomes even more significant when additional actions such as enhanced transit service and transportation marketing programs are also taken.

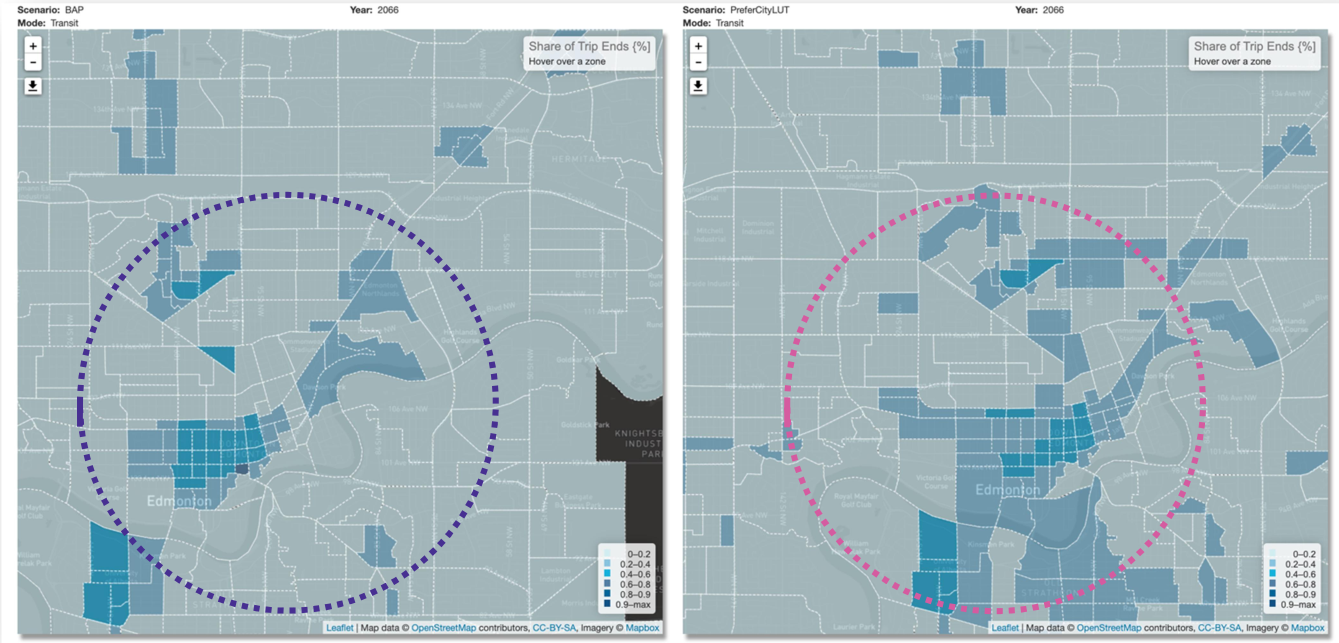

Figure 9: Transit Mode Share, BAP Scenario (left) and Preferred Scenario (right) (land-use impacts only), 2065

Land use policy enables GHG emissions reductions.

The Preferred Scenario includes an increase in the proportion of medium and high density housing in the network of nodes and corridors and a greater mixed use land uses. This efficiency in the built environment results in building energy consumption savings, improved viability of district energy, and a reduction in the number of vehicle kilometres travelled (VKT) by car. The result is a 6% per person reduction in greenhouse gas emissions compared to today. Figure 10 compares total VKT between the BAP and Preferred Scenarios- darker blue indicates more VKT.

Reducing VKT decreases:

- greenhouse gas emissions,
- costs to the city for road maintenance,
- traffic and parking congestion,
- the burden of electrification of transportation on the electricity system, and
- overall vehicle operating costs for residents, such as fuel and maintenance costs.

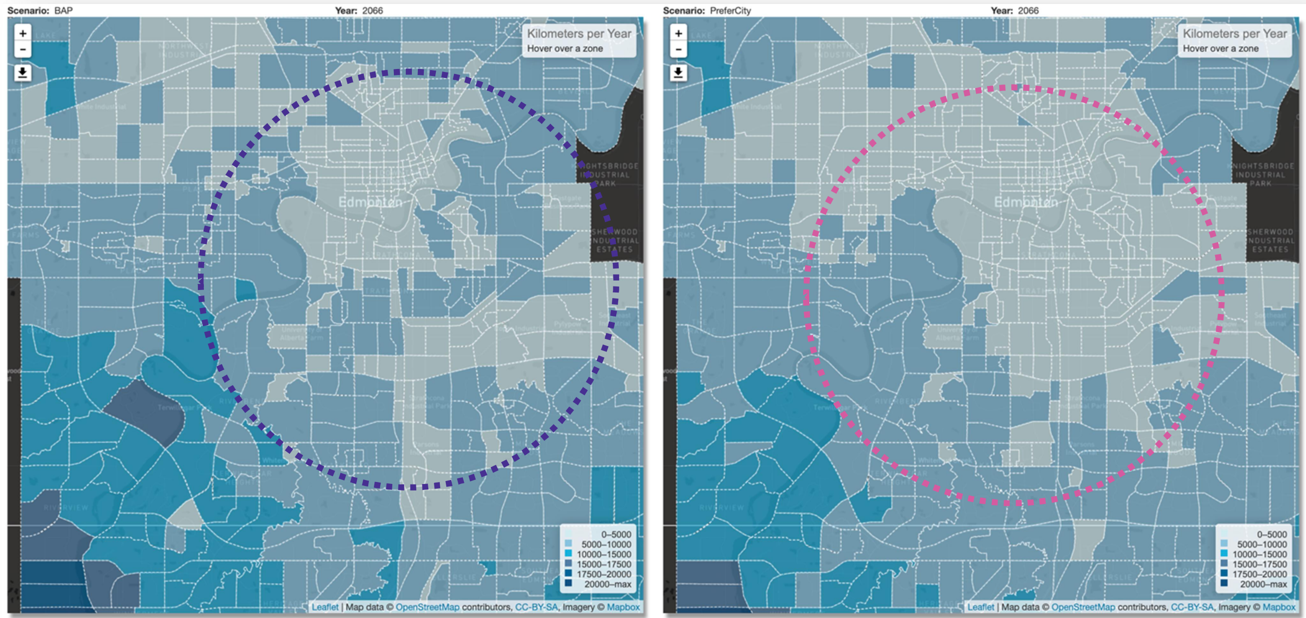

Figure 10: Home-based VKT, BAP (left) and Preferred (right) Scenarios, 2065

Energy is used more efficiently.

Energy is expensive and complicated to make, whatever its source. Using as much as possible of the energy generated for its intended purpose and using it as close as possible to where it is generated reduces losses, costs, and greenhouse gas emissions.[7]

Sankey diagrams illustrate the flow of energy through the city, beginning on the left with fuel sources, moving through sectors and concluding on the right with whether the energy is used as intended or lost through conversion. In 2016, just under 50% of the energy generated in Edmonton was not used for its intended purpose.

The energy system in the Preferred Scenario is much more efficient. Conversion losses fall to 27%, just over half of 2016. These improvements are due to a few factors. Electrification of transportation leads to reductions as the electric engine is more efficient than the internal combustion engine. There are also gains in buildings as a result of retrofits, the introduction of efficient heating systems such as heat pumps and a built environment with a greater share of apartments and duplexes. Shared surfaces such as walls and ceilings of these types of dwellings improve energy performance relative to detached houses.

[7] McDonald, R. I., Fargione, J., Kiesecker, J., Miller, W. M., & Powell, J. (2009). Energy Sprawl or Energy Efficiency: Climate Policy Impacts on Natural Habitat for the United States of America. PLoS ONE, 4(8), e6802.

As a result of this efficiency, the total energy system in the Preferred Scenario in 2065 requires 95 PJ of energy, whereas in 2016, total energy consumption is 164 PJ. The efficiency of the system is such that even though the population doubles by 2065, overall energy required decreases. This decrease in energy consumption provides a financial incentive for the implementation of the Preferred Scenario.

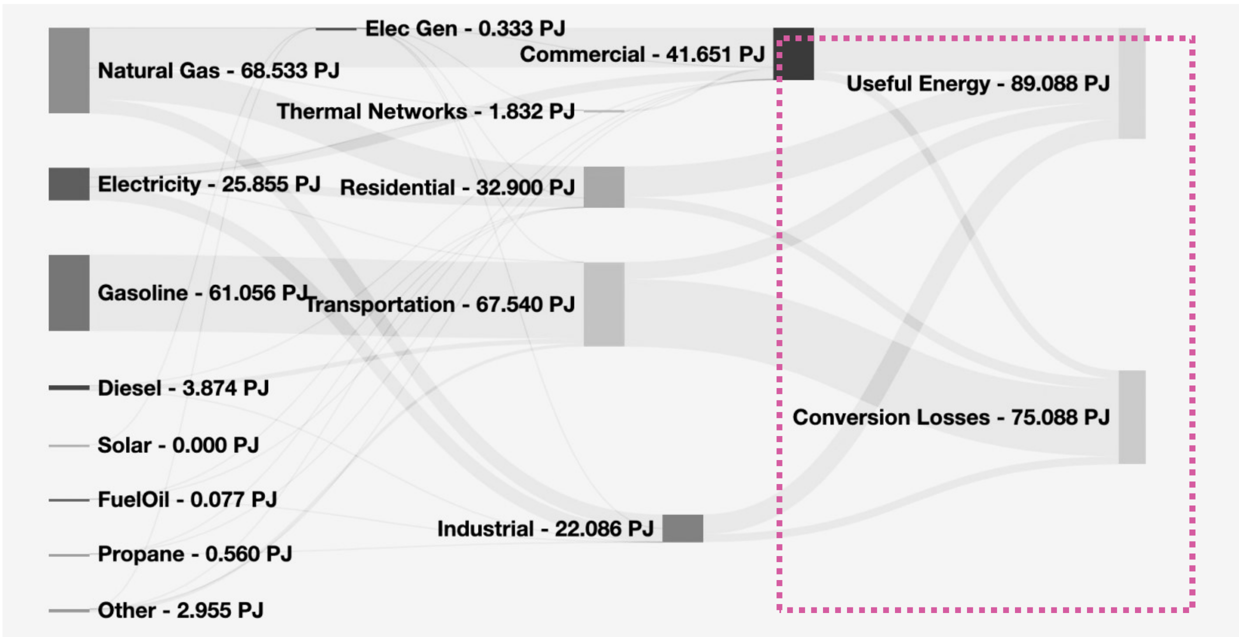

Figure 11: The Energy System, BAP Scenario, 2016

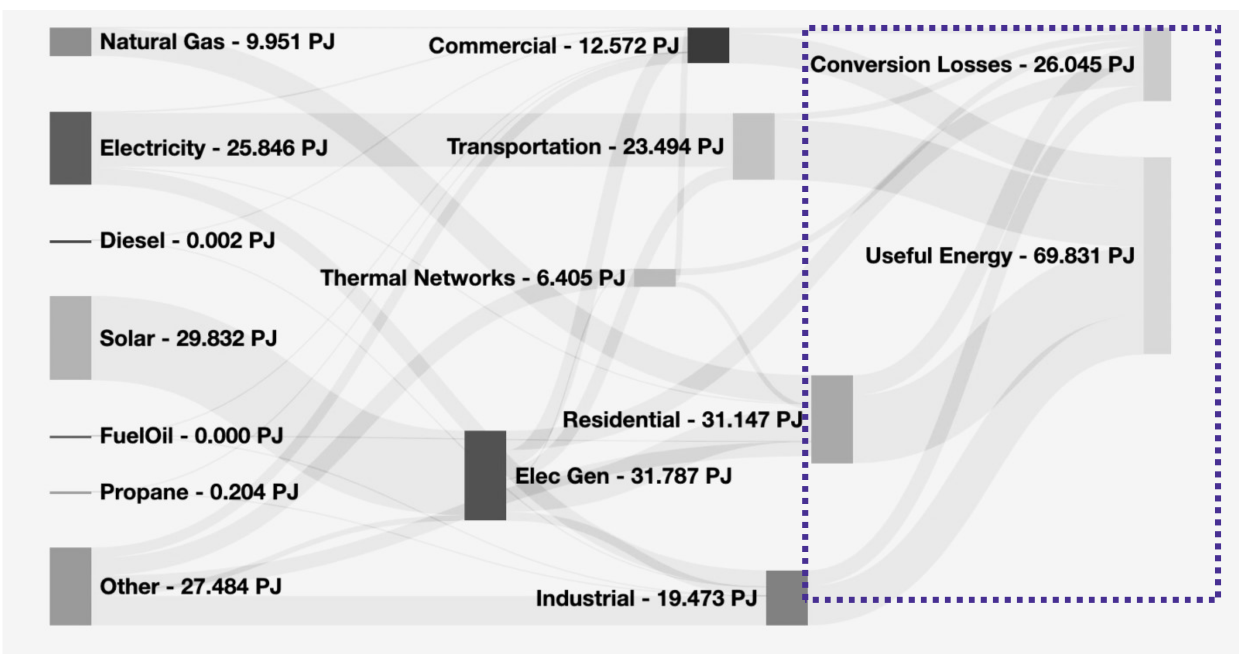

Figure 12: The Energy System, Preferred Scenario, 2065

Table 2: Summary of energy consumption for the BAP and Preferred Scenario

	Energy consumption in 2065	
Scenario	BAP	Preferred Scenario
2065 total (PJ)	211.3	95.9
2065 per capita (GJ)	99	45
% reduction in 2065 over BAP	N/A	55%

The viability of district energy is enhanced

The viability of district energy is determined by the heat density of buildings on the landscape. The increased densities of dwellings in the Preferred Scenario result in an increase in areas which can be serviced by district energy, as illustrated by the size of the thermal network node in the Sankey diagrams. The district energy system (thermal network) in 2016 is 1.8 PJ versus just over 6 PJ in the Preferred Scenario, and future technological improvements could increase the area serviced. District energy provides a range of benefits including flexibility of energy supply, resilience and economies of scale.

Observations

While the Preferred Scenario achieves significant GHG emissions reductions despite an increasing population, it does not stay within the city's carbon budget of 135 MtCO2e. By 2065, cumulative GHG emissions total 287 MtCO2e, nearly twice the budget.

Early interventions in the form of green electricity incentives or the purchase of carbon offsets for the community as a whole by 2024, combined with the implementation of the Preferred Scenario, creates a viable pathway for remaining within the carbon budget.

The Preferred Scenario results in a city focussed on transit and active transportation, accounting for nearly 50% or more of the total mode share in intensified areas of the city. In addition to reduced GHG emissions, the benefits of this shift also include reduced congestion, improved health outcomes, reduced operation and maintenance costs and reduced household energy costs.

The Preferred Scenario electrifies both transportation and heating in buildings by 2050. The costs of this transition are reduced through land use policy that shifts travel to transit, walking and cycling. Reduced vehicular travel creates a more energy efficient built environment.

Annual GHG emissions in 2065 are 3.4 $MtCO_2e$ in the Preferred Scenario versus 14.5 $MtCO_2e$ in the BAP scenario, an annual reduction of 77%. GHG emissions per capita in 2065 decrease to 1.6 tCO_2e in the Preferred Scenario from 6.9 tCO_2e in the BAP scenario.

Appendix 1: Description of the CityInSight Model

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 (e.g. crude oil, uranium, wind), 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, conversation rates, trade and losses at each stage in the journey from source to end use. Sankey diagrams provide a visual representation or “picture” of energy flows, transformations and energy balance.

Various factors shape the picture of energy and emissions flows, including: the population and the energy services it requires; commercial floorspace; energy production and trade; the deployed technologies which deliver energy services (service technologies); and the deployed technologies which transform energy sources to currencies (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).

CityInSight incorporates the accounting framework articulated by the GHGProtocol for Cities according to Figure 1.

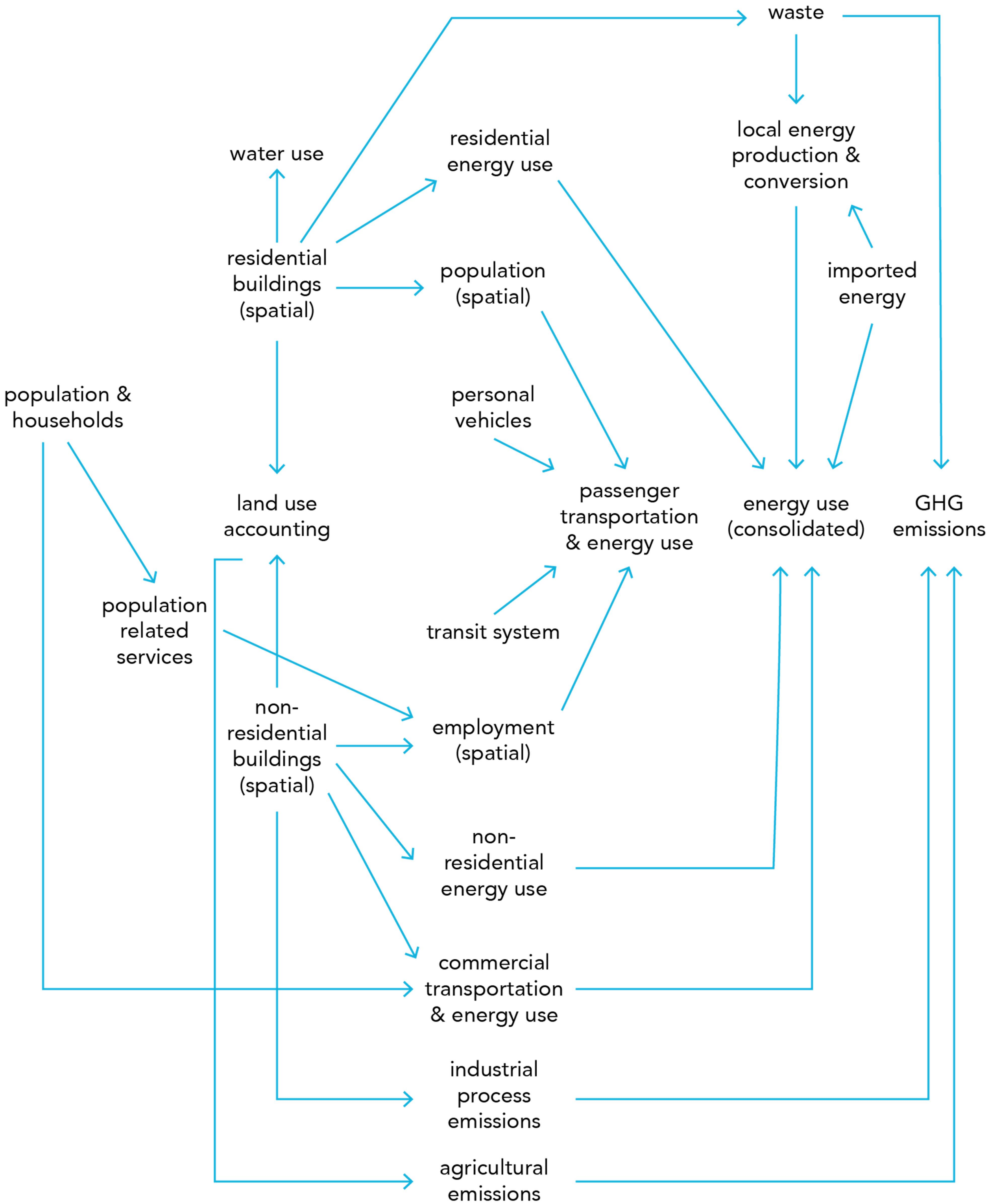

Figure 13: Schematic of CityInSight

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