City of Winnipeg

Community Energy Investment Roadmap

Appendices

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Appendix A: Data, Modelling Scope, Method, and Process

December 2021

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Summary

This Data, Methods, and Assumptions (DMA) Manual details the modelling approach used to provide community energy and emissions benchmarks and projections and provides a summary of the data and assumptions used in scenario modelling. The DMA makes the modelling elements fully transparent and illustrates the scope of data required for future modelling efforts.

Accounting and Reporting Principles

This municipal greenhouse gas (GHG) inventory baseline development and scenario modelling approach correlates with the Global Protocol for Community-Scale GHG Emissions Inventories (GPC). The GPC provides a fair and true account of emissions via the following principles:

Relevance: The reported GHG emissions shall appropriately reflect emissions occurring as a result of activities and consumption within the municipal boundary. The inventory will also serve the decision-making needs of the municipality, taking into consideration relevant local, subnational, and national regulations. Relevance applies when selecting data sources and determining and prioritizing data collection improvements.

Completeness: The inventory will account for all emissions sources within the inventory boundary. 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. The accuracy should be 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.

I. Modelling Scope

1. GEOGRAPHIC BOUNDARY

The geographic boundary of the modelling assessment is the municipal boundary of the City of Winnipeg (Figure 1).

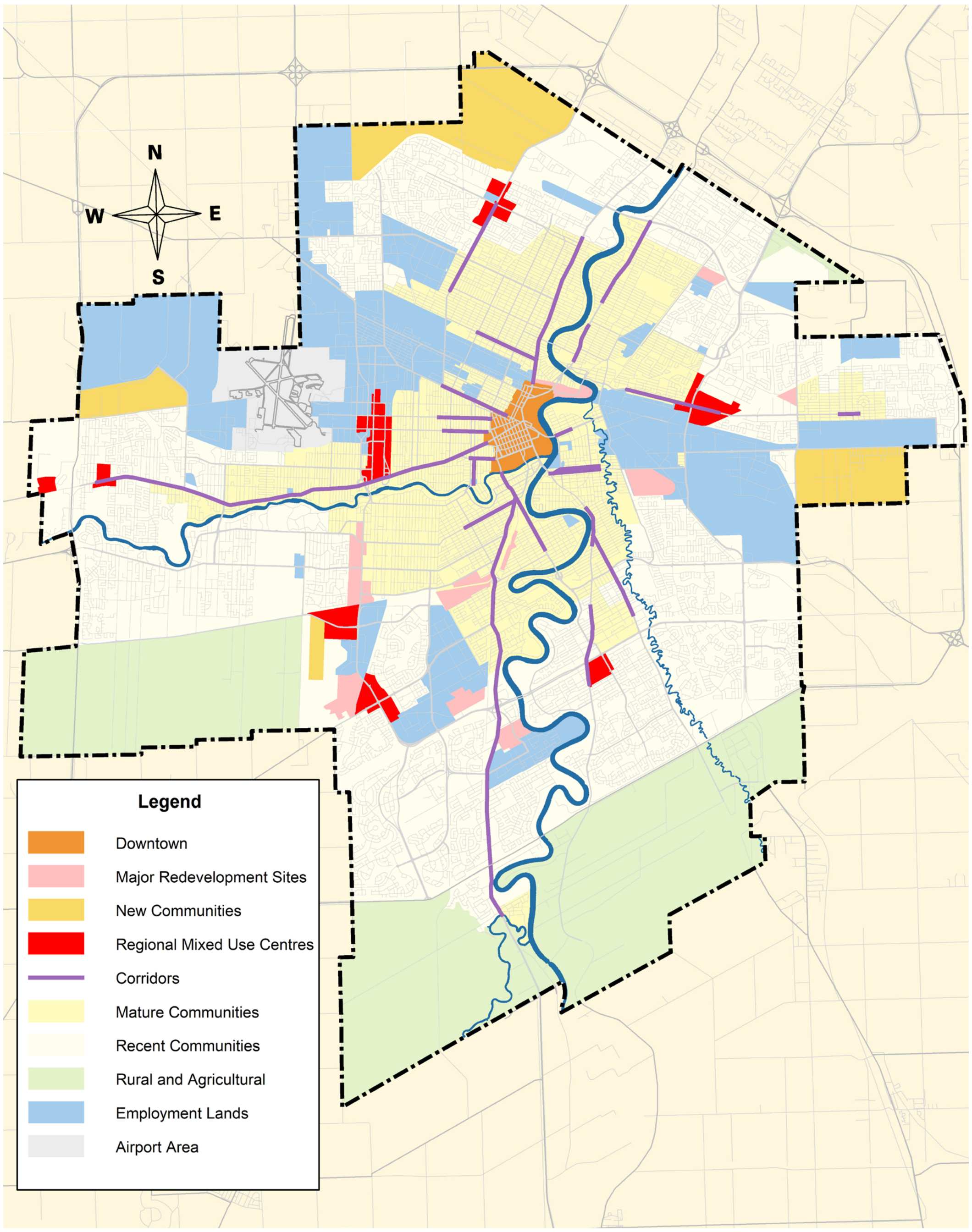

Figure 1. City of Winnipeg boundaries that will be used in the modelling process.[1]

[1] Winnipeg Urban Structure. Our Winnipeg. Retrieved in 2021.

2. TIME SCOPE

The assessment will cover the years from 2016 (base year) to 2050 (target year).

The year 2016 will be used as a base year within the model. The rationale for using this as the base year is that:

- Census data is a key data source for the model. At the time of modelling, the most recent census year for which data is available is 2016.
- The model requires a calibration of a base year system state (known as the initial conditions) using as much observed data as possible to develop an internally consistent snapshot of the city.

One-year increments are modelled from the 2016 baseline year until the 2050 target year. The first simulation period/year is 2016.

The forecasts of energy use and emissions will extend to 2050.

3. EMISSIONS SCOPE

The emissions assessed are those from the stationary energy (buildings), transportation, and waste sectors. The inventory will include Global Protocol for Community Greenhouse Gas Emissions Inventories (GPC) Scope 1 and 2 and some aspects of Scope 3 emissions. Refer to Table 1 and Table 2 for GPC scope definitions and a list of included GHG emission sources by scope.

Table 1. GPC scope definitions.

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

Table 2. Sources included in the Winnipeg model.

	SCOPE 1	SCOPE 2	SCOPE 3	NOTES
Stationary energy				
Residential buildings	Y	Y		
Commercial and institutional buildings and facilities	Y	Y		
Manufacturing industries and construction	Y	Y		
Energy industries	Y	Y		
Energy generation supplied to the grid				Additional renewable electricity is included beyond what is currently included in emissions factors projections.
Agriculture, forestry, and fishing activities	Y	Y		
Non-specified sources				NA
Fugitive emissions from mining, processing, storage, and transportation of coal				NA

	SCOPE 1	SCOPE 2	SCOPE 3	NOTES
Fugitive emissions from oil and natural gas systems	Y			
Transportation				
On-road	Y	Y		
Railways	Y	Y		
Waterborne navigation				NA
Aviation				NA
Off-road	Y	Y		
Waste				
Disposal of solid waste generated in the city			Y	
Disposal of solid waste generated outside the city				NA
Biological treatment of waste generated in the city			Y	
Biological treatment of waste generated outside the city				NA
Incineration and open burning of waste generated in the city				NA
Incineration and open burning of waste generated outside the city				NA
Wastewater generated in the city	Y		Y	
Wastewater generated outside the city				NA
Industrial processes and product use (IPPU)				
Industrial processes	Y			
Product use				NA
Agriculture, forestry, and other land use (AFOLU)				
Livestock	Y			
Land	Y			
Aggregate sources and non-CO_2 emissions sources on land	Y			
Other Scope 3			Y	

4. EMISSIONS FACTORS

Table 3. Emissions accounting framework and global warming potential.

CATEGORY	BASELINE DATA/ASSUMPTION	SOURCE
Emissions accounting framework		
Accounting framework	Global Protocol for Community-Scale GHG Emission Inventories (GPC)	Global Protocol for Community-Scale GHG Emission Inventories (GPC)
Emissions scope	Scope 1, 2, and partial Scope 3	See GPC emissions scope table for Scope 3 items included.
Sectors	Stationary energy (buildings) Transportation Waste	See GPC emissions scope table for sectors and subsectors included.
Boundary	Municipal boundary of the City of Winnipeg	City of Winnipeg
Reporting	GPC BASIC and partial BASIC+	Global Protocol for Community-Scale GHG Emission Inventories (GPC)
Transportation methodology	GPCinduced activity method	Global Protocol for Community-Scale GHG Emission Inventories (GPC)
Baseline year	2016	N/A
Projection year	2050	N/A
Global warming potential (GWP)		
Greenhouse gases	CO_2 = 1 CH_4 = 34 N_2O = 298	Myhre, G. et al., 2013: Anthropogenic and Natural Radiative Forcing. Table 8.7. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Table 4. Emissions factors for fuels in the Winnipeg model.

CATEGORY	BASELINE DATA/ASSUMPTIONS	SOURCE
Emissions factors		
Natural gas	49 kg CO_2e/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.

CATEGORY	BASELINE DATA/ASSUMPTIONS	SOURCE
Electricity	**2016:** CO_2: 28.9 g/kWh CH_4: 0.007 g/kWh N_2O: 0.001 g/kWh **2050:** CO_2: 82.32 g/kWh CH_4: 0.02 g/kWh N_2O: 0.00 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** CO_2: 2316 CH_4: 0.32 N_2O: 0.66	NIR Part 2 Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Diesel	**g/L** CO_2: 2690.00 CH_4: 0.07 N_2O: 0.21	NIR Part 2 Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Fuel oil	**g/L** Residential CO_2: 2560 CH_4: 0.026 N_2O: 0.006 **Commercial** CO_2: 2753 CH_4: 0.026 N_2O: 0.031 **Industrial** CO_2: 2753 CH_4: 0.006 N_2O: 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
Wood	**kg/GJ** **Residential** CO_2: 299.8 CH_4: 0.72 N_2O: 0.007 **Commercial** CO_2: 299.8 CH_4: 0.72 N_2O: 0.007 **Industrial** CO_2: 466.8 CH_4: 0.0052 N_2O: 0.0036	Environment and Climate Change Canada. National Inventory Report 1990–2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–56 Emission Factors for Biomass

CATEGORY	BASELINE DATA/ASSUMPTIONS	SOURCE
Propane	**g/L** **Transport** CO_2: 1515.00 CH_4: 0.64 N_2O: 0.03 **Residential** CO_2: 1515.000 CH_4 : 0.027 N_2O: 0.108 **All other sectors** CO_2: 1515.000 CH_4: 0.024 N_2O: 0.108	NIR Part 2 Table A6–3 Emission Factors for Natural Gas Liquids Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Waste/ wastewater	**Wastewater** CH_4: 0.48 kg CH4/kg BOD N_2O: 3.2 g/(person * year) from advanced treatment 0.005 g/g N from wastewater discharge **Landfill emissions** (waste) are calculated from first order decay of degradable organic carbon deposited in landfill derived emission factor in 2016 = 0.015 kg CH_4/tonne solid waste (assuming 70% recovery of landfill methane), .05 kg CH_4/tonne solid waste not accounting for recovery	CH4 wastewater: IPCC Guidelines Vol 5 Ch 6, Tables 6.2 and 6.3. We use the MCF value for anaerobic digester. N_2O from advanced treatment: IPCC Guidelines Vol 5 Ch 6 Box 6.1 N_2O from wastewater discharge: IPCC Guidelines Vol 5 Ch 6 Section 6.3.1.2 Landfill emissions: IPCC Guidelines Vol 5 Ch 3, Equation 3.1

5. MODEL ASSUMPTIONS

The modelling assessment uses a series of data assumptions to model the three scenarios: business-as-usual, business-as-planned, and net-zero scenarios. Appendix A details the data assumptions used in the City of Winnipeg's energy and emissions assessment.

II. Modelling Method

1. ABOUT CITYINSIGHT

CityInSight is an integrated, spatially-disaggregated energy, emissions, and finance model developed by Sustainability Solutions Group and whatIf? Technologies. The model enables bottom-up accounting for energy supply and demand, including renewable resources, conventional fuels, energy-consuming technology stocks (e.g. vehicles, heating systems, dwellings, and buildings), and all intermediate energy flows (e.g. electricity and heat).

CityInSight incorporates and adapts concepts from the system dynamics approach to complex systems analysis. Energy and GHG emissions are derived from a series of connected stock and flow models. The model accounts for physical flows (e.g. energy use, new vehicles, and vehicle kilometres travelled) as determined by stocks (e.g. buildings, vehicles, and heating equipment). For any given year within its time horizon, CityInSight traces the flows and transformations of energy from sources through energy currencies
(e.g. gasoline and electricity) to end uses (e.g. personal vehicle use and space heating),energy costs, and GHG emissions. The flows evolve based on current and future geographic and technology decisions/assumptions (e.g. EV uptake rates). An energy balance is achieved by accounting for efficiencies, conservation rates, and trade and losses at each stage in the journey from source to end use. The characteristics of CityInSight are described in Table 5.

The model is spatially explicit. All buildings, transportation, and land-use data are tracked within the model through a GIS platform and by varying degrees of spatial resolution. Where applicable, a zone-type system can be applied to break up the city into smaller configurations. 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 dates using GIS-based platforms. CityInSight's GIS outputs can be integrated with city mapping systems.

Table 5. 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 dozens 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 people's ability to walk and cycle, the accessibility of transit, the feasibility of district energy, etc. Therefore, CityInSight 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	CityInSight is designed to report emissions according to the GHGProtocol for Cities (GPC) framework and principles.
Economic impacts	CityInSight incorporates a full 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 allows for the generation of marginal abatement curves to illustrate the cost and/or savings of policies, strategies, and actions.

2. MODEL STRUCTURE

The major components of the model (sub-models) and the first level of modelled relationships (influences) are represented in Figure 2. These sub-models are all interconnected through various energy and financial flows. Additional relationships may be modelled in CityInSight 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.

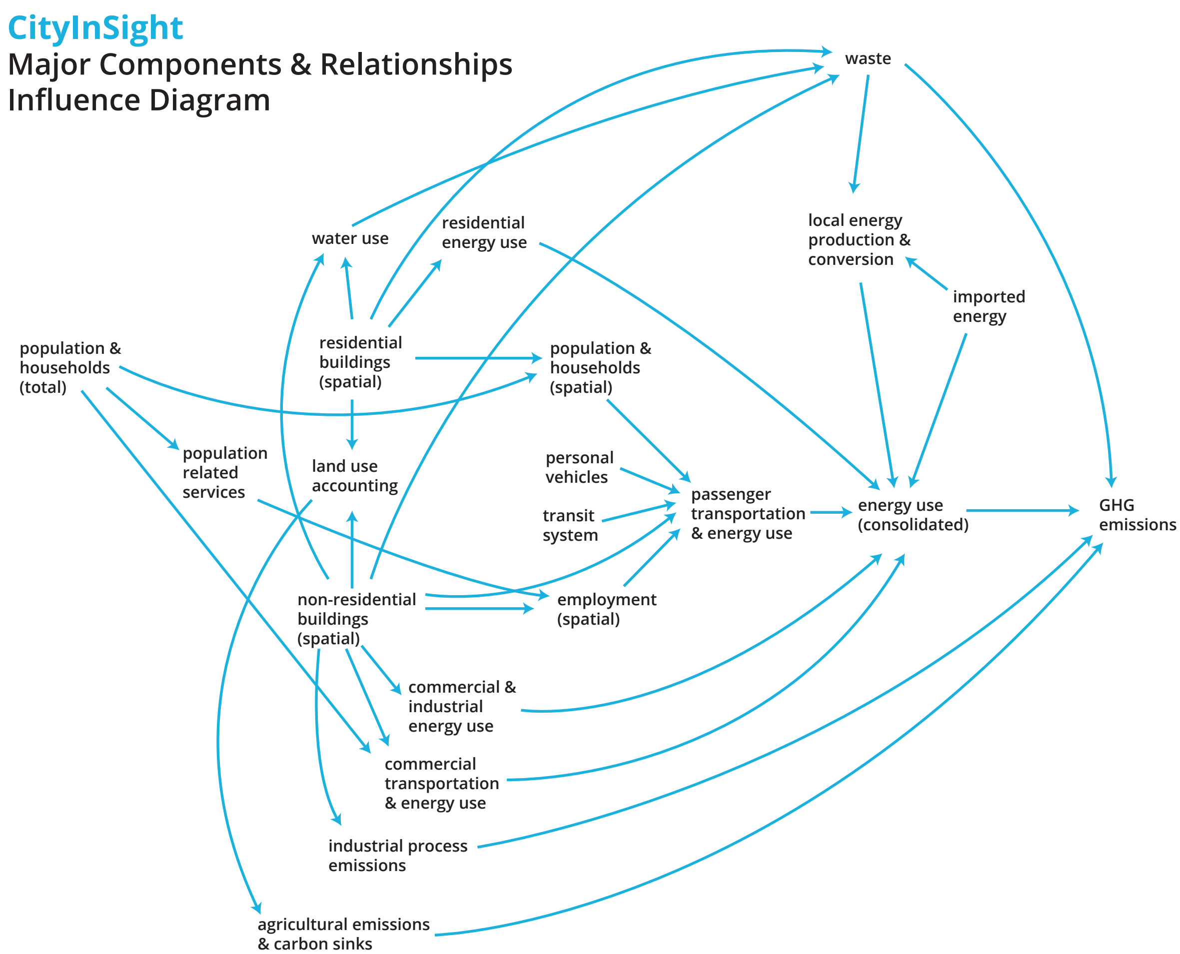

Figure 1. Representation of CityInSight's structure.

3. STOCKS AND FLOWS

Within each sub-model are a number of stocks and flows that represent energy and emissions processes in cities. For any given year, various factors shape the picture of energy and emissions flows in a city, including the population and the energy services it requires, commercial floor space, energy production and trade, the deployed technologies that deliver energy services (service technologies), and the deployed technologies that transform energy sources to currencies (harvesting technologies). The model creates an explicit mathematical relationship between the factors—some contextual and some part of the energy consuming or producing infrastructure—making up the energy flow picture.

Some factors are modelled as stocks (i.e. 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 with a similarly classified fuel consumption intensity classified by size, engine type, and model year. 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 harvesting technologies (e.g. electricity generating capacity).

4. SUB-MODELS

The stocks and flows that make up each sub-model are described below.

POPULATION, HOUSEHOLDS, AND DEMOGRAPHICS

- City-wide population is modelled using the standard population cohort-survival method, which tracks population by age and gender on a year-by-year basis. It accounts for various components of change such as births, deaths, immigration, and emigration.
- Population is allocated to households and these are placed spatially in zones via physical dwellings (see the land-use accounting sub-model).
- The age of the population is tracked over time and is used for analyzing demographic trends, generational differences, and implications for shifting energy-use patterns.
- The population sub-model influences energy consumption in various sub-models:
    - School enrollment totals (transportation)
    - Workforce totals (transportation)
    - Personal vehicle use (transportation)
    - Waste generation

BUILDING LAND-USE ACCOUNTING

Land-use accounting identifies buildings in space and over time, through construction, retrofits, and demolitions. In the baseline, this is often directly informed by building-related geospatial data. Land-use accounting consists of the following elements:

- Quantitative spatial projections of residential dwelling units by:
    - Residential structure type (single detached, semi detached, row house, apartment, etc.);
    - Development type (greenfield, intensification); and
    - Population assigned to dwelling units.
- Quantitative spatial projections of non-residential buildings by:
    - Non-residential structure type (retail, commercial, institutional);
    - Development type (greenfield, intensification);
    - Classification of buildings into archetypes (such as school, hospital, industrial—see Table 2).[2] This allows the model to account for differing intensities that would occur in relation to various non-residential buildings; and

[2] Where possible, this data comes directly from the municipality.

    - Job allocation to zones via non-residential floor area, using a floor-area-per-worker intensity.
- Land-use accounting takes the following "components of change" into account year over year:
    - New development;
    - Removals/demolitions; and
    - Year of construction.
- Land-use accounting influences other aspects of the model, notably:
    - Passenger transportation: The location of residential buildings influences where home-to-work and home-to-school trips originate, which in turn,influences their trip length and the subsequent mode selected. Similarly, the location and identification of non-residential buildings influences the destination for many trips. For example, buildings identified as schools would be identified in home-to-school trips.
    - Access to energy sources by buildings: Building location influences access to energy sources. For example, a rural dwelling may not have access to natural gas or a dwelling may not be in proximity to an existing district energy system. It can also be used to identify suitable projects. For example, the location and density of dwellings is a consideration for district energy development.
    - Non-residential building energy: The identification of non-residential building archetypes influences their energy consumption based on their use type. For example, a building identified as a hospital would have a higher energy-use intensity than a building identified as a school.

Table 6. Non-residential archetypes represented in the model.

CATEGORY	UNIT
Education	• College, university • School
Government buildings and space	• Municipal building • Fire station • Penal institution • Police station • Military base or camp
Healthcare	• Retirement or nursing home • Special care home • Hospital
Community and culture	• Greenspace • Recreation • Community centre • Museum, art gallery • Religious institution

CATEGORY	UNIT
Commercial space	• Restaurant • Hotel, motel, inn • Retail • Commercial retail • Commercial • Commercial residential • Retail residential • Warehouse commercial • Warehouse • Warehouse retail
Utilities	• Energy utility • Water pumping or treatment station
Transportation	• Transit terminal or station • Airport • Parking
Agriculture	• Industrial farm • Barn • Greenhouse
Industry and manufacturing	• Vehicle and heavy equipment service • Industrial generic • Manufacturing plant, miscellaneous processing plant • Chemical manufacturing plant • Printing and publishing plants • Food processing plant • Textile manufacturing plant • Furniture manufacturing plant • Refineries—all types • Fabricated metal product plant • Asphalt manufacturing plant • Concrete manufacturing plant
Miscellaneous large surfaces	• Golf course • Surface infrastructure

RESIDENTIAL AND NON-RESIDENTIAL BUILDING ENERGY

Building energy consumption is closely related to the land-use accounting designation it receives based on where the building is located, its archetype, and when it was constructed. Building energy consumption is calculated in the model by considering:

- Total energy-use intensity of the building type (including the proportion from thermal demand) is built from energy end uses in the building. End uses include heating, lighting, and auxiliary demand. The energy intensity of end uses is related to the building or dwelling archetype and its age.
- Energy use by fuel is determined based on the technologies used in each building (e.g. electricity and heating system types). Heating system types are assigned to building equipment stocks (e.g., heating systems, air conditioners, water heaters).
- Building energy consumption in the model also considers:
    - Solar gains and internal gains from sharing walls;
    - Local climate (heating and cooling degree days); and
    - Energy losses in the building.
- Building equipment stocks (e.g. water heaters and air conditioners) are modelled with a stock-turnover approach that captures equipment age, retirements, and additions. In future projections, the natural replacement of stocks is often used as an opportunity to introduce new (and more efficient) technologies.

The model has residential and non-residential building energy sub-models. They influence and produce important model outputs such as:

- Total residential energy consumption and emissions and residential energy and emissions by building type, end use, and fuel;
- Total non-residential energy consumption and emissions and residential energy and emissions by building type, end use, and fuel; and
- Local/imported energy balance (i.e how much energy will need to be imported after considering local capacity and production).

Figure 3 details the flows in the building energy sub-model at the building level.

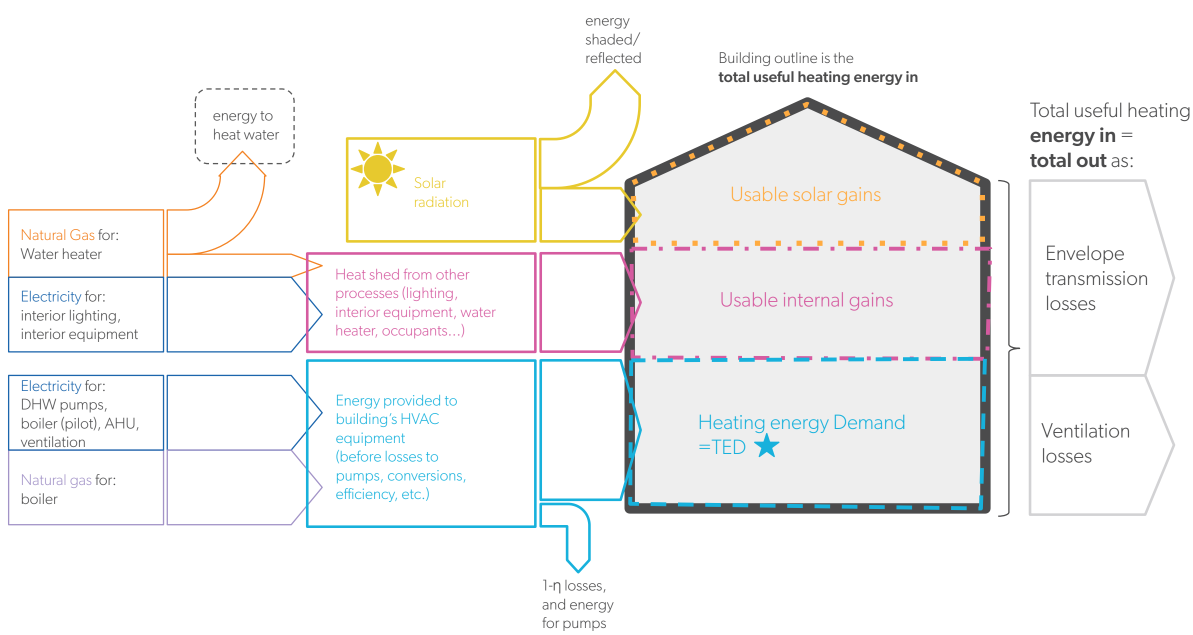

Figure 2. Building energy sub-model schematic.

TRANSPORTATION

CityInSight includes a spatially explicit passenger transportation sub-model that responds to changes in land use, transit infrastructure, vehicle technology, travel behaviour changes, etc. The sub-model has the following features:

- CityInSight uses the induced method for accounting for transportation-related emissions; the induced method accounts for in-boundary trips and 50% of transboundary trips that originate or terminate within the city boundary. This shares energy and GHGs between municipalities.
- The model accounts for "trips" in the following sequence:
    1. Trip generation. Trips are divided into four types (home-work, home-school, home-other, and non-home-based) that are each produced and attracted by different combinations of spatial influences identified in the land-use accounting sub-model: dwellings, employment, classrooms, and non-residential floor space.
    2. Trip distribution. Trips are distributed by the number of trips specified for each zone of origin and zone of destination pair. Origin-Destination (O-D) matrix data is based on local travel surveys and transportation models.
    3. Mode share. For each origin-destination pair, trips are shared over walk/bike, public transit, and automobile.
        a. Walk/bike trips are identified based on a distance threshold of ~2 km for walking and ~5–10 km for biking.
        b. Transit trips are trips with an origin or destination within a certain distance to a transit station.
    3. Vehicle distance. Vehicle kilometres travelled (VKT) are calculated based on the number of trips by mode and the distance of each trip based on a network distance matrix for the origin-destination pairs.
- VKT is assigned to a stock of personal vehicles based on vehicle type, fuel type, and fuel efficiency. The number of vehicles is influenced by the total number of households identified in the population sub-model. The model also uses a stock-turnover approach to model vehicle replacements, new sales, and retirements.
- The energy use and emissions associated with personal vehicles are calculated using the VKT of the stock of personal vehicles and their type, fuel, and efficiency characteristics.
- The personal mobility sub-model is one of the core components of the model. It influences and produces the following important model outputs:
    - Total transportation energy consumption by fuel, including electricity consumption.
    - Active trips and transit trips by zone distance.

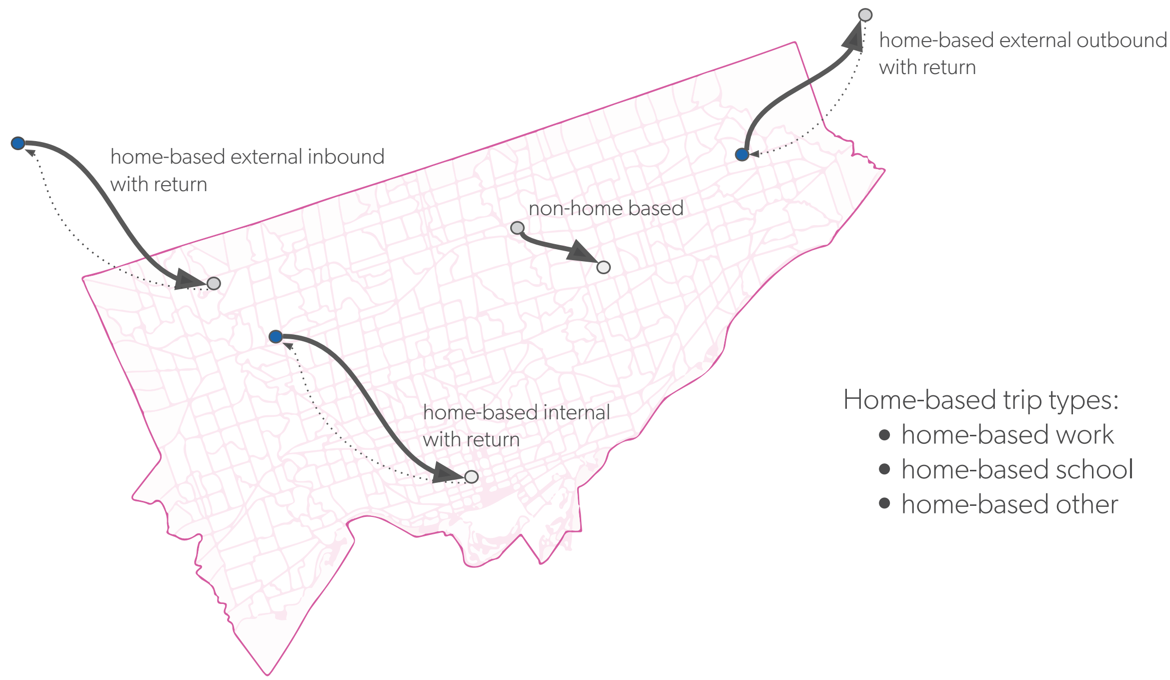

Figure 3. Trips assessed in the personal mobility sub-model.

WASTE

Households and non-residential buildings generate solid waste and wastewater, and the model traces various pathways to disposal, compost, and sludge. If present in the city, the model can also capture energy recovery from incineration and biogas. Waste generation is translated to landfill emissions based on first order decay models of carbon to methane.

LOCAL ENERGY PRODUCTION

The model accounts for energy generated within city boundaries. It models energy produced from local sources (e.g. solar, wind, biomass) alongside energy imported from other resources (e.g. the electricity grid and the natural gas distribution system) and accounts for conversion efficiency. Local energy generation can be spatially defined.

FINANCIAL AND EMPLOYMENT IMPACTS

Energy-related financial flows and employment impacts are captured through an additional layer of model logic. Costs are calculated as new stock is incorporated into the model through energy flows (annual fuel costs) and other operating and maintenance costs. Costs are based on a suite of assumptions that are inputted into the model. See Section 6 for financial variables tracked within the model.

The model calculates employment based on non-residential building archetypes and their floor area. Employment related to investments is calculated using standard employment multipliers and is often expressed as person-years of employment per million dollars of investment.

5. ENERGY AND GHG EMISSIONS ACCOUNTING

CityInSight accounts for the energy flows through the model, as shown in Figure 6. Source fuels crossing the geographic boundary of the city are shown on the left. The four "final demand" sectors—residential, commercial, industrial, and transportation—are shown towards the right. Some source fuels are consumed directly in the final demand sectors (e.g. natural gas used by furnaces for residential heating and gasoline used by personal vehicles for transportation). Other source fuels are converted to another energy carrier before consumption in the final demand sectors (e.g. solar energy converted to electricity via photovoltaic cells and natural gas combusted in heating plants and the resulting hot water distributed to end-use buildings via district energy networks). Finally, efficiencies of the various conversion points (e.g. end uses, local energy production) are estimated to split flows into either "useful" energy or conversion losses at the far right side of the diagram.

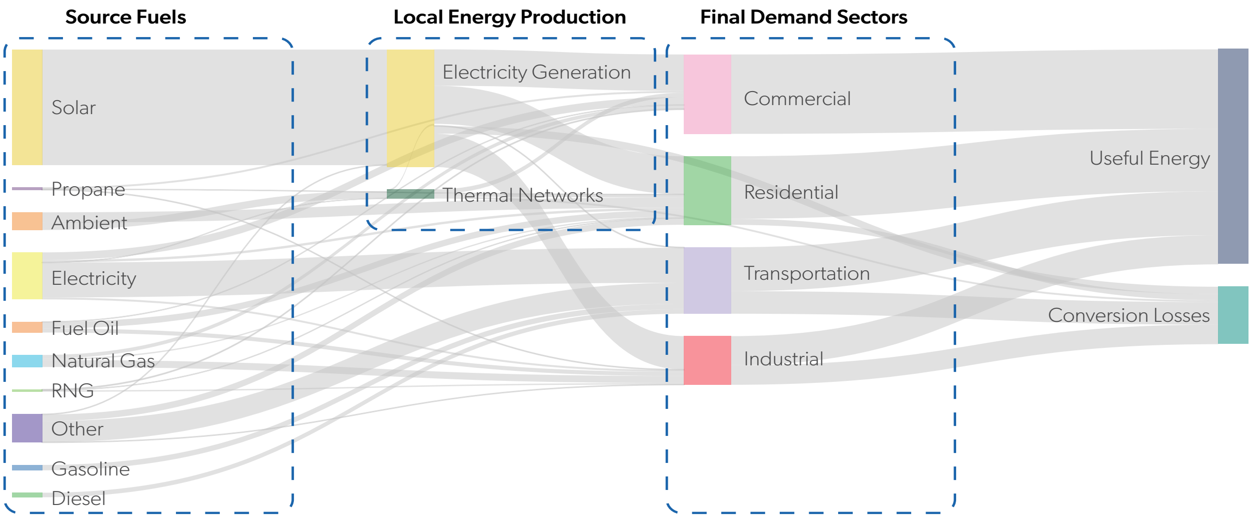

Figure 4. An example energy flow Sankey diagram showing main node groups.

Figure 5 below shows the potential for ambiguity when energy is reported. For example, which of the energy flows circled are included and how do you prevent double counting? To address these ambiguities, CityInSight defines two main energy reports:

- Energy demand (shown in Figure 6). Energy demand includes the energy flows just before the final demand sectors (left of the dotted red line). Where the demand sectors are supplied by local energy production nodes, the cut occurs after the local energy production and before demand.
- Energy supply (shown in Figure 7). Energy supply includes the energy flows just after the source fuel nodes (left of the dotted red line). Where the source fuels supply local energy production nodes, the cut occurs between the source fuels and local energy production.

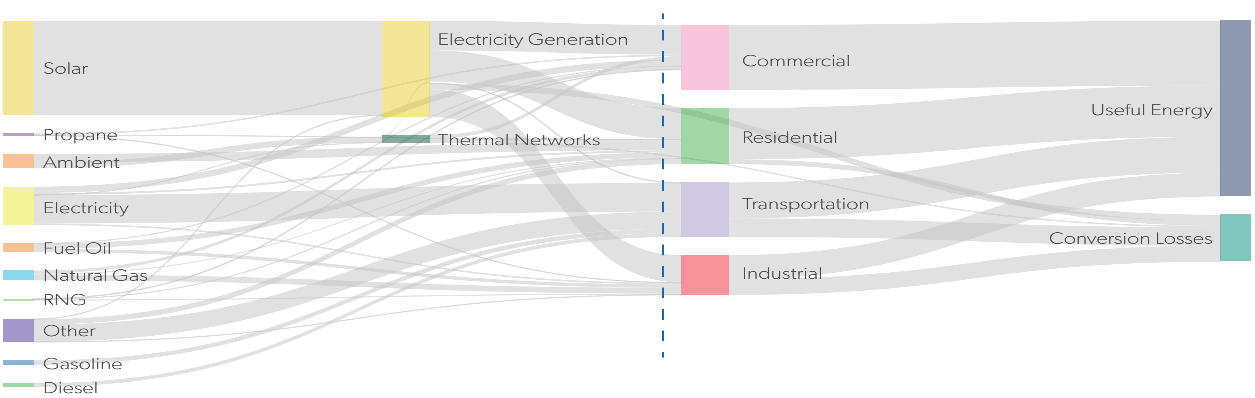

Figure 5. An example of an energy demand report definition.

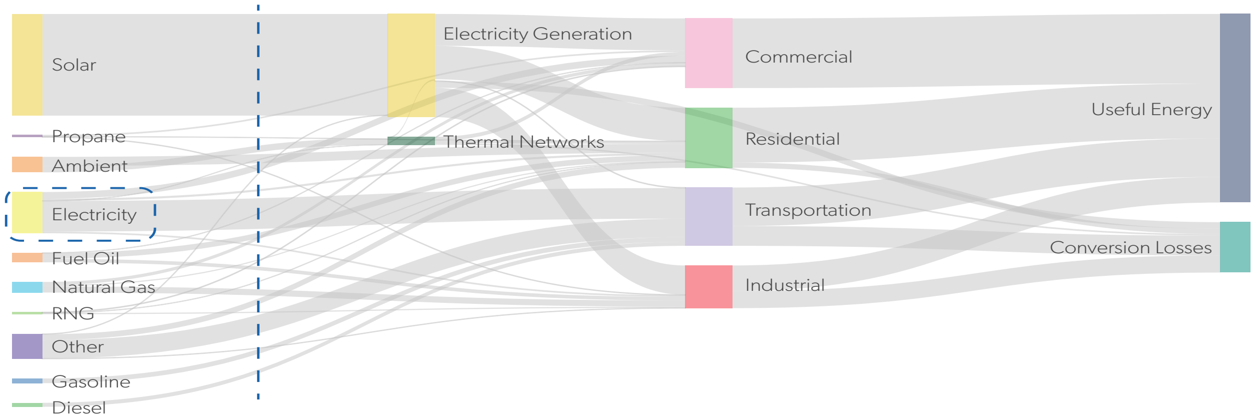

Figure 6. An example of an energy supply report definition.

In the integrated CityInSight energy and emissions accounting framework, GHG emissions are calculated after energy consumption is known.

6. FINANCIAL ACCOUNTING

The model also expresses a financial analysis for most of its stocks and flows. Costs and savings modelling considers:

- Upfront capital expenditures related to new stocks such as new vehicles or new building equipment;
- Operating and maintenance costs (annualized costs, such as vehicle maintenance, associated with stocks);
- Energy costs related to energy flows in the model and accounting for fuel and electricity costs; and
- Carbon pricing calculated based on emissions generation.

The expenditure types evaluated in the model are summarized in Table 7. Financial assumptions will be included in further iterations of the Winnipeg model.

Table 7. Categories of expenditures.

CATEGORY	DESCRIPTION
Residential buildings	Cost of dwelling construction and retrofitting and operating and maintenance costs (non-fuel).
Residential equipment	Cost of appliances and lighting, heating and cooling equipment.
Residential fuel	Energy costs for dwellings and residential transportation.
Residential emissions	Costs resulting from a carbon price on GHG emissions from dwellings and transportation.
Commercial buildings	Cost of building construction and retrofitting and operating and maintenance costs (non-fuel).
Commercial equipment	Cost of lighting, heating, and cooling equipment.
Commercial vehicles	Cost of vehicle purchase and operating and maintenance costs (non-fuel).
Non-residential fuel	Energy costs for commercial buildings, industry, and transport.
Non-residential emissions	Costs resulting from a carbon price on GHG emissions from commercial buildings, production, and transportation.
Energy production emissions	Costs resulting from a carbon price on GHG emissions for fuel used in the generation of electricity and heating.
Energy production fuel	Cost of purchasing fuel for generating local electricity, heating, or cooling.
Energy production equipment	Cost of the equipment for generating local electricity, heating, or cooling.
Municipal capital	Cost of the transit system additions (no other forms of municipal capital assessed).
Municipal fuel	Cost of fuel associated with the transit system.
Municipal emissions	Costs resulting from a carbon price on GHG emissions from the transit system.
Energy production revenue	Revenue derived from the sale of locally generated electricity or heat.
Personal use vehicles	Cost of vehicle purchase and operating and maintenance costs (non-fuel).
Transit fleet	Costs of transit vehicle purchase.
Active transportation infrastructure	Costs of bike lane and sidewalk construction.

FINANCIAL REPORTING PRINCIPLES

The financial analysis is guided by the following reporting principles:

1. Sign convention: Costs are negative; revenue and savings are positive.
2. The financial viability of investments will be measured by their net present value.
3. All cash flows are assumed to occur on the last day of the year and, for purposes of estimating their present value in Year 1, will be discounted back to time zero (the beginning of Year 1). This means that even the initial capital outlay in Year 1 will be discounted by a full year for purposes of present value calculations.
4. We will use a discount rate of three percent in evaluating the present value of future government costs and revenues.
5. Each category of stocks will have a different investment horizon.
6. Any price increases for fuel, electricity, carbon, or capital costs included in our analysis will be real price increases, net of inflation.
7. Where a case can be made that a measure will continue to deliver savings after its economic life (e.g. after 25 years in the case of the longest lived measures), we will capitalize the revenue forecast for the post-horizon years and add that amount to the final year of the investment horizon cash flow.
8. When presenting the results of the financial analysis, we will round them to the nearest thousand dollars unless additional precision is meaningful.
9. Only actual cash flows will be included in the financial analysis.

7. INPUTS AND OUTPUTS

The model relies on a suite of assumptions that define the various stocks and flows within the model for every time step (year) in the model.

BASE YEAR

For the baseline year, many model inputs come from calibrating the model with real energy datasets. This includes real building and transportation fuel data and city data on population, housing stock, and vehicle stock. Other assumptions come from underlying relationships between energy stocks and flows identified through research, like the fuel efficiency of personal vehicles or the efficiency of solar PV.

FUTURE PROJECTIONS

CityInSight is designed to project how the energy flow picture and the emissions profile will change in the long term by modelling potential changes in:

- the context (e.g. population, development patterns) and
- emissions reduction actions that influence energy demand and the composition of stocks.

Potential changes in the system are also based on a suite of input assumptions and are frequently referred to as "actions". Actions are intervention points in the model that change the relationship between a certain stock and flow at a certain time. Action assumptions can be based on existing projections and on proposed policy design and can be as wide ranging as the stocks and flows present in the model.

Stock-turnover models enable users to directly address questions about the penetration rates of new technologies over time that are constrained by assumptions such as new stock, market shares, and stock retirements. Examples of projection outputs include energy mix, mode split, vehicle kilometres of travel (VKT), total energy costs, household energy costs, and GHG emissions. Energy, emissions, capital, and operating costs are outputs for each scenario.

The emission and financial impacts of alternative climate mitigation scenarios are usually presented relative to a reference or "business as planned" scenario. For example, an action may assume that starting in 2030, all new personal vehicles will be electric.

This assumption would be input into the model, and, starting in 2030, every time a vehicle reaches the end of its life, rather than be replaced with a gas- or diesel-powered vehicle, it is replaced with an electric vehicle. As a result, the increase in the electric vehicle stock means greater VKT allocated to electricity and less to gasoline, thereby lowering emissions.

8. SPATIAL DISAGGREGATION

As previously discussed, a key feature of CityInSight is the geocoded stocks and flows that underlie the energy and emissions in the community. All buildings and transportation activities are tracked within a discrete number of geographic zones 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 years in the study horizon. CityInSight outputs can be integrated with city mapping and GIS systems. This feature allows CityInSight to support the assessment of a variety of urban climate mitigation strategies that are out of reach of more aggregate representations of the energy systems. Some examples include district energy, microgrids, combined heat and power, distributed energy, personal mobility (the number, length, and mode choice of trips), local supply chains, and EV infrastructure.

For stationary energy use, the foundation for the spatial representation consists of land use, zoning, and property assessment databases routinely maintained by municipal governments. These databases have been geocoded in recent years and contain detailed information about the built environment that is useful for energy analysis.

For transportation energy use and emissions, urban transportation survey data characterizes personal mobility by origin, destination, trip time, and trip purpose. This, in turn, supports the spatial mapping of personal transportation energy use and greenhouse gas emissions by origin or destination.

III. Modelling Process

CityInSight is designed to support the development of a municipal strategy for greenhouse gas mitigation. Usually, the model is engaged to identify a pathway for a community to meet a greenhouse gas emissions target by a certain year or to stay within a cumulative carbon budget over a specified period.

1. Data Collection, Calibration, and Baseline

The CityInSight engagement begins with an intensive data collection and calibration exercise in which the model is systematically populated with data on a wide range of stocks and flows in the community that affect greenhouse gas emissions. From this data, a picture emerges that begins to identify where opportunities for climate change mitigation are likely to be found in the modelled community.

The calibration and inventory exercise helps establish a common understanding among affected and interested parties about how the greenhouse gas emissions in their community are connected to the way they live, work, and play. Relevant data are collected for variables that drive energy and emissions,such as characteristics of buildings and transportation technologies, and these datasets are reconciled with observed data from utilities and other databases. The surface area of buildings is modelled in order to accurately estimate energy performance by end use. Each building is tracked by vintage, structure, and location, and a similar process is used for transportation stocks. Additional analyses at this stage include local energy generation, district energy, and the provincial electricity grid. The primary outcome of this process is an energy and GHG inventory for the baseline year, with corresponding visualizations.

2. The Base Year and Reference Projection

Once the baseline is completed, a reference projection—referred to as the business-as-planned scenario—to the target year is developed. The reference projection is based on a suite of input assumptions inserted into the model that reflect the future conditions. This is often based on existing municipal projections for buildings and population and historical trends in stocks that can be determined during model calibration. In particular, the project allocates future population and employment to building types and spaces. During this process, the model is calibrated against historical data, providing a technology stock as well as a historical trend for the model variables. This process ensures that the demographics are consistent with the municipality's GIS and transportation modelling.

The projection typically includes approved developments and official plans combined with the simulation of committed energy infrastructure to be built, existing regulations and standards (e.g. renewable energy and fuel efficiency), and communicated policies. The projection incorporates conventional assumptions about the future development of the electrical grid, uptake of electric vehicles, building code revisions, changes in climatic conditions, and other factors. The resulting projection serves as a reference line against which the impact and costs of GHG mitigation measures can be measured. Sensitivity analyses and data visualizations are used to identify key factors and points of leverage within the reference projection.

3. Low-Carbon Scenario and Action Plan

The low-carbon scenario—referred to as the net-zero scenario—uses a new set of input assumptions to explore the impacts of emissions reduction actions on the emissions profile. This begins with developing a list of candidate measures for climate mitigation in the community and is supplemented by additional measures and strategies identified through the engagement process. For many actions, CityInSight draws on an in-house database that specifies the performance and cost of technologies and measures for greenhouse gas abatement.

The low-carbon scenario is analyzed relative to the reference projection. The actions in the low-carbon scenario are grouped together to ensure that there is no double counting and that the interactive effects of the proposed measures are captured in the analysis.

IV. Addressing Uncertainty

There is extensive discussion about the uncertainty in models and modelling results. The assumptions underlying a model can be from other locations or large datasets that do not reflect local conditions or behaviours, and in cases where they do accurately reflect local conditions, it is still exceptionally difficult to predict how the conditions and behaviours will respond to broader societal changes and what those changes will be (the "unknown unknowns").

The modelling approach identifies four strategies for managing uncertainty related to community energy and emissions modelling:

1. Sensitivity analysis: From a methodological perspective, one of the most basic ways of studying complex models is the sensitivity analysis, which quantifies uncertainty in a model's output. During thes assessment, each of the model's input parameters is drawn from a statistical distribution in order to capture the uncertainty in the parameter's true value (Keirstead, Jennings, & Sivakumar, 2012).
   - Approach: Each of the variables will be increased by 10–20% to illustrate the impact that an error of that magnitude has on the overall total.
2. Calibration: One way to challenge untested assumptions is to use backcasting to ensure the model can forecast the past accurately. The model can then be calibrated to generate historical outcomes, which usually refers to "parameter adjustments" that "force" the model to better replicate observed data.
   - Approach: The model calibrates variables for which there are two independent sources of data. For example, the model calibrates building energy use (derived from buildings data) against actual electricity data from the electricity distributor.
3. Scenario analysis: Scenarios are used to demonstrate that a range of future outcomes is possible given the current conditions that no one scenario is more likely than another.
   - Approach: The model will develop a reference scenario.
4. Transparency: The provision of detailed sources for all assumptions is critical to enabling policy-makers to understand the uncertainty intrinsic in a model.
   - Approach: The assumptions and inputs are presented in this document.

Appendix A1: Model Assumptions

Table 8. Summary of business-as-usual (BAU), business-as-planned (BAP), and net-zero scenario (NZS) assumptions modelled for the City of Winnipeg's Community Energy Investment Roadmap.

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
Population and Employment				
Population	Increases by 34% by 2050 from 2016 total	Same as BAU	Same as BAU	City
Employment	Increases by 33% by 2050 from 2016 total	Same as BAU	Same as BAU	City
Buildings				
New buildings growth				
Building growth projections	Dwelling projections Residential Growth (2016–2050) Non-residential growth (2016–2050)	Dwelling projections Residential Growth (2016–2050) Non-residential growth (2016–2050)	20% of new dwellings to be single-detached by 2050.	BAU and BAP: Data derived from PLUM model

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
New buildings energy performance				
Residential	No improvements to new building standards	Assume base rate of 5% improvement every 5 years	As of 2031, all new homes have 50% annual load coverage by solar PV. By increasing storage capacity (i.e. batteries) with every renewable that is installed, reduce curtailment (i.e. the amount of time renewable energy supply is simply turned off, because it is not needed at that exact moment on the electricity grid) from 15% to 10% as renewables are installed. All new buildings are substantially more efficient and electric by 2030. Efficiency improvements are modelled as follows: 2022: 2013 NBC 2024: 10% better 2026: 20% better 2030: 40% better	BAU and BAP: Derived from PLUM model
Multi-residential	No improvements to new building standards	Assume base rate of 5% improvement every 5 years		
Commercial and institutional	No improvements to new building standards	Assume base rate of 5% improvement every 5 years	Include rooftop PV. All new buildings are substantially more efficient and electric by 2030. Efficiency improvements are modelled as follows: 2022: NECB 2020 2024: 25% better 2026: 50% better 2030: 60% better	

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
Industrial	No improvements to new building standards	Assume base rate of 5% improvement every 5 years		
Existing buildings retrofitting				
Residential	No retrofitting of existing building stock	Assume a 1% annual renovation rate of building stock with a 10% energy reduction	Starting in 2021, retrofit 100% of all existing dwellings built before 1980, exponentially, by 2035, achieving an average thermal savings of 50% and an electrical savings of 50%, including shifting to on-demand water heaters and heat pumps for space heating. Starting in 2035, retrofit 100% of all dwellings built between 1980 and 2016, exponentially, by 2050 (following pre-1980 dwellings). Achieve average thermal savings of 50% and electrical savings of 50%, including shifting to on-demand water heaters and heat pumps for space heating.	
Multi-residential				
Commercial and institutional			Starting in 2021, increase efficiency by 50% by 2050 (linearly).	
Industrial			Starting in 2021, increase efficiency to reduce overall process-related energy consumption by 33% by 2050 (linear).	

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
End use				
Space heating Water heating Space cooling	Fuel shares for end use unchanged; held from 2016–2050.	Fuel shares for end use unchanged; held from 2016–2050.	Fuel shares for end use unchanged; held from 2016–2050.	Canadian Energy Systems Analysis Research. Canadian Energy System Simulator. Retrieved from http://www.cesarnet.ca/research/caness-model
Projected climate impacts				
Heating and cooling degree days	Heating degree days are expected to decrease, and cooling degree days will increase.	Heating degree days are expected to decrease, and cooling degree days will increase.	Heating degree days are expected to decrease, and cooling degree days will increase.	Downscaled climate data from Pacific Climate Impacts Consortium. Retrieved from Climateatlas.ca - BCCAqv2
Renewable energy generation (on-site, building scale)				
Installation of heat pumps	NA	NA	100% of buildings by 2050	
Solar PV	NA	NA	Starting in 2021, install solar PV on 50% of pre-2016 buildings, achieving, on average, 50% of building electric load; scaling up to 50% of these buildings by 2050.	
Energy Generation				
Low- or zero-carbon energy generation (community scale)				
Rooftop Solar PV	Existing solar PV holds constant	Existing solar PV holds constant	We assume the current generation is held constant to 2050.	
Ground mount solar	Existing solar PV holds constant	Existing solar PV holds constant	We assume the current generation is held constant to 2050.	
District Energy Generation			We assume the current generation is held constant to 2050.	
Wind	Existing wind holds constant	Existing wind holds constant	We assume the current generation is held constant to 2050.	

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
Transport				
Transit				
Expanded transit	No expansion of fleet	No expansion of fleet	Expand transit	
Electrify transit system	No electrification of fleet	8% of fleet is electrified by 2030	100% by 2035	Winnipeg's Climate Action Plan: Planning for Climate Change. Acting for People. Retrieved from: https://winnipeg.ca/Sustainability/PublicEngagement/ClimateAction Plan/#tab-related links
Active				
Mode share	No change to mode shares over time. 2016: 80% vehicle trips 10% transit 7% active 3% school bus	Proportional change in mode share: increasing transit mode share.2016: 80% vehicle trips 10% transit 7% active 3% school bus By 2030: 77% vehicle trips 14% transit 7% active 2% school bus By 2050: 72% vehicle trips 21% transit 7% active 0% school bus	Home based work/ transportation marketing and individual planning: "Private vehicle trips decline by 9% per person and vehicular trip lengths declined 6%. All areas of Winnipeg are affected. Implement smart commute home-based work." Increase/improve cycling and walking infrastructure: "By 2050, mode shift 50% of 2 km trips to walking and 5 km to cycling." By 2050: 51% vehicle trips 17% transit 32% active 0% school bus	2016 mode share from City of Winnipeg internal modelling. BAP 2030 mode share from Winnipeg's Climate Action Plan, and then extrapolated linearly to 2050. NZS modelling shifts short trips to active modes, away from transit and other vehicles, based on the length of the trip.

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
Private/personal use				
Electrify municipal fleet	No change to municipal fleets	No change to municipal fleets	100% electric by 2035	
Electrify personal vehicles	No change to EV sales	100% of new sales by 2035	Same as BAP assumption	Axsen, J., Wolinetz, M. (2018). Reaching 30% plug-in vehicle sales by 2030: Modeling incentive and sales mandate strategies in Canada. Transportation Research Part D: Transport and Environment Volume 65, Pages 596-617 Canada, N. R. (2021). Government of Canada. Retrieved from https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/zero-emission-vehicle-infrastructure-program/21876
Electrify commercial vehicles	No change to EV sales	100% of new sales for light-duty vehicles by 2035	Same as BAP assumption	Canada, N. R. (2021). Government of Canada. Retrieved from https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/zero-emission-vehicle-infrastructure-program/21876
Vehicle kilometres travelled	Calculated in the model	Calculated in the model		Expert estimates derived from location of residents, jobs, schools, and other services; Average trip lengths derived from Statistics Canada. (see text of DMA for further details)

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
Vehicle fuel efficiencies/ tailpipe emission standards	CAFE Fuel standards: 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. ------ Light duty: 2015: 200 gCO_2e/km 2025: 119 gCO_2e/km 2030: 105 gCO_2e/km Heavy duty: 20% reduction in emissions intensity by 2025 relative to 2015 and 24% reduction in emissions intensity in 2030 relative to 2015.	CAFE Fuel standards: 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. ------ Light duty: 2015: 200 gCO_2e/km 2025: 119 gCO_2e/km 2030: 105 gCO_2e/km Heavy duty: 20% reduction in emissions intensity by 2025 relative to 2015 and 24% reduction in emissions intensity in 2030 relative to 2015.	BY 2040, all heavy-duty vehicles (semi-trucks) are green hydrogen based. Light-duty commercial vehicles are 100% electric by 2050 (Taxi-Fleet).	EPA. (2012). EPA and NHTSA set standards to reduce greenhouse gases and improve fuel economy for model years 2017-2025 cars and light trucks. Retrieved from https://www3.epa.gov/otaq/climate/documents/420f12050.pdf Corporate Average Fuel Economy. Retrieved from: http://www.nhtsa.gov/fuel-economy SOR/2010-201. Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations. Retrieved from: http://laws-lois.justice.gc.ca SOR/2018-98. Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations and other Regulations Made Under the Canadian Environmental Protection Act, 1999. Retrieved from: https://pollution-waste.canada.ca

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
Vehicle stock	All vehicle stock unchanged other than natural turnover. The total number of personal use and corporate vehicles is proportional to the projected number of households in the BAU.	Personal vehicle stock changes between 2016 and2050. Commercial vehicle stock unchanged between 2016 and2050. The total number of personal use and corporate vehicles is proportional to the projected number of households in the BAU.	Personal vehicle stock changes between 2016 and2050. Commercial vehicle stock unchanged between 2016 and 2050. The total number of personal use and corporate vehicles is proportional to the projected number of households in the BAU.	CANSIM and Natural Resources Canada's Demand and Policy Analysis Division.
Water and Waste				
Waste				
Waste generation	1250 kg/ household year— no change	1250 kg/ household/ year— no change		BAU and BAP: City of Winnipeg Solid Waste Division
Waste diversion	No change to waste diversion	Residential waste diversion: 50% by 2025 59% by 2030 ICI waste: By 2025,the City manages 31% of waste. By 2040, 80% diversion. C&D waste: By 2025, the City manages 25% of waste.By 2040, 80% diversion.	75% residential diversion, 80% ICI and construction/demolition waste	Comprehensive Waste Management Strategy (2011). Retrieved from http://clkapps.winnipeg.ca/DMIS/DocExt/ViewDoc.asp?DocumentTypeId=2&DocId=3673

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
Waste treatment	No change is waste treatment	No change is waste treatment	Increase efficiency by 30% by 2050; upgrades of sludge handling will reduce GHG emissions associated with the blower energy consumption. By 2050, biogas production: 75% methane recovery and conversion to biogas.	
Water/ wastewater	Not included	Not included	By 2050, 25% reduction in water/wastewater consumption (behaviour change, leak detection system, greywater reuse).	
Industry and Agriculture				
Industrial efficiencies	No change	No change		
Agriculture	No change	No change		
Sequestration and Land Accounting				
Natural areas	Not included	Not included	Effect of Action 1, land use and remaining net populations put in greenfield areas.	
Renewable Energy Procurement				
Purchases of renewable electricity	Not included	Not included	Calculate remaining emissions needed to get to net zero.	
Purchases of renewable natural gas	Not included	Not Included	Calculate remaining emissions needed to get to net zero	

Appendix B: Business-as-Usual, Business-as-Planned, and Net-Zero Scenario Modelling Assumptions and Results

December 2021

About this Document

This report was developed by SSG as a technical resource to support and inform the development of the City of Winnipeg's Community Energy Investment Roadmap. This report details the key energy use and greenhouse gas (GHG) assumptions used to model Winnipeg's 2016 to 2050 business-as-usual (BAU), business-as-planned (BAP), and net-zero energy scenarios (NZS), as well as the model results.

A separate document, the Data, Methods, and Assumptions Manual, details the model used to produce the results outlined in this document.

Disclaimer

We used reasonable skill, care, and diligence to assess the information acquired during the preparation of this analysis; however, 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, and the associated factors are subject to changes beyond the control of the author. The information provided by others is believed to be accurate but has not been verified.

This analysis includes strategic-level estimates of the City of Winnipeg that should not be relied upon for design or other purposes without verification. The authors do not accept responsibility for the use of this analysis for any purpose other than that stated above, and do not accept responsibility to any third party for the use, in whole or in part, of the contents of this document. This analysis applies to the City of Winnipeg and cannot be applied to other jurisdictions without analysis. Any use by the City of Winnipeg, its 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.

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Table 1. Summary of the business-as-usual (BAU), business-as-planned (BAP), and net-zero scenario (NZS) assumptions modelled for the City of Winnipeg's Community Energy Investment Roadmap.

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
Population and employment				
Population	Increases by 34% by 2050 from 2016 total	Same as BAU	Same as BAU	City
Employment	Increases by 33% by 2050 from 2016 total	Same as BAU	Same as BAU	City
Buildings				
New buildings growth				
Building growth projections	Dwelling projections Residential growth (2016–2050) Non-residential growth (2016–2050)	Dwelling projections Residential growth (2016–2050) Non-residential growth (2016–2050)	20% of new dwellings to be single-detached by 2050	BAU and BAP: Data derived from PLUM model

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
New buildings energy performance				
Residential	No improvements to new building standards	Assume base rate of 5% improvement every 5 years	As of 2031, all new homes have 50% annual load coverage by solar PV. By increasing storage capacity (i.e. batteries) with every renewable that is installed, reduce curtailment (i.e. the amount of time renewable energy supply is simply turned off, because it is not needed at that exact moment on the electricity grid) from 15% to 10% as renewables are installed. All new buildings are substantially more efficient and electric by 2030. Efficiency improvements are modelled as follows: 2022: 2013 NBC 2024: 10% better 2026: 20% better 2030: 40% better	BAU and BAP: Derived from PLUM model
Multi-residential	No improvements to new building standards	Assume base rate of 5% improvement every 5 years		
Commercial and institutional	No improvements to new building standards	Assume base rate of 5% improvement every 5 years	Include rooftop PV All new buildings are substantially more efficient and electric by 2030. Efficiency improvements are modelled as follows: 2022: NECB 2020 2024: 25% better 2026: 50% better 2030: 60% better	
Industrial	No improvements to new building standards	Assume base rate of 5% improvement every 5 years		

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
Existing buildings retrofitting				
Residential	No retrofitting of existing building stock	Assume a 1% annual renovation rate of building stock, with a 10% energy reduction	Starting in 2021 and finishing by 2035, exponentially retrofit all dwellings built before 1980 to achieve an average thermal savings of 50% and an electrical savings of 50%. The retrofit includes shifting to on-demand water heaters and heat pumps for space heating. Starting in 2035 and finishing by 2050, exponentially retrofit all dwellings built between 1980 and 2016 (following pre-1980 dwellings). This achieves an average thermal savings of 50% and an electrical savings of 50%. The retrofit includes shifting to on-demand water heaters and heat pumps for space heating.	
Multi-residential				
Commercial and institutional			Starting in 2021, increase efficiency by 50% by 2050 (linearly).	
Industrial			Starting in 2021, increase efficiency to reduce overall process-related energy consumption by 33% by 2050 (linear).	
End use				
Space heating	Fuel shares for end use unchanged; held from 2016–2050	Fuel shares for end use unchanged; held from 2016–2050	Fuel shares for end use unchanged; held from 2016–2050	Canadian Energy Systems Analysis Research. Canadian Energy System Simulator. Retrieved from http://www.cesarnet.ca/research/caness-model
Water heating				
Space cooling				
Projected climate impacts				
Heating and cooling degree days	Heating degree days are expected to decrease, and cooling degree days will increase.	Heating degree days are expected to decrease, and cooling degree days will increase.	Heating degree days are expected to decrease, and cooling degree days will increase.	Downscaled climate data from Pacific Climate Impacts Consortium. Retrieved from Climateatlas.ca - BCCAqv2

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
Renewable energy generation (on-site, building scale)				
Installation of heat pumps	NA	NA	100% of buildings by 2050	
Solar PV	NA	NA	Starting in 2021, install solar PV on 50% pre-2016 buildings, achieving, on average, 50% of building electric load, scaling up to 50% of these buildings by 2050.	
Energy generation				
Low- or zero-carbon energy generation (community scale)				
Rooftop solar PV	Existing solar PV hold constant	Existing solar PV hold constant	We assume the current generation holds constant to 2050.	
Ground mount solar	Existing solar PV hold constant	Existing solar PV hold constant	We assume the current generation holds constant to 2050.	
District energy generation			We assume the current generation holds constant to 2050.	
Wind	Existing wind holds constant	Existing wind holds constant	We assume the current generation holds constant to 2050.	
Transport				
Transit				
Expanded transit	No expansion of fleet	No expansion of fleet	Expand transit	
Electrify transit system	No electrification of fleet	8% of fleet is electrified by 2030	100% by 2035	Winnipeg's Climate Action Plan: Planning for Climate Change. Acting for People. Retrieved from: https://winnipeg.ca/Sustainability/PublicEngagement/ClimateActionPlan/#tab-relatedlinks

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
Active				
Mode share	No change to mode shares	Proportional change in mode share: increasing transit mode share. By 2031, pm peak: 79% vehicle trips 11% transit 7% active 3% school bus 2016 pm peak: 80% vehicle trips 10% transit 7% active 3% school bus	Home-based work/transportation marketing and individual planning: "Private vehicle trips decline by 9% per person and vehicular trip lengths decline 6%. All areas of Winnipeg are affected. Implement smart commute/home-based work." Increase/improve cycling and walking infrastructure: "By 2050, mode shift 50% of 2 km trips to walking and 5 km to cycling."	
Private/personal use				
Electrify municipal fleet	No change to municipal fleets	No change to municipal fleets	100% electric by 2035	
Electrify personal vehicles	No change to EV sales	100% of new sales by 2035	Same as BAP assumption	Axsen, J., Wolinetz, M. (2018). Reaching 30% plug-in vehicle sales by 2030: Modeling incentive and sales mandate strategies in Canada. Transportation Research Part D: Transport and Environment Volume 65, Pages 596-617 Canada, N. R. (2021). Government of Canada. Retrieved from https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/zero-emission-vehicle-infrastructure-program/21876

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
Electrify commercial vehicles	No change to EV sales	100% of new sales for light-duty vehicles by 2035	Same as BAP assumption	Canada, N. R. (2021). Government of Canada. Retrieved from https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/zero-emission-vehicle-infrastructure-program/21876
Vehicle kilometres travelled	Calculated in the model	Calculated in the model		Expert estimates derived from location of residents, jobs, schools, and other services. Average trip lengths derived from Statistics Canada (see text of DMA for further details).

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
Vehicle fuel efficiencies/ tailpipe emission standards	CAFE fuel standards: 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. ------ **Light duty:** 2015: 200 gCO_2e/km 2025: 119 gCO_2e/km 2030: 105 gCO_2e/km **Heavy duty:** A 20% reduction in emissions intensity by 2025 relative to 2015 and a 24% reduction in emissions intensity in 2030 relative to 2015.	CAFE fuel standards: 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. ------ **Light duty:** 2015: 200 gCO_2e/km 2025: 119 gCO_2e/km 2030: 105 gCO_2e/km **Heavy duty:** A 20% reduction in emissions intensity by 2025 relative to 2015 and a 24% reduction in emissions intensity in 2030 relative to 2015.	By 2040, all heavy-duty vehicles (semi-trucks) are green hydrogen based. Light-duty commercial vehicles are 100% electric by 2050 (Taxi-Fleet).	EPA. (2012). EPA and NHTSA set standards to reduce greenhouse gases and improve fuel economy for model years 2017–2025 cars and light trucks. Retrieved from https://www3.epa.gov/otaq/climate/documents/420f12050.pdf Corporate Average Fuel Economy. Retrieved from: http://www.nhtsa.gov/fuel-economy SOR/2010-201. Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations. Retrieved from: http://laws-lois.justice.gc.ca SOR/2018-98. Regulations Amending the Heavy-Duty Vehicle and Engine Greenhouse Gas Emission Regulations and other Regulations Made Under the Canadian Environmental Protection Act, 1999. Retrieved from: https://pollution-waste.canada.ca

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
Vehicle stock	All vehicle stock unchanged other than natural turnover. The total number of personal-use and corporate vehicles is proportional to the projected number of households in the BAU.	Personal vehicle stock changes between 2016–2050. Commercial vehicle stock unchanged 2016–2050. The total number of personal-use and corporate vehicles is proportional to the projected number of households in the BAU.	Personal vehicle stock changes between 2016–2050. Commercial vehicle stock unchanged 2016–2050. The total number of personal-use and corporate vehicles is proportional to the projected number of households in the BAU.	CANSIM and Natural Resources Canada's Demand and Policy Analysis Division.
Water and waste				
Waste				
Waste generation	1250 kg/household/year—no change	1250 kg/household/year—no change	1250 kg/household/year—no change	BAU and BAP: City of Winnipeg Solid Waste Division
Waste diversion	No change to waste diversion	Residential waste diversion: 50% by 2025 59% by 2030 ICI waste: By 2025, 31% of waste managed by City By 2040, 80% diversion. C&D waste: By 2025, 25% of waste managed by City. By 2040, 80% diversion.	75% residential diversion, 80% ICI, and construction/demolition waste.	Comprehensive Waste Management Strategy (2011). Retrieved from http://clkapps.winnipeg.ca/DMIS/DocExt/ViewDoc.asp?DocumentTypeId=2&DocId=3673
Waste treatment	No change to waste treatment.	No change to waste treatment.	Increase efficiency by 30% by 2050. Upgradingsludge handling will reduce GHG emissions associated with the blower energy consumption. By 2050, biogas production: 75% methane recovery and conversion to biogas.	
Water/wastewater	Not included	Not included	By 2050, 25% reduction in water/wastewater consumption (behaviour change, leak detection system, greywater reuse).	

CATEGORY	BAU ASSUMPTION	BAP ASSUMPTION	NET-ZERO ASSUMPTION	SOURCE
Industry and agriculture				
Industrial efficiencies	No change	No change	Starting in 2021, increase efficiency by 50% by 2050 (linearly).	
Agriculture	No change	No change	No change	
Sequestration and land accounting				
Natural areas	Not included	Not included	Effect of Action 1, land use and remaining net populations put in greenfield areas	
Renewable energy procurement				
Purchases of renewable electricity	Not included	Not included	Calculate remaining emissions needed to get to net zero	
Purchases of renewable natural gas	Not included	Not Included	Calculate remaining emissions needed to get to net zero	

Community Energy and Emissions

Table 2. Per capita community energy use and emissions in 2016 and 2050 in a business-as-usual, business-as-planned, and net-zero scenario.

	2016	2050 BAU	2050 BAP	2050 NZS	% +/- 2016-2050NZS	% +/- 2050 BAU-2050 NZS	% +/- 2050 BAP-2050 NZS
Per capita energy (GJ/cap)	134,306	110,544	86,259	45,903	-66%	-58%	-47%
Per capita emissions (tCO_2eJ/cap)	6.2	4.9	2.8	0.3	-95%	-95%	-91%

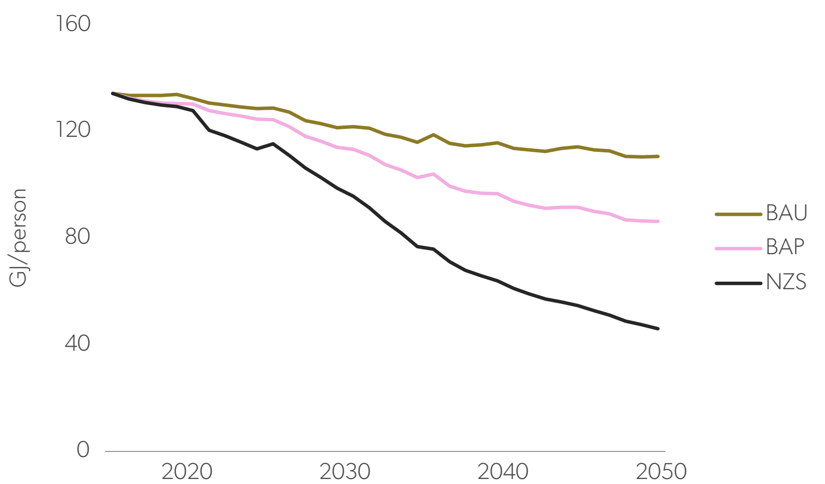

Figure 1. Energy use per capita in a business-as-usual, business-as-planned, and net-zero scenario, 2016–2050.

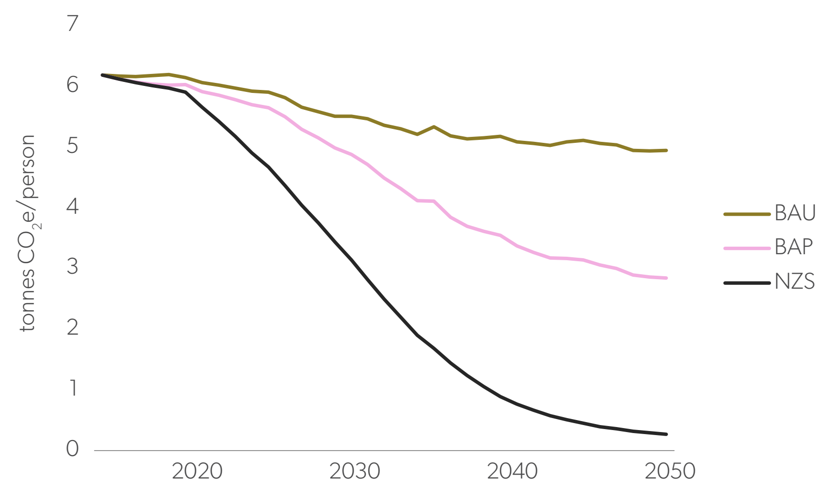

Figure 2. Greenhouse gas emissions per capita in a business-as-usual, business-as-planned, and net-zero scenario, 2016-2050.

Table 3. Community energy use, by fuel, in 2016 and 2050 in a business-as-usual scenario, a business-as-planned scenario, and a net-zero scenario.

ENERGY BY FUEL (GJ)	2016	SHARE 2016	2050 BAU	SHARE 2050	2050 BAP	SHARE 2050	2050 NZS	SHARE 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS	% +/- 2050 BAP-2050 NZS
Coal	27,881	0%	32,744	0%	32,755	0%	21,787	0%	-22%	-33%	-33%
Diesel	7,694,175	8%	7,544,074	7%	6,189,211	7%	9,280	0%	-100%	-100%	-100%
Gasoline	26,858,500	27%	24,890,180	23%	679,677	1%	23,470	0%	-100%	-100%	-97%
Grid electricity	25,409,671	26%	30,678,533	28%	37,075,028	43%	24,461,338	65%	-4%	-20%	-34%
Hydrogen	0	0%	0	0%	0	0%	1,733,633	5%	100%	100%	100%
Local electricity	0	0%	0	0%	0	0%	7,966,833	21%	100%	100%	100%
Natural gas	36,446,759	37%	44,942,529	41%	40,110,579	47%	0	0%	-100%	-100%	-100%
Other	199,188	0%	201,528	0%	170,544	0%	24,479	0%	-88%	-88%	-86%
Propane	806,720	1%	992,746	1%	858,325	1%	643	0%	-100%	-100%	-100%
RNG	0	0%	0	0%	0	0	3,221,456	9%	100%	100%	100%
Wood	942,474	1%	864,611	1%	833,508	1%	299,482	1%	-68%	-65%	-64%
TOTAL	**98,385,368**	**100%**	**110,146,946**	**100%**	**85,949,627**	**100%**	**37,762,402**	**100%**	**-62%**	**-66%**	**-56%**

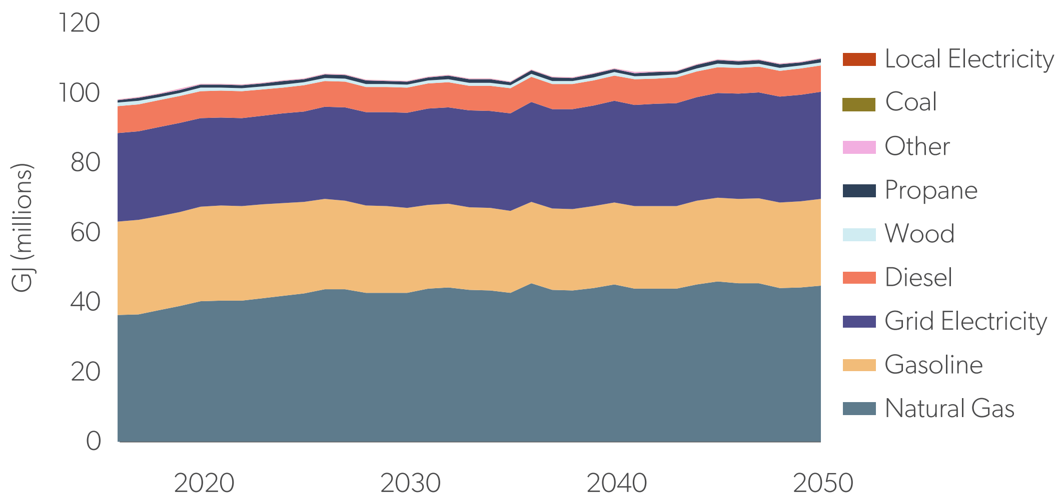

Figure 3. Community energy use, by fuel, in a business-as-usual scenario, 2016–2050.

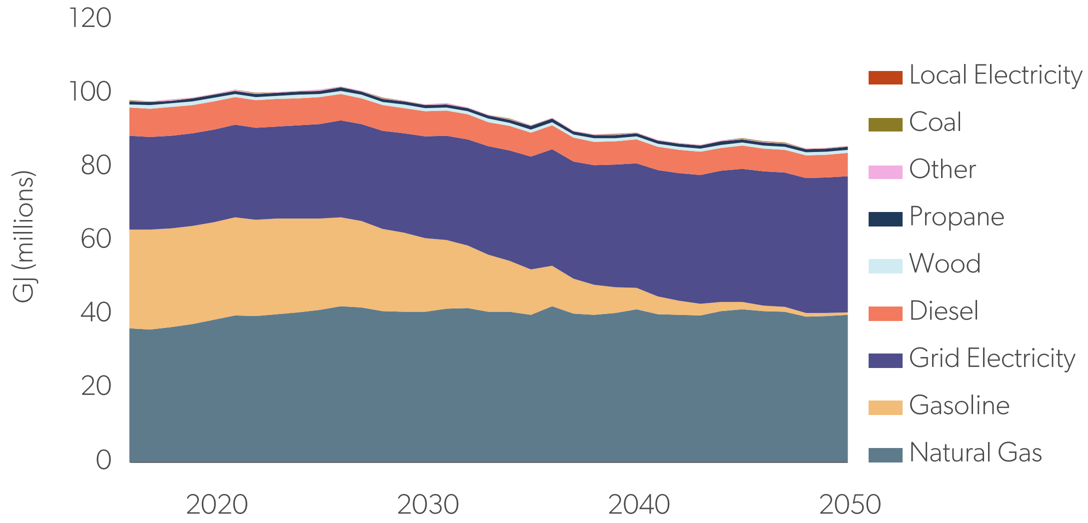

Figure 4. Community energy use, by fuel, in a business-as-planned scenario, 2016–2050.

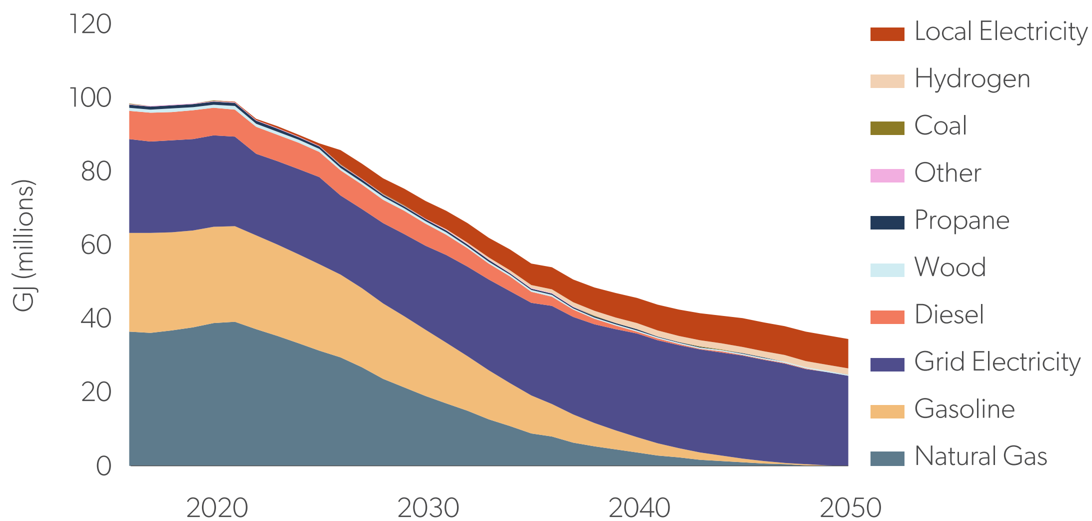

Figure 5. Community energy use, by fuel, in a net-zero scenario, 2016–2050.

Table 4. Community energy use, by sector, in 2016 and in 2050 in a business-as-usual scenario, a business-as-planned scenario, and a net-zero scenario.

ENERGY BY SECTOR(GJ)	2016	SHARE 2016	2050 BAU	SHARE 2050	2050 BAP	SHARE 2050	2050 NZS	SHARE 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS	% +/- 2050 BAP-2050 NZS
Commercial	26,400,481	27%	34,914,321	32%	31,206,338	36%	12,806,665	34%	-51%	-63%	-59%
Industrial	13,551,869	14%	15,298,864	14%	13,343,020	16%	7,334,085	19%	-46%	-52%	-45%
Residential	24,491,230	25%	27,487,794	25%	25,552,024	30%	8,311,706	22%	-66%	-70%	-67%
Transportation	33,941,789	34%	32,445,966	29%	15,848,245	18%	9,309,946	25%	-73%	-71%	-41%
TOTAL	**98,385,368**	**100%**	**110,146,946**	**100%**	**85,949,627**	**100%**	**37,762,402**	**100%**	**-62%**	**-66%**	**-56%**

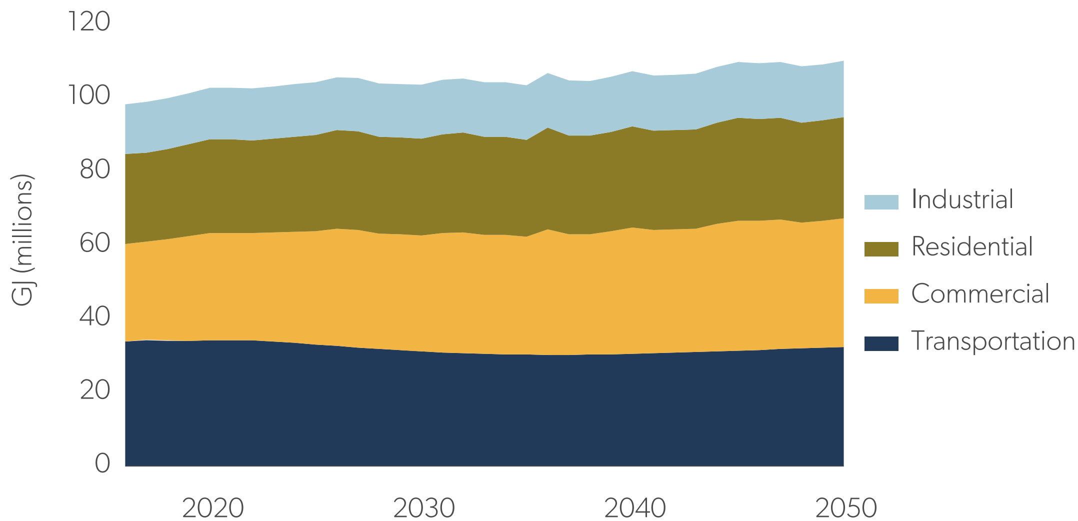

Figure 6. Community energy use, by sector, in a business-as-usual scenario, 2016–2050.

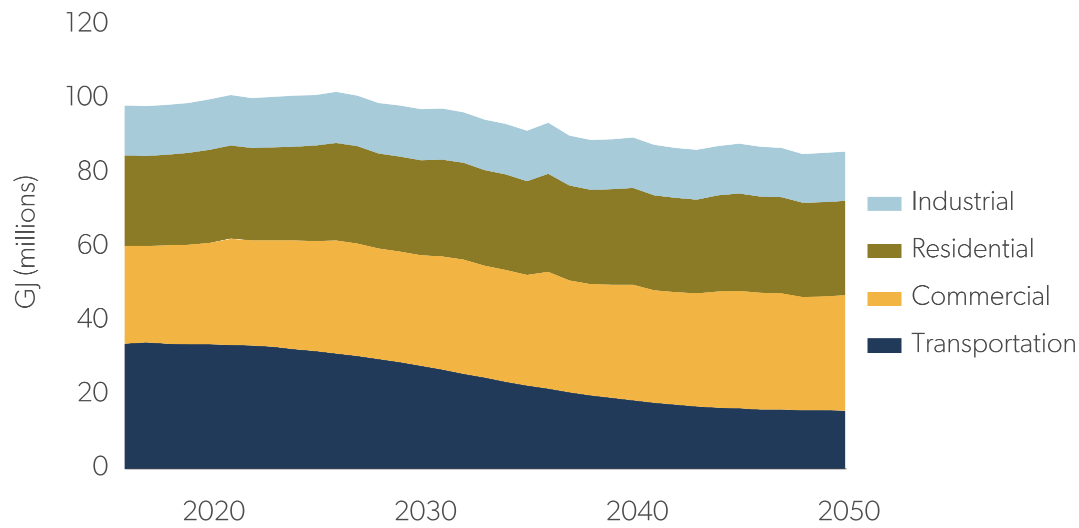

Figure 7. Community energy use, by sector, in a business-as-planned scenario, 2016–2050.

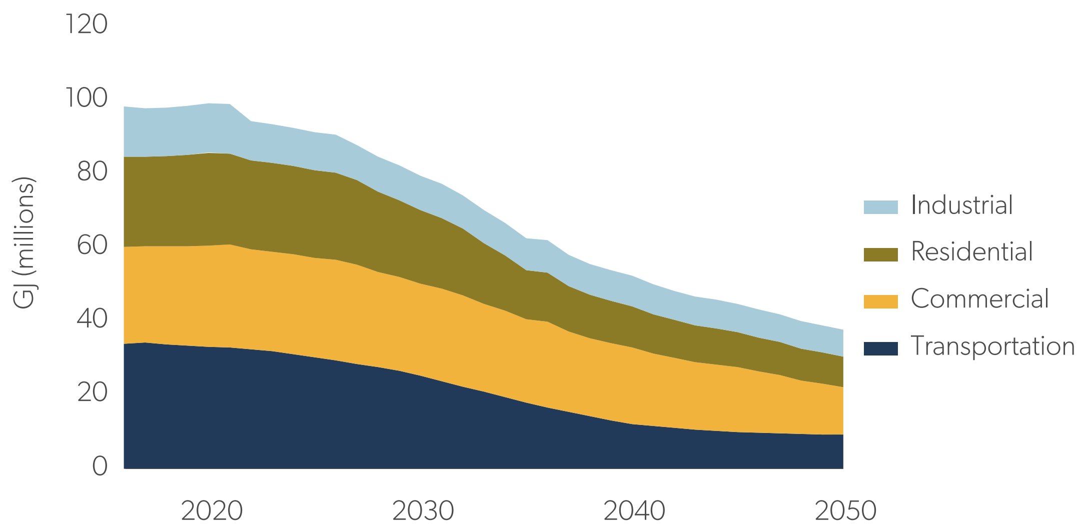

Figure 8. Community energy use, by sector, in a net-zero scenario, 2016–2050.

Table 5. Community greenhouse gas emissions, by sector, in 2016 and 2050 in a business-as-usual scenario, a business-as-planned scenario, and a net-zero scenario.

EMISSIONS BY SECTOR (TCO_2E)	2016	SHARE 2016	2050 BAU	SHARE 2050	2050 BAP	SHARE 2050	2050 NZS	SHARE 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS	% +/- 2050 BAP-2050 NZS
Agriculture	8,619	0%	8,619	0%	8,619	0%	8,619	3%	0%	0%	0%
Commercial	922,964	20%	1,162,128	24%	1,007,505	36%	1,263	0%	-100%	-100%	-100%
Fugitive	44,180	1%	54,478	1%	48,621	2%	0	0%	-100%	-100%	-100%
Industrial	238,573	5%	265,869	5%	248,562	9%	4,820	2%	-98%	-98%	-98%
Residential	748,824	17%	891,550	18%	813,551	29%	708	0%	-100%	-100%	-100%
Transportation	2,285,831	51%	2,145,883	44%	441,481	16%	2,777	1%	-100%	-100%	-99%
Waste	276,035	6%	392,043	8%	263,539	9%	247,901	93%	-10%	-37%	-59%
TOTAL	**4,525,026**	**100%**	**4,920,570**	**100%**	**2,831,877**	**100%**	**266,088**	**100%**	**-94%**	**-95%**	**-91%**

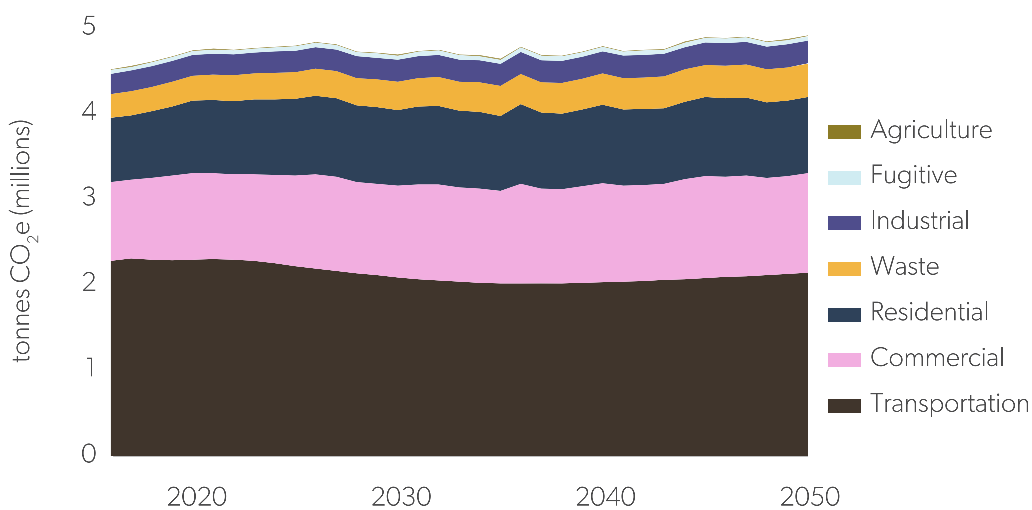

Figure 9. Community greenhouse gas emissions, by sector, in a business-as-usual scenario, 2016–2050.

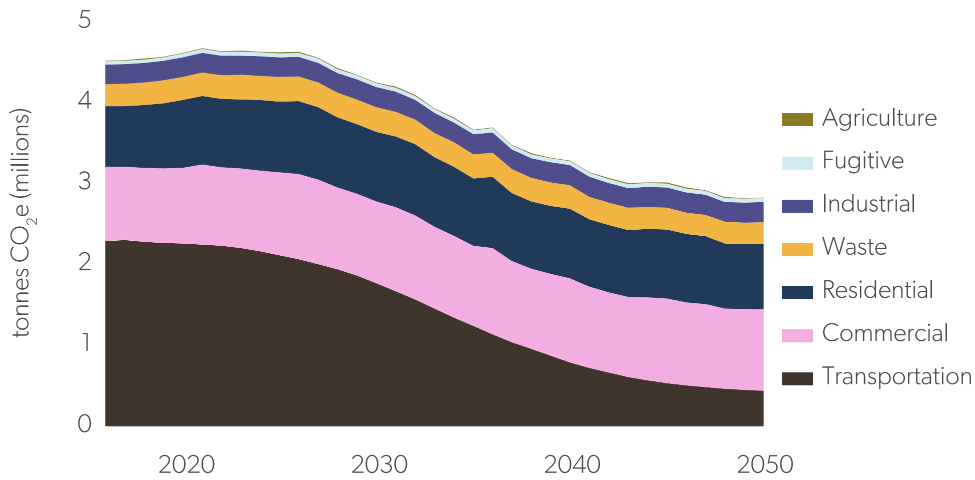

Figure 10. Community greenhouse gas emissions, by sector, in a business-as-planned scenario, 2016–2050.

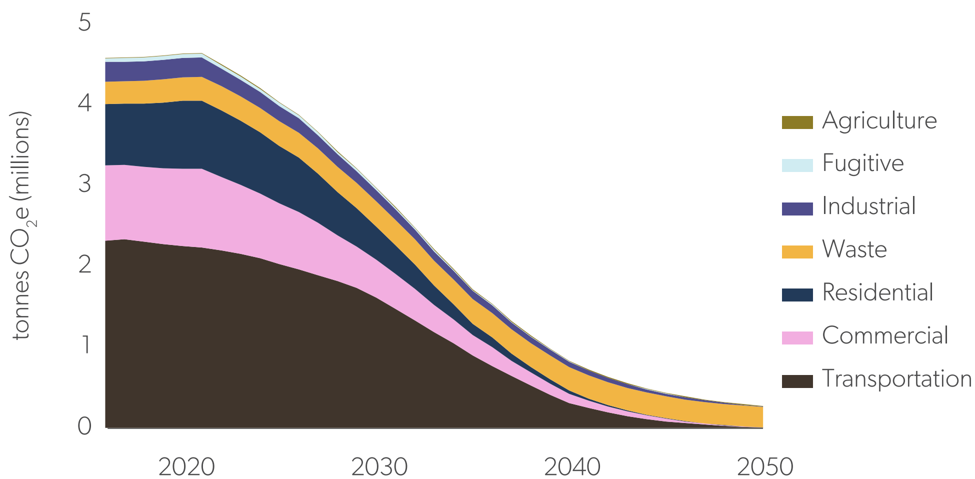

Figure 11. Community greenhouse gas emissions, by sector, in a net-zero scenario, 2016–2050.

Table 6. Community greenhouse gas emissions, by fuel, in 2016 and 2050 in a business-as-usual scenario, a business-as-planned scenario, and a net-zero scenario.

EMISSIONS BY FUEL (TCO_2E)	2016	SHARE 2016	2050 BAU	SHARE 2050	2050 BAP	SHARE 2050	2050 NZS	SHARE 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS	% +/- 2050 BAP-2050 NZS
Coal	14	0%	31	0%	31	0%	18	0%	26%	-99%	-99%
Diesel	550,547	12%	539,859	11%	442,369	16%	662	0%	-100%	-100%	-100%
Gasoline	1,790,769	40%	1,659,868	34%	46,102	2%	1,561	1%	-100%	-100%	-100%
Grid electricity	15,229	0%	4,337	0%	5,241	0%	3,458	1%	-77%	-99%	-99%
Natural gas	1,772,016	39%	2,185,082	44%	1,950,152	69%	0	0%	-100%	-100%	-100%
Non- energy	328,834	7%	455,140	9%	320,779	11%	256,520	96%	-22%	-99%	-99%
Other	2,945	0%	3,459	0%	3,460	0%	2,301	1%	-22%	-99%	-99%
Propane	49,340	1%	60,718	1%	52,497	2%	39	0%	-100%	-100%	-100%
RNG	0	0%	0	0%	0	0%	918	0%	100%	100%	100%
Wood	15,331	0%	12,077	0%	11,247	0%	611	0%	-96%	-100%	-100%
TOTAL	**4,525,026**	**100%**	**4,920,570**	**100%**	**2,831,877**	**100%**	**266,088**	**100%**	**-94%**	**-100%**	**-100%**

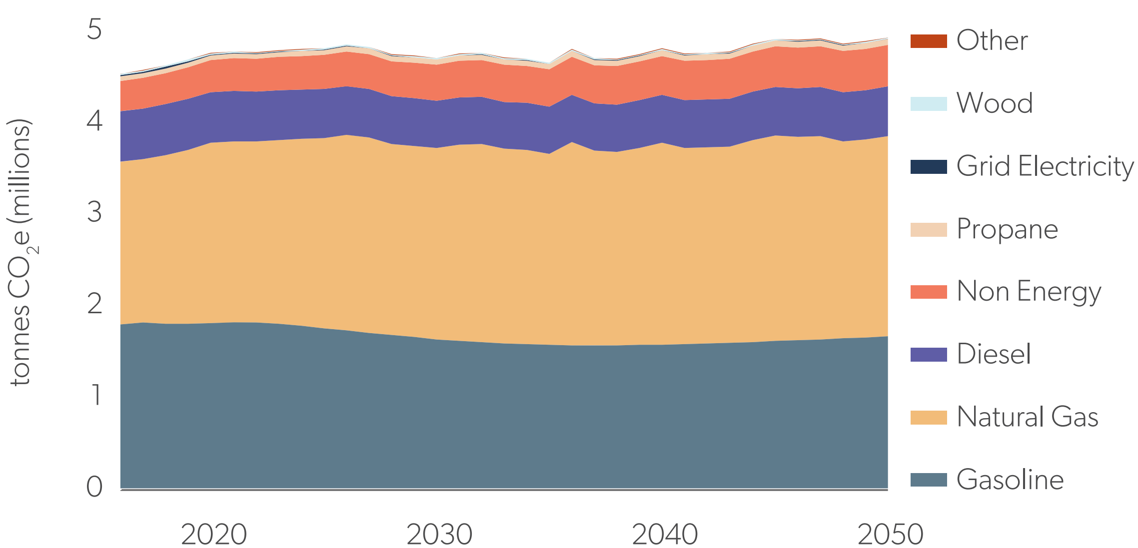

Figure 12. Community greenhouse gas emissions, by fuel, in a business-as-usual scenario, 2016–2050.

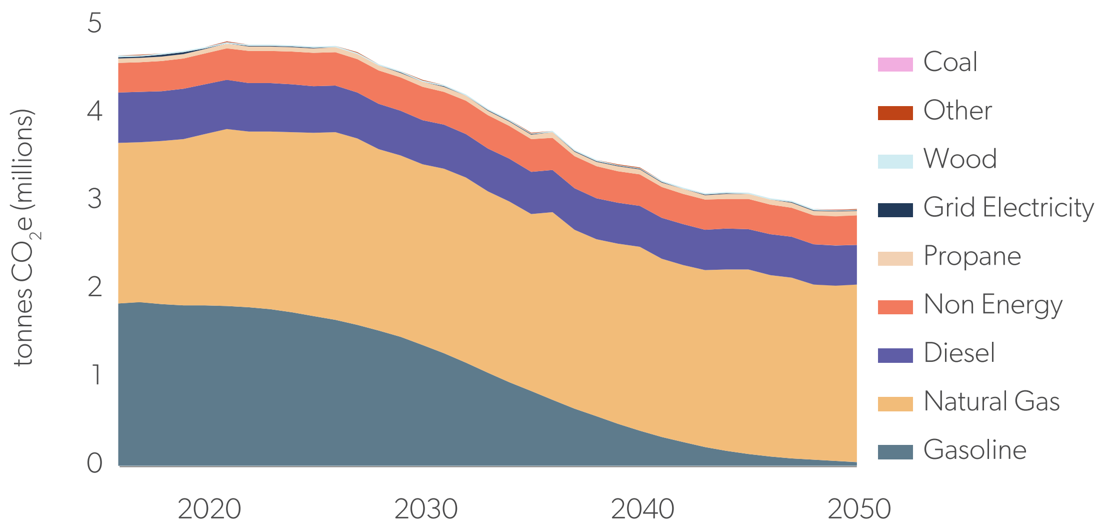

Figure 13. Community greenhouse gas emissions, by fuel, in a business-as-planned scenario, 2016–2050.

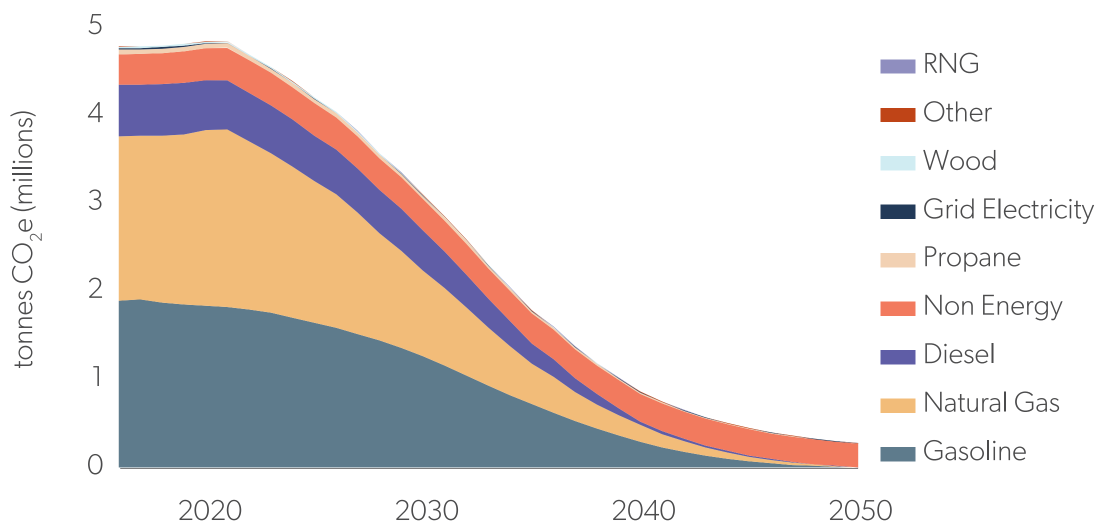

Figure 14. Community greenhouse gas emissions, by fuel, in a net-zero scenario, 2016–2050.

Buildings Energy and Emissions

Table 7. Buildings energy use in 2016 and 2050, by end use, in a business-as-usual scenario, a business-as-planned scenario, and a net-zero scenario.

ENERGY BY END USE (GJ)	2016	SHARE 2016	2050 BAU	SHARE 2050	2050 BAP	SHARE 2050	2050 NZS	SHARE 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS	% +/- 2050 BAP-2050 NZS
Industrial processes	7,780,157	12%	8,802,377	11%	8,804,807	13%	5,929,451	21%	-24%	-99%	-99%
Lighting	4,874,928	8%	6,533,685	8%	5,710,336	8%	2,787,525	10%	-43%	-100%	-100%
Major appliances	2,510,160	4%	3,599,023	5%	3,565,282	5%	1,963,975	7%	-22%	-99%	-99%
Plug load	5,233,036	8%	7,476,694	10%	7,213,977	10%	4,276,962	15%	-18%	-99%	-99%
Space cooling	656,175	1%	972,275	1%	802,374	1%	382,581	1%	-42%	-100%	-100%
Space heating	36,869,363	57%	41,768,930	54%	37,003,510	53%	11,183,375	39%	-70%	-100%	-100%
Water heating	6,519,763	10%	8,548,002	11%	7,001,096	10%	1,928,586	7%	-70%	-100%	-100%
TOTAL	**64,443,581**	**100%**	**77,700,988**	**100%**	**70,101,382**	**100%**	**28,452,454**	**100%**	**-56%**	**-100%**	**-100%**

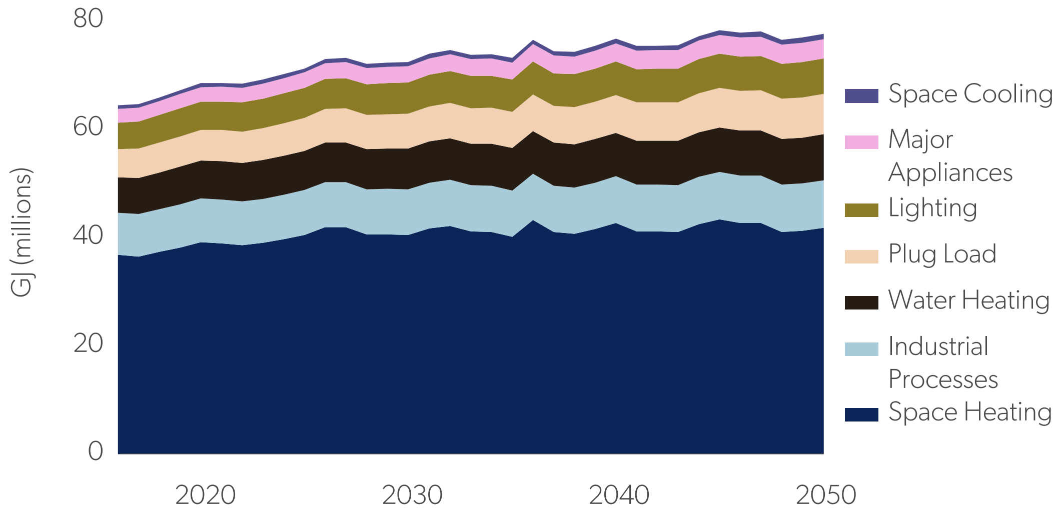

Figure 15. Building energy use, by end use, in a business-as-usual scenario, 2016–2050.

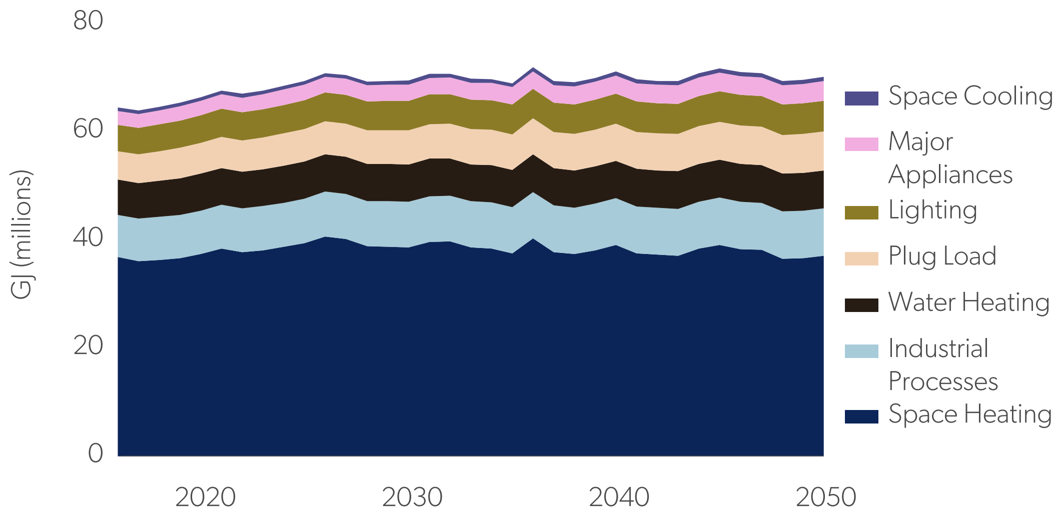

Figure 16. Building energy use, by end use, in a business-as-planned scenario, 2016–2050.

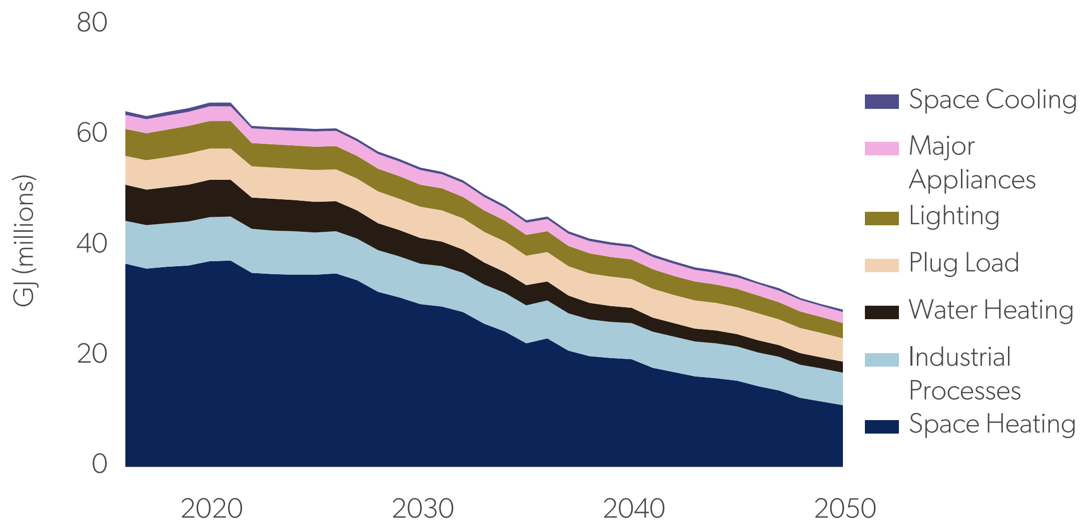

Figure 17. Building energy use, by end use, in a net-zero scenario, 2016–2050.

Table 8. Buildings energy use in 2016 and 2050, by fuel, in a business-as-usual scenario, a business-as-planned scenario, and a net-zero scenario.

ENERGY BY FUEL (GJ)	2016	SHARE 2016	2050 BAU	SHARE 2050	2050 BAP	SHARE 2050	2050 NZS	SHARE 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS	% +/- 2050 BAP-2050 NZS
Coal	27,881	0%	32,744	0%	32,755	0%	21,787	0%	-22%	-99%	-99%
Diesel	779,334	1%	757,420	1%	678,882	1%	7,203	0%	-99%	-100%	-100%
Grid electricity	25,409,151	39%	30,074,215	39%	27,550,606	39%	16,910,621	59%	-33%	-99%	-99%
Local electricity	0	0%	0	0%	0	0%	7,966,833	28%	100%	100%	100%
Natural gas	36,446,761	57%	44,942,536	58%	40,110,580	57%	0	0%	-100%	-100%	-100%
Other	31,262	0%	36,715	0%	36,726	0%	24,429	0%	-22%	-99%	-99%
Propane	806,720	1%	992,746	1%	858,326	1%	643	0%	-100%	-100%	-100%
RNG	0	0%	0	0%	0	0%	3,221,456	11%	100%	100%	100%
Wood	942,474	1%	864,611	1%	833,508	1%	299,482	1%	-68%	-100%	-100%
TOTAL	**64,443,581**	**100%**	**77,700,988**	**100%**	**70,101,382**	**100%**	**28,452,454**	**100%**	**-56%**	**-100%**	**-100%**

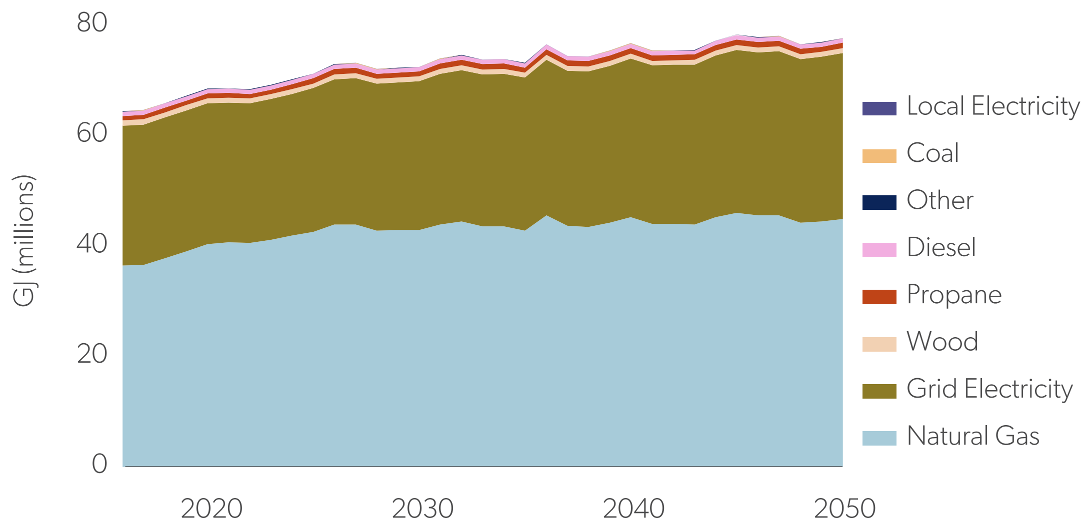

Figure 18. Building energy use, by fuel type, in a business-as-usual scenario, 2016–2050.

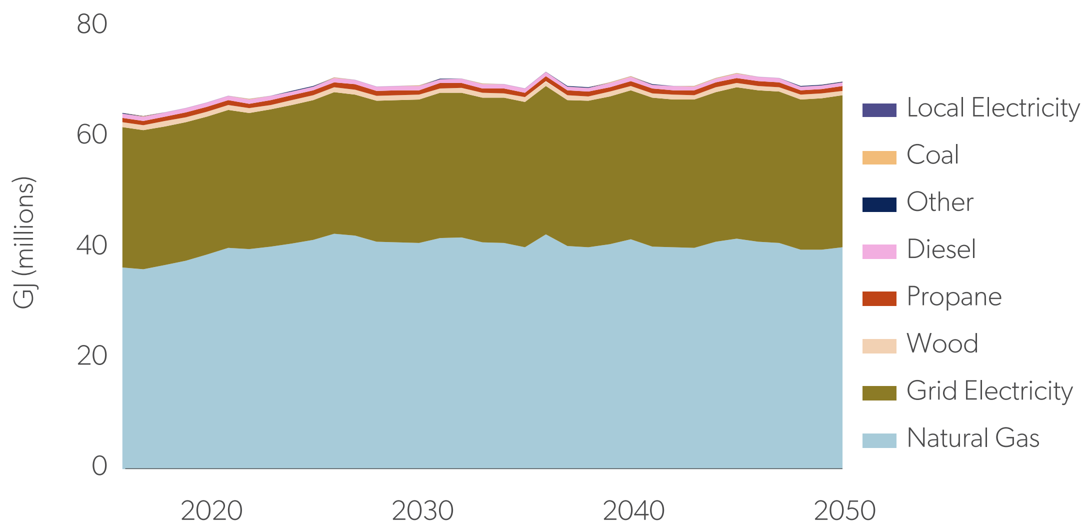

Figure 19. Building energy use, by fuel type, in a business-as-planned scenario, 2016–2050.

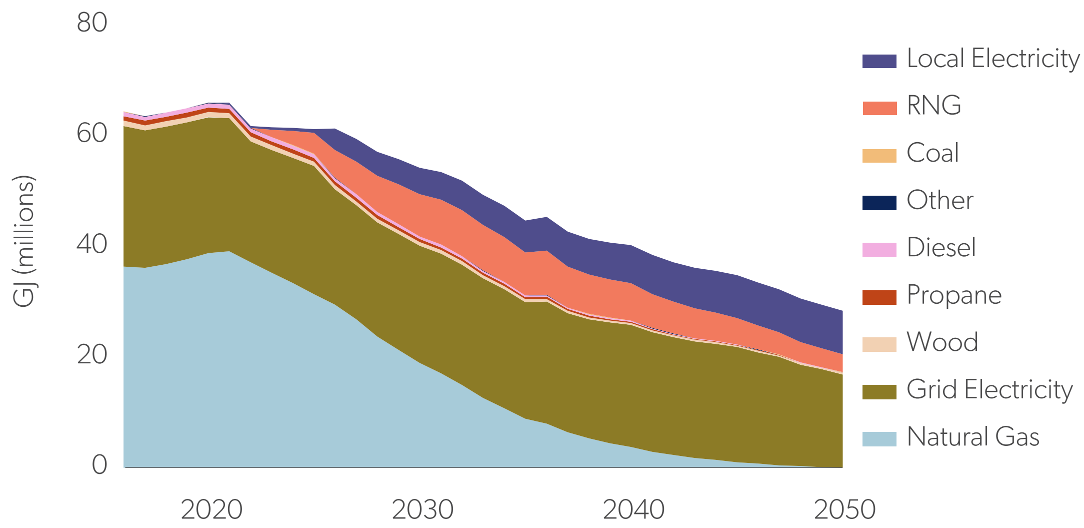

Figure 20. Building energy use, by end use, in a net-zero scenario, 2016–2050.

Table 9. Building greenhouse gas emissions in 2016 and 2050, by end use, in a business-as-usual scenario, a business-as-planned scenario, and a net-zero scenario.

EMISSIONS BY END USE (TCO_2E)	2016	SHARE 2016	2050 BAU	SHARE 2050	2050 BAP	SHARE 2050	2050 NZS	SHARE 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS	% +/- 2050 BAP-2050 NZS
Industrial processes	185,376	10%	208,229	9%	208,297	10%	4,608	68%	-98%	-98%	-98%
Lighting	2,922	0%	924	0%	807	0%	271	4%	-91%	-71%	-66%
Major appliances	11,733	1%	15,314	1%	15,170	1%	198	3%	-98%	-99%	-99%
Plug load	3,136	0%	1,057	0%	1,020	0%	396	6%	-87%	-63%	-61%
Space cooling	5,543	0%	6,010	0%	4,216	0%	43	1%	-99%	-99%	-99%
Space heating	1,479,367	77%	1,792,439	77%	1,590,605	77%	1,065	16%	-100%	-100%	-100%
Water heating	222,285	12%	295,575	13%	249,503	12%	211	3%	-100%	-100%	-100%
TOTAL	**1,910,361**	**100%**	**2,319,547**	**100%**	**2,069,618**	**100%**	**6,791**	**100%**	**-100%**	**-100%**	**-100%**

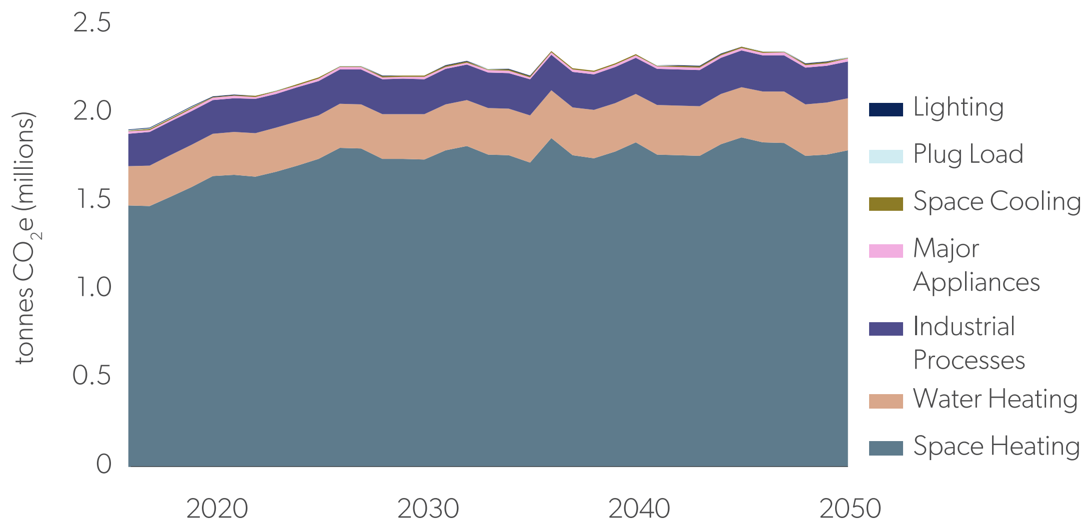

Figure 21. Building greenhouse gas emissions, by end use, in a business-as-usual scenario, 2016–2050.

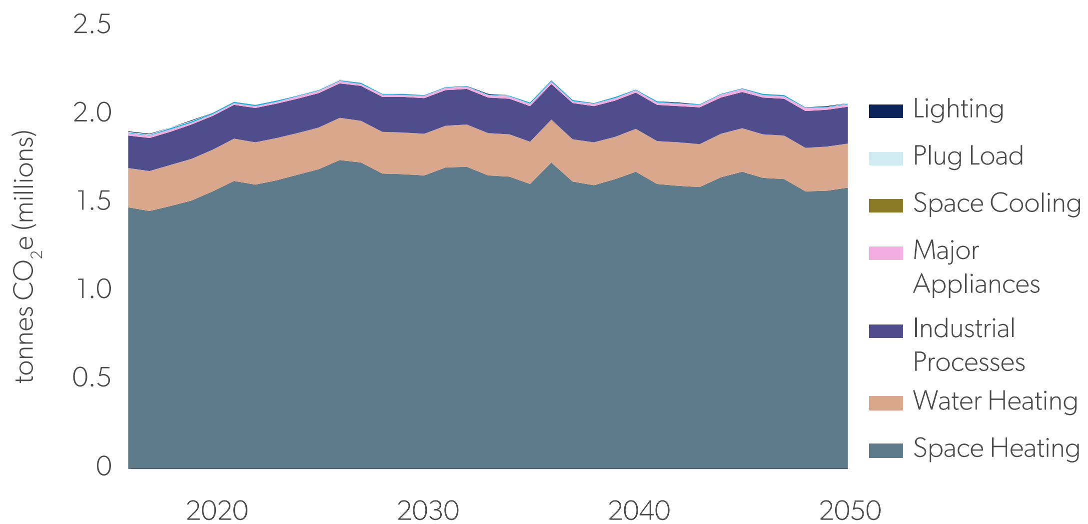

Figure 22. Building greenhouse gas emissions, by end use, in a business-as-planned scenario, 2016–2050.

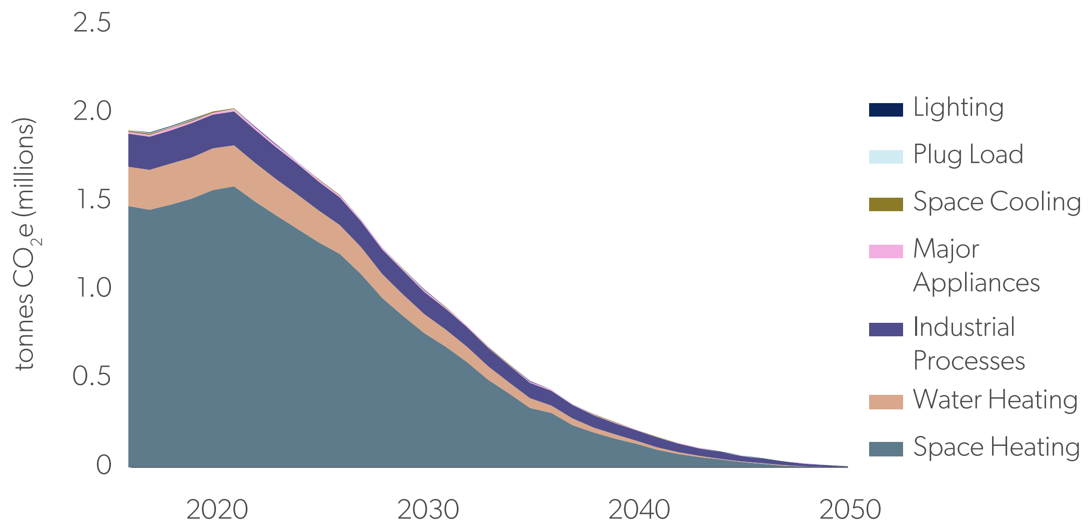

Figure 23. Building greenhouse gas emissions, by end use, in a net-zero scenario, 2016–2050.

Table 10. Building greenhouse gas emissions in 2016 and 2050, by fuel, in a business-as-usual scenario, a business-as-planned scenario, and a net-zero scenario.

EMISSIONS BY FUEL (TCO_2E)	2016	SHARE 2016	2050 BAU	SHARE 2050	2050 BAP	SSHARE 2050	2050 NZS	SHARE 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS	% +/- 2050 BAP-2050 NZS
Coal	14	0%	31	0%	31	0%	18	0%	26%	-42%	-42%
Diesel	55,486	3%	53,929	2%	48,336	2%	513	8%	-99%	-99%	-99%
Grid electricity	15,228	1%	4,251	0%	3,895	0%	2,390	35%	-84%	-44%	-39%
Natural gas	1,772,015	93%	2,185,082	94%	1,950,152	94%	0	0%	-100%	-100%	-100%
Other	2,945	0%	3,459	0%	3,460	0%	2,302	34%	-22%	-33%	-33%
Propane	49,340	3%	60,718	3%	52,497	3%	39	1%	-100%	-100%	-100%
RNG	0	0%	0	0%	0	0%	918	14%	100%	100%	100%
Wood	15,331	1%	12,077	1%	11,247	1%	611	9%	-96%	-95%	-95%
TOTAL	**1,910,361**	**100%**	**2,319,547**	**100%**	**2,069,618**	**100%**	**6,791**	**100%**	**-100%**	**-100%**	**-100%**

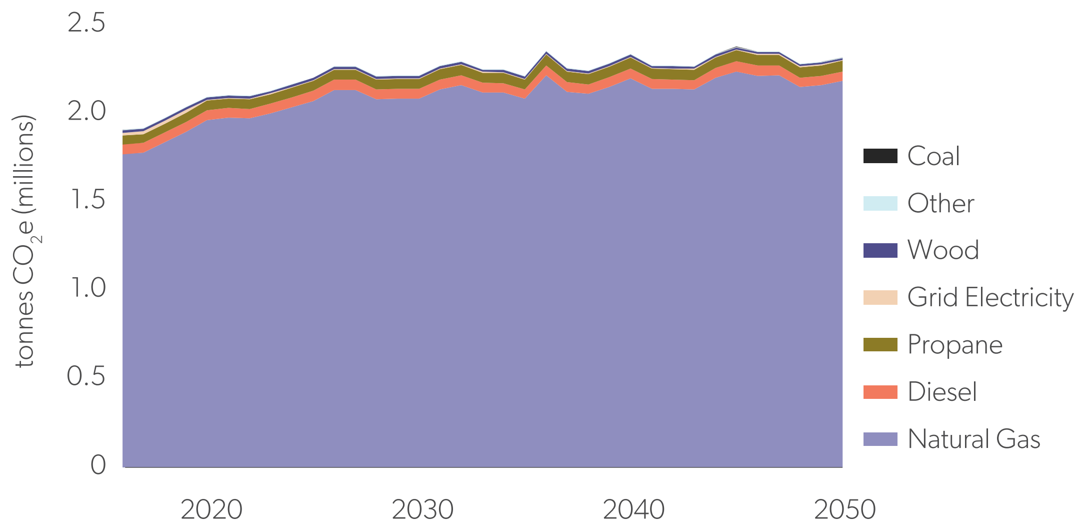

Figure 24. Building greenhouse gas emissions, by fuel, in a business-as-usual scenario, 2016–2050.

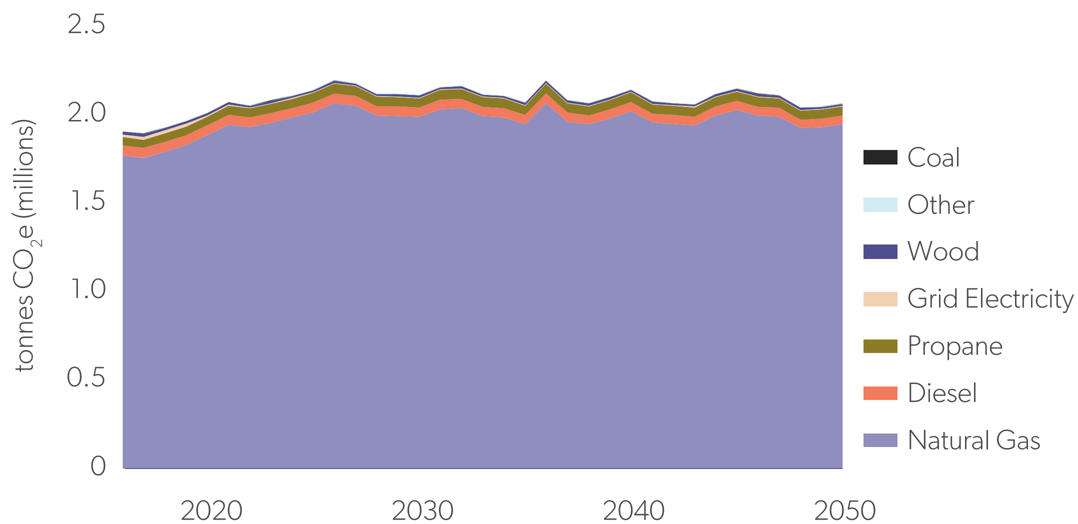

Figure 25. Building greenhouse gas emissions, by fuel, in a business-as-planned scenario, 2016–2050.

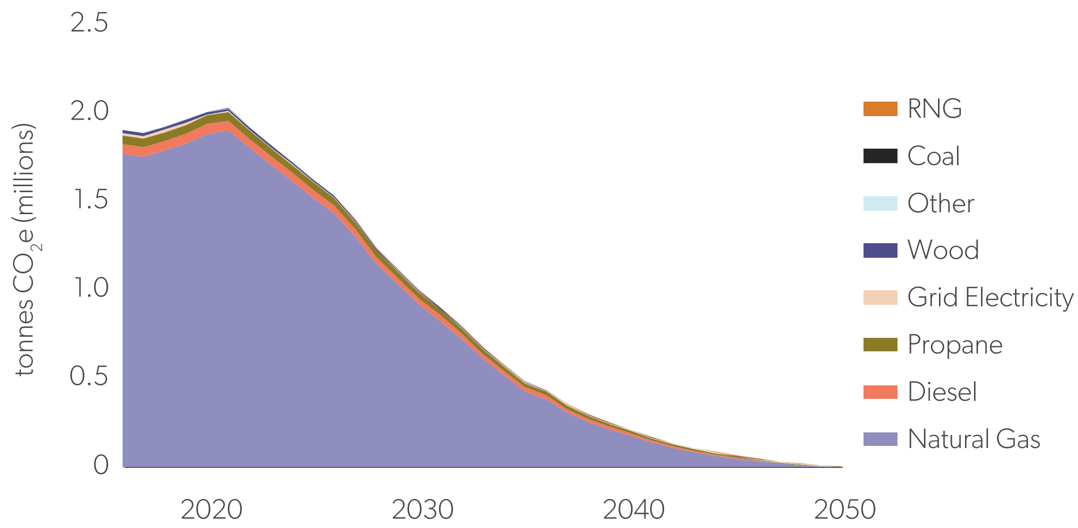

Figure 26. Building greenhouse gas emissions, by fuel, in a net-zero scenario, 2016–2050.

Transportation Energy and Emissions

Table 11. Transportation energy use in 2016 and 2050, by fuel, in a business-as-usual scenario, a business-as-planned scenario, and a net-zero scenario.

ENERGY BY SOURCE (GJ)	2016	SHARE 2016	2050 BAU	SHARE 2050	2050 BAP	SHARE 2050	2050 NZS	SHARE 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS	% +/- 2050 BAP-2050 NZS
Diesel	6,914,841	21%	6,786,654	22%	5,510,329	39%	2,077	0%	-100%	-100%	-100%
Gas	25,429,581	79%	23,461,264	76%	679,677	5%	23,470	0%	-100%	-100%	-97%
Grid electricity	521	0%	604,319	2%	8,095,502	57%	6,121,796	78%	1174858%	913%	-24%
Hydrogen	0	0%	0	0%	0	0%	1,733,633	22%	100%	100%	100%
TOTAL	**32,344,943**	**100%**	**30,852,237**	**100%**	**14,285,508**	**100%**	**7,880,975**	**100%**	**-76%**	**-74%**	**-45%**

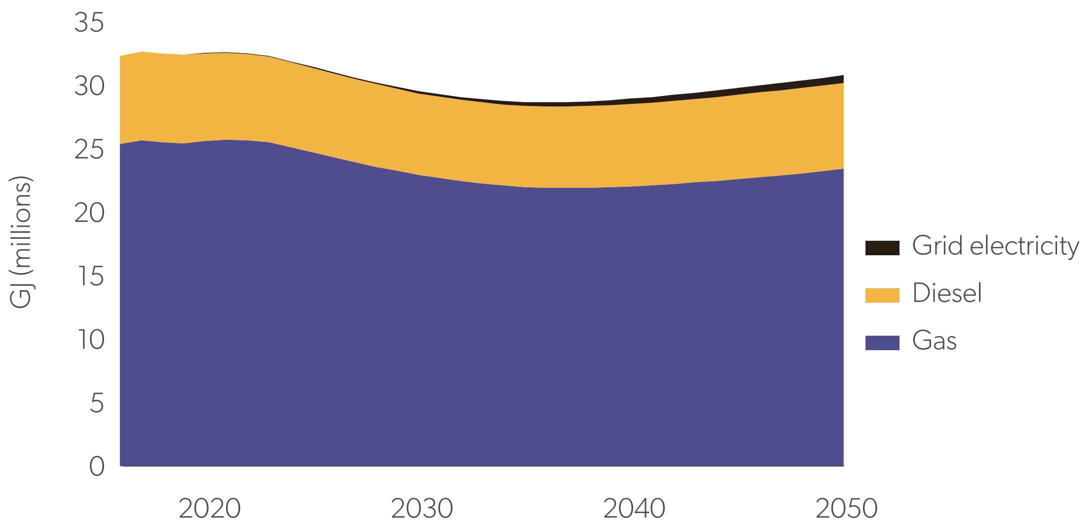

Figure 27. Transportation energy use, by fuel, in a business-as-usual scenario, 2016–2050.

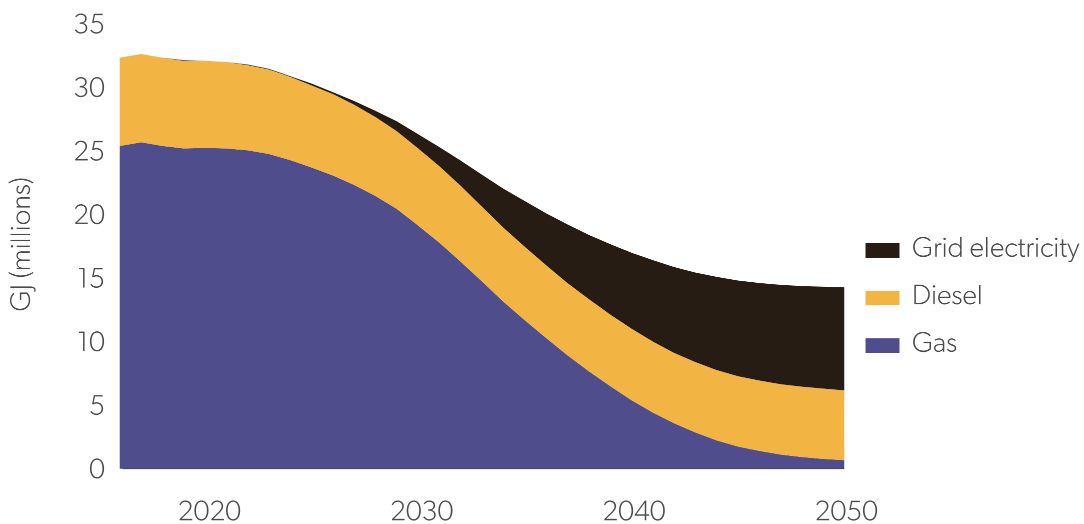

Figure 28. Transportation energy use, by fuel, in a business-as-planned scenario, 2016–2050.

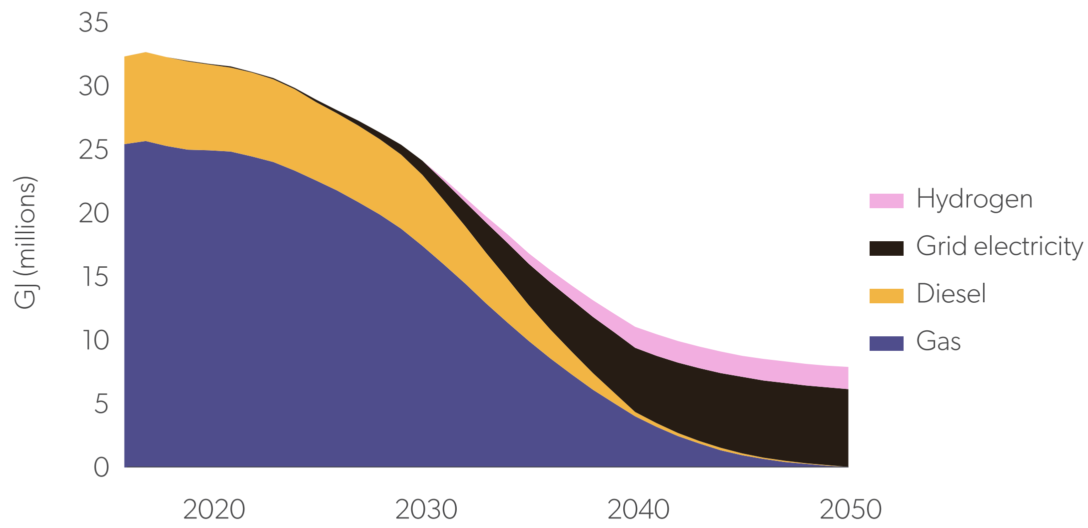

Figure 29. Transportation energy use, by fuel, in a net-zero scenario, 2016–2050.

Table 12. Transportation energy use in 2016 and 2050, by vehicle type, in a business-as-usual scenario, a business-as-planned scenario, and a net-zero scenario.

ENERGY BY VEHICLE(GJ)	2016	SHARE 2016	2050 BAU	SHARE 2050	2050 BAP	SHARE 2050	2050 NZS	SHARE 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS	% +/- 2050 BAP-2050 NZS
Car	11,242,316	35%	7,570,824	25%	2,204,991	15%	1,601,444	20%	-86%	-79%	-27%
Heavy truck	5,728,487	18%	5,518,098	18%	5,517,243	39%	1,747,596	22%	-69%	-68%	-68%
Light truck	14,759,645	46%	17,148,821	56%	5,948,779	42%	4,316,907	55%	-71%	-75%	-27%
Urban bus	614,494	2%	614,494	2%	614,494	4%	215,028	3%	-65%	-65%	-65%
TOTAL	**32,344,943**	**100%**	**30,852,237**	**100%**	**14,285,508**	**100%**	**7,880,975**	**100%**	**-76%**	**-74%**	**-45%**

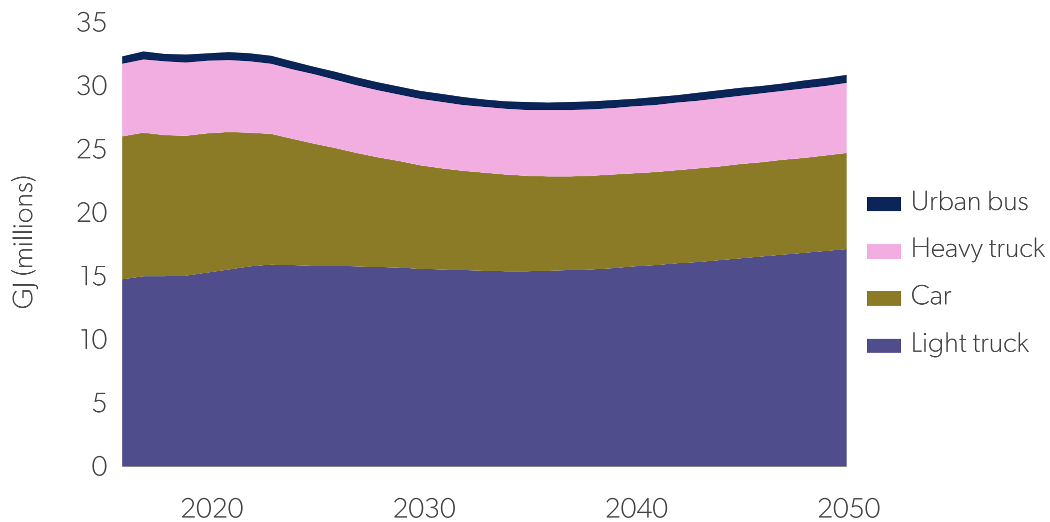

Figure 30. Transportation energy use, by vehicle type, in a business-as-usual scenario, 2016–2050.

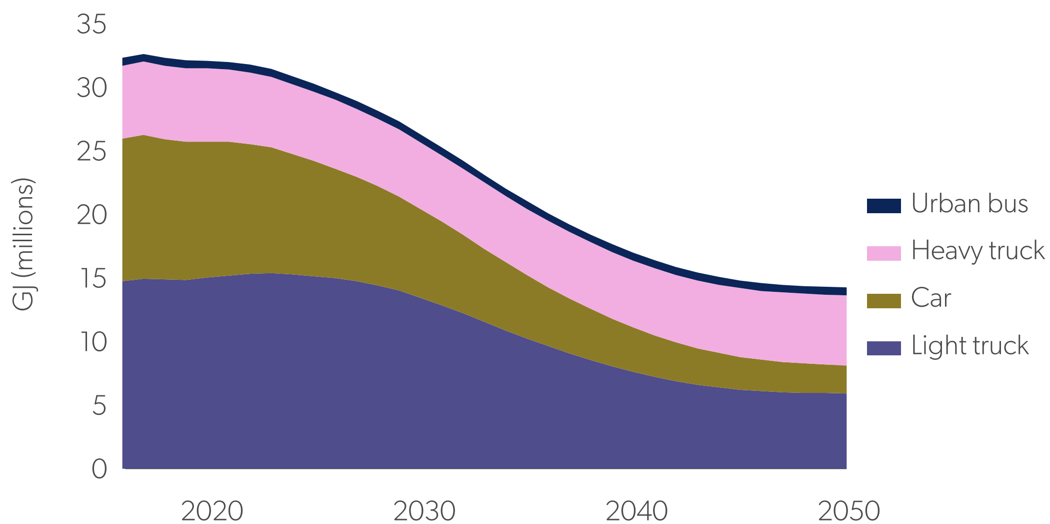

Figure 31. Transportation energy use, by vehicle type, in a business-as-planned scenario, 2016–2050.

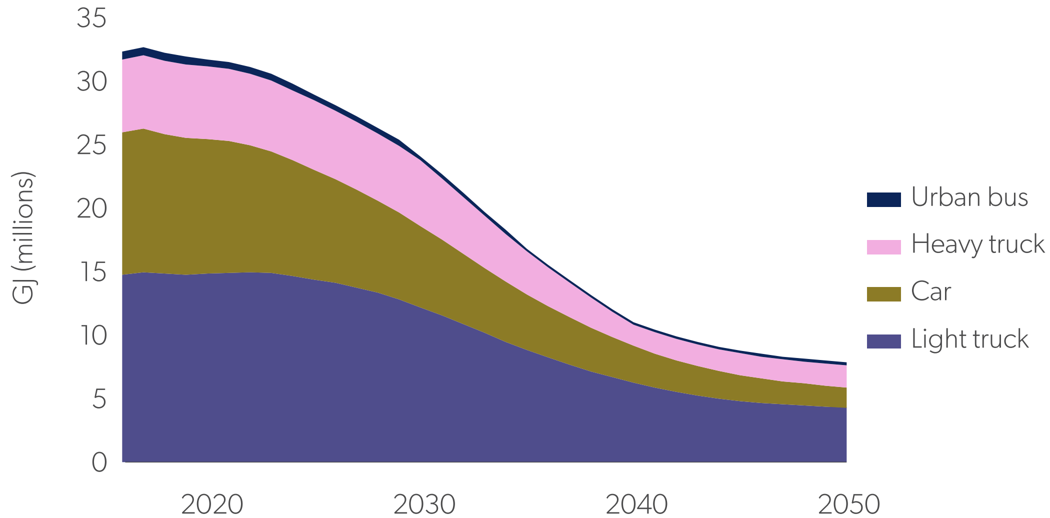

Figure 32. Transportation energy use, by vehicle type, in a net-zero scenario, 2016–2050.

Table 13. Transportation greenhouse gas emissions in 2016 and 2050, by fuel, in a business-as-usual scenario, a business-as-planned scenario, and a net-zero scenario.

EMISSIONS BY SOURCE (TCO_2E)	2016	SHARE 2016	2050 BAU	SHARE 2050	2050 BAP	SHARE 2050	2050 NZS	SHARE 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS	% +/- 2050 BAP-2050 NZS
Diesel	495,061	22%	485,930	23%	394,033	89%	149	5%	-100%	-100%	-100%
Gas	1,790,769	78%	1,659,868	77%	46,102	10%	1,561	56%	-100%	-100%	-97%
Grid electricity	0	0%	85	0%	1,346	0%	1,067	38%	100%	1155%	-21%
TOTAL	**2,285,831**	**100%**	**2,145,883**	**100%**	**441,481**	**100%**	**2,777**	**100%**	**-100%**	**-100%**	**-99%**

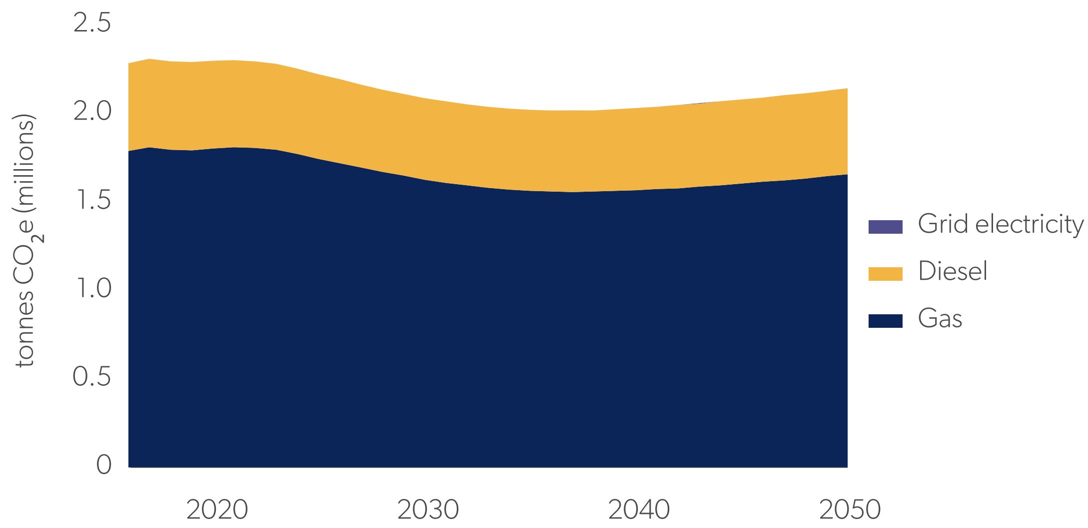

Figure 33. Transportation greenhouse gas emissions, by fuel type, in a business-as-usual scenario, 2016–2050.

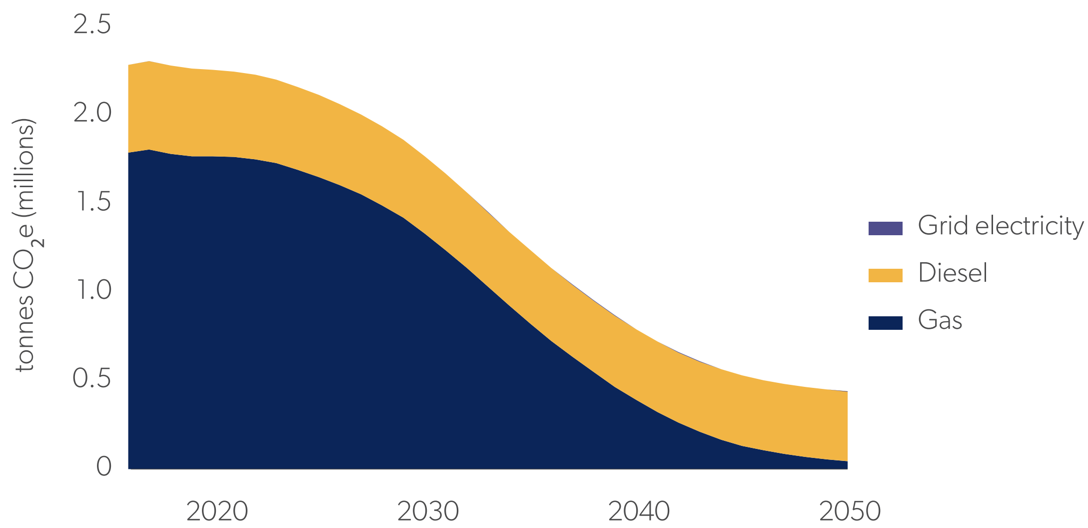

Figure 34. Transportation greenhouse gas emissions, by fuel type, in a business-as-planned scenario, 2016–2050.

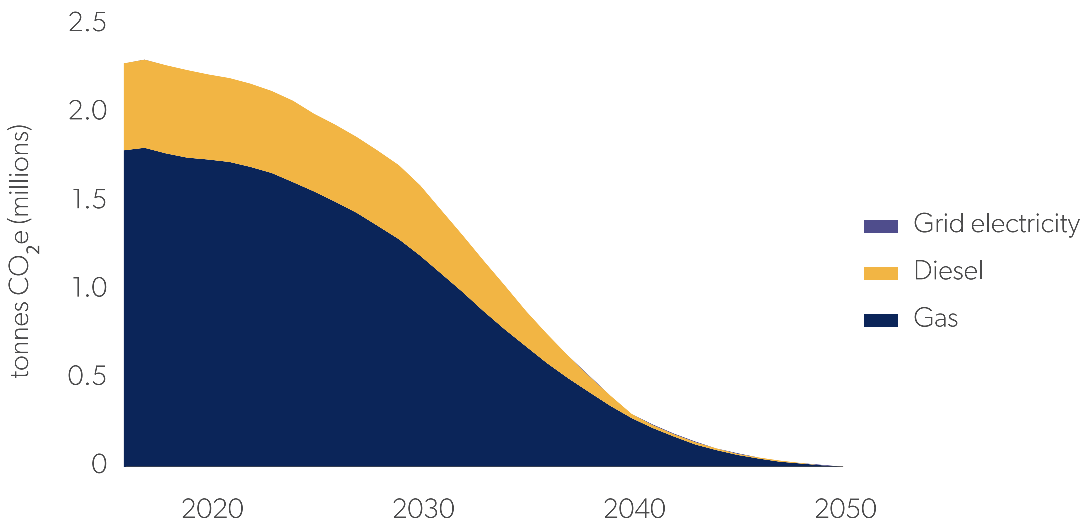

Figure 35. Transportation greenhouse gas emissions, by fuel type, in a net-zero scenario, 2016–2050.

Table 14. Transportation greenhouse gas emissions in 2016 and2050, by vehicle type, in a business-as-usual scenario, a business-as-planned scenario, anda net-zero scenario.

EMISSIONS BY VEHICLE (TCO_2E)	2016	SHARE 2016	2050 BAU	SHARE 2050	2050 BAP	SHARE 2050	2050 NZS	SHARE 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS	% +/- 2050 BAP-2050 NZS
Car	750,480	33%	494,919	23%	1,124	0%	805	29%	-100%	-100%	-28%
Heavy truck	406,883	18%	391,921	18%	392,220	89%	18	1%	-100%	-100%	-100%
Light truck	985,563	43%	1,116,135	52%	3,994	1%	1,626	59%	-100%	-100%	-59%
Off-road	98,910	4%	98,910	5%	202	0%	202	7%	-100%	-100%	0%
Urban bus	43,994	2%	43,998	2%	43,941	10%	126	5%	-100%	-100%	-100%
TOTAL	**2,285,831**	**100%**	**2,145,883**	**100%**	**441,481**	**100%**	**2,777**	**100%**	**-100%**	**-100%**	**-99%**

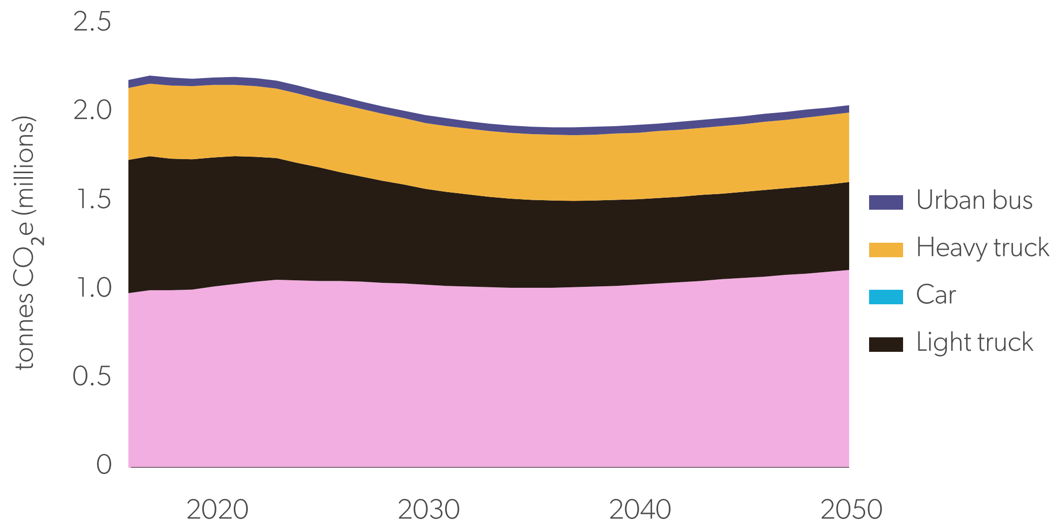

Figure 36. Transportation greenhouse gas emissions, by vehicle type, in a business-as-usual scenario, 2016–2050.

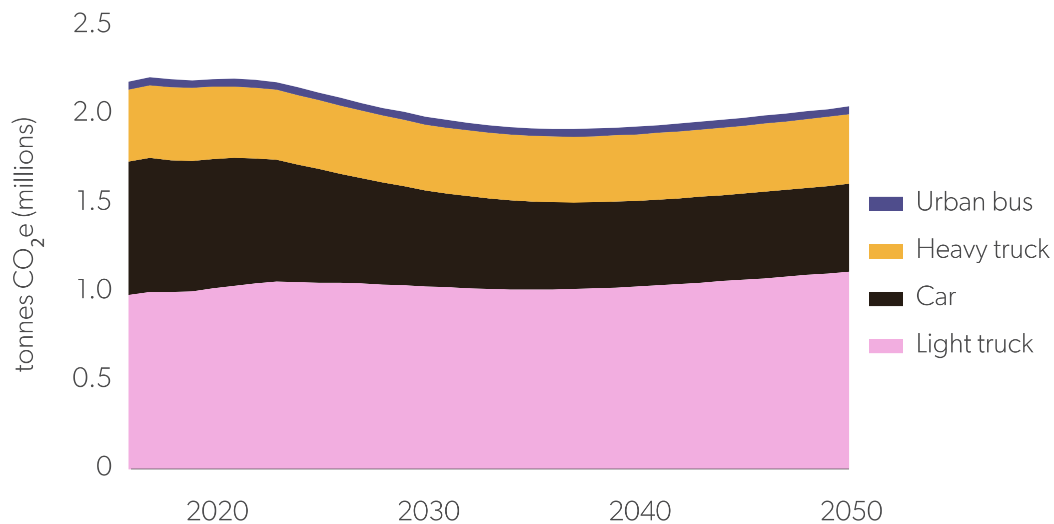

Figure 37. Transportation greenhouse gas emissions, by vehicle type, in a business-as-planned scenario, 2016–2050.

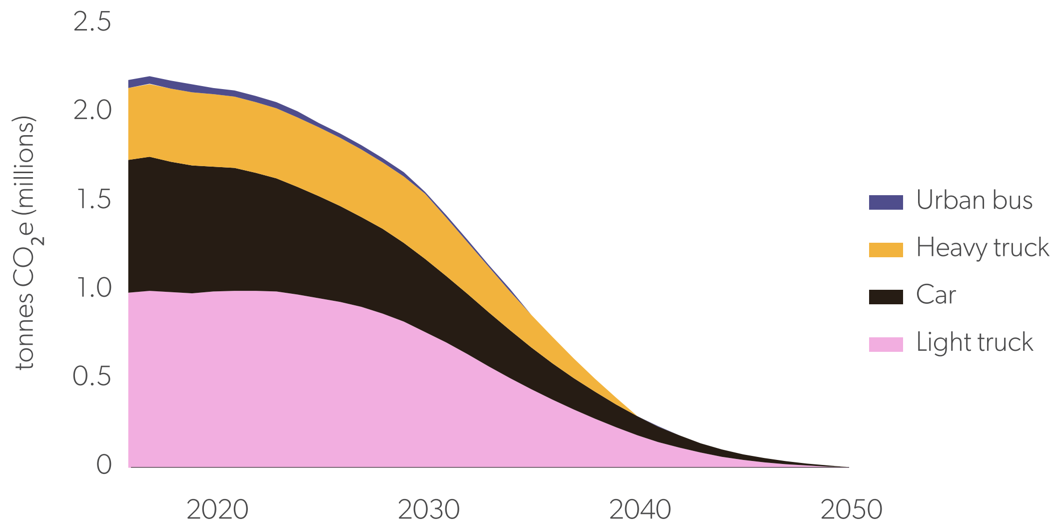

Figure 38. Transportation greenhouse gas emissions, by vehicle type, in a net-zero scenario, 2016–2050.

Waste Emissions

Table 15. Waste greenhouse gas emissions, by waste type, in 2016 and2050 in a business-as-usual scenario and a net-zero scenario.

EMISSIONS BY WASTE TYPE (TCO_2E)	2016	SHARE 2016	2050 BAU	SHARE 2050	2050 BAP	SHARE 2050	2050 NZS	SHARE 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS	% +/- 2050 BAP-2050 NZS
Biological	8,641	3%	11,674	3%	19,943	8%	25,285	10%	193%	117%	27%
Landfill	224,015	81%	327,021	83%	190,248	72%	178,284	72%	-20%	-45%	-6%
Wastewater	43,380	16%	53,348	14%	53,348	20%	44,332	18%	2%	-17%	-17%
TOTAL	**276,035**	**100%**	**392,043**	**100%**	**263,539**	**100%**	**247,901**	**100%**	**-10%**	**-37%**	**-6%**

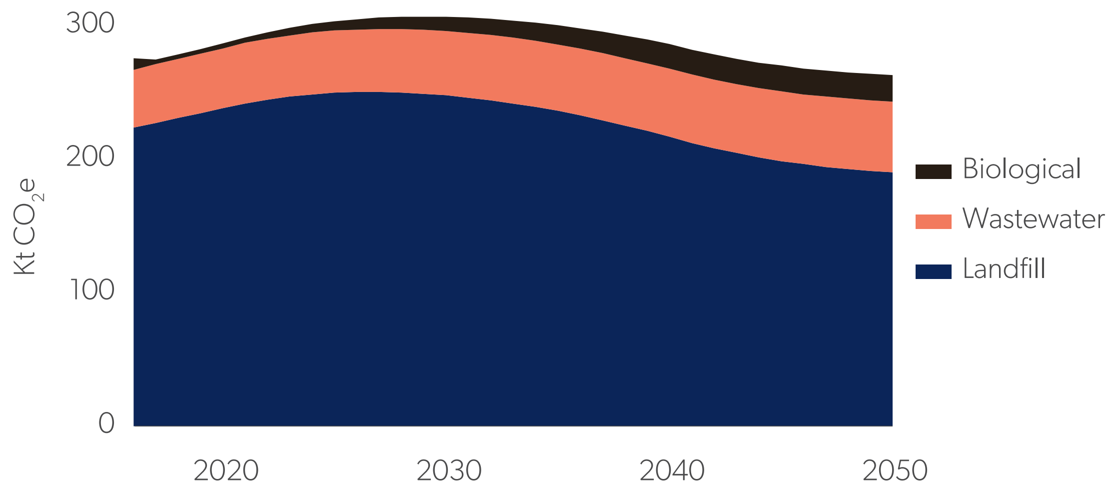

Figure 39. Waste emissions, by waste type, in a business-as-usual scenario, 2016–2050.

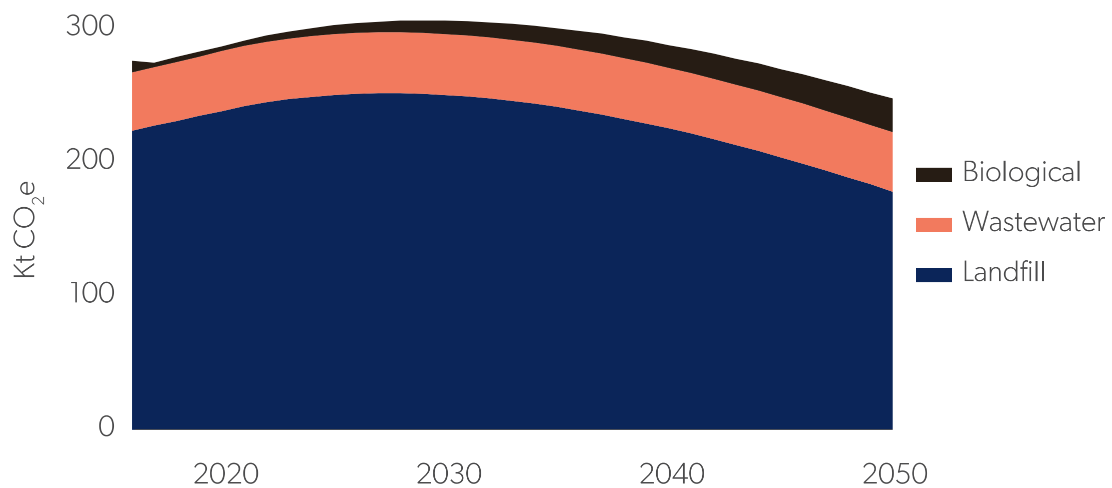

Figure 40. Waste emissions, by waste type, in a net-zero scenario, 2016–2050.

Appendix C: CEIR Implementation Framework

December 2021

Purpose of this Document

The Implementation Framework provides guidance for the near-term implementation of the CEIR. It is not a comprehensive list, but is rather meant to be a quick guide. Many of these actions have the potential for greater efficiency and effectiveness if undertaken in collaboration with other neighbouring municipalities, levels of government, and organizations.

Zero Emissions Buildings

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Program #1: Zero Emissions New Construction					
1.1 Zero emissions building coalition	Ongoing	• CoW • Local industry associations • Sustainable Building Manitoba • Canada Green Building Council • Winnipeg Construction Association • Mechanical Contractors Association • BOMA MB • Assiniboine Credit Union	• CoW staff time	• Identify key partners for working group, and develop a Terms of Reference for the group • Identify opportunities for pilot projects to retrofit private homes, rental units, small businesses, and ICI buildings • Undertake deep retrofits in municipal buildings to stimulate the sector	# of buildings or residential units retrofit average % reduction in GHG emissions from each building retrofit # of jobs created

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
1.2 Sustainable development guideline	Ongoing	• CoW UDI Manitoba • Manitoba Home Builders Association • University of Manitoba • Red River Community College • Sustainable Building Manitoba • PP&D department	• CoW staff time	• Require improved sustainability performance of new development projects, with future tiers requiring enhanced performance • Review development checklists in other cities and jurisdictions (Toronto Green Standard, Whitby Green Development, Vancouver Zero Emissions Building Plan/BC Step Code) • Develop a development checklist, and implement for Winnipeg	number of projects achieving each tier of performance
1.3 Efficient building incentives	Ongoing	• CoW • Sustainable Building Manitoba • Efficiency Manitoba	• CoW staff time	• Explore incentive options currently used in other jurisdictions, including priority permitting, reduced taxation or financial rebates • Develop an attentive program for Winnipeg • Align incentive program with performance tiers in the sustainable development guideline	no additional indicators

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
1.4 Net-zero building code	Ongoing	• CoW Sustainable Building Manitoba • Canada Green Building Council • Winnipeg Construction Association • Efficiency Manitoba • UDI Manitoba • Manitoba Home Builders Association • University of Manitoba • Red River Community College • Other communities with green building codes (Toronto, Whitby, Vancouver)	• CoW staff time	• Develop a strategy for achieving net zero emissions buildings for new construction (possibly in alignment with Task 1.2) Establish a tiered approach to incrementally increase performance targeting net zero emissions by 2030 • Align with the sustainable development checklist and incentives	% of new buildings achieving net zero emissions

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Program #2: Zero Emissions Retrofits					
2.1 Residential retrofit stream	2022: Pilot projects 2024: Full deployment of programs	• CoW • Manitoba Home Builders Association Efficiency Manitoba • Climate Action Team • Winnipeg Construction Association • Neighbourhood Renewal Corporations • Canada Green Building Council • Sun Certified Builders • BUILD Inc. • Assiniboine Credit Union	• CoW staff time • PACE funding led by the City of Winnipeg • Partnerships with local credit units for low-interest loans • Provincial and Federal government • FCM • Canada Mortgage and Housing Corporation	• Develop a program to implement deep retrofits with streams for owned and rented residential and commercial buildings, including financing. • Develop a revolving loan fund for low-interest loans for deep energy retrofits • Pilot a neighbourhood-scale building retrofit to explore economies of scale and opportunities to industrialize retrofits. • Develop a centralized online tool for residents to find information on programs, rebates, and funding available for them, as well as lists of certified contractors and equipment providers. • Pilot neighbourhood-level district energy systems for larger, ground-source heat pumps	# of buildings/homes retrofit GHG intensity of retrofitted buildings
2.2 Low-Income retrofit stream	Immediate	• CoW Efficiency Manitoba • Climate Action Team • Winnipeg anti-poverty NGOs • BUILD Inc. • SEED Winnipeg	• CoW staff time • funding from City, Province, and Federal governments for pilot projects, as recommended by the working group	• Identify key partners for working group, and develop a Terms of Reference for the group • Develop a deep retrofit program focused on households experiencing energy poverty	# of low income households retrofit

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
2.3 Large buildings stream	2022: Pilot projects 2024: Full deployment of programs	• CoW • Efficiency Manitoba • Local industry associations • Canada Green Building Council	• CoW staff time • PACE funding led by the City of Winnipeg • Partnerships with local credit units for low-interest loans • Provincial and Federal government • FCM	• Develop a revolving loan fund for low-interest loans for deep energy retrofits • Develop a green lease program, including templates to address the split incentive challenge • Retrofit municipal buildings to net-zero standards to demonstrate leadership	m^2 of retrofitted floorspace GHG intensity of retrofitted buildings
2.4 Carbon co-operative	2022: Pilot projects 2024: Full deployment of programs	• CoW • Efficiency Manitoba • Local industry associations • Social enterprises • Carbon Co-op (based in the UK)	• CoW staff time	• Issue a request for proposals for an organization to establish a retrofit co-operative. • Provide a grant with start-up funding for the establishment of the retrofit co-operative.	establishment of a Carbon Co-operative # of homes included in programs

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
2.5 Neighbourhood retrofit pilot	2022: Pilot projects 2024: Full deployment of programs	• CoW • Manitoba Home Builders Association Efficiency Manitoba • Climate Action Team • Winnipeg Construction Association • Neighbourhood Renewal Corporations • Canada Green Building Council • BUILD Inc.	• CoW staff time • PACE funding led by the City of Winnipeg • Partnerships with local credit units for low-interest loans • Provincial and Federal government • FCM	• Develop a PACE/ LIC programme to fund a neighbourhood retrofit • Develop a revolving loan fund for low-interest loans for deep energy retrofits • Issue a request for proposals for a neighbourhood-scale building retrofit to explore economies of scale and opportunities to industrialize retrofits • Pilot neighbourhood-level district energy systems for larger, ground-source heat pumps	# of buildings/homes retrofit GHG intensity of retrofitted buildings
2.6 Embodied carbon and refrigerants	Ongoing	• CoW • Other jurisdictions with similar programs, such as the City of Vancouver	• CoW staff time	• Require new buildings to calculate and report the life-cycle equivalent annual carbon dioxide emissions of each building, in $kgCO2e/m^2$, from the emission of refrigerants. • Require new buildings to report the life-cycle equivalent carbon dioxide emissions (i.e. global warming potential impact, or 'embodied carbon') of each building, in $kgCO2e/m^2$, as calculated by a whole-building life-cycle assessment (LCA)	average embodied GHG emissions per m^2 for new buildings

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
2.7 Workforce Development Program	Ongoing	• CoW • BUILD • University of Manitoba, University of Winnipeg • Red River College • Winnipeg Construction Association • Sustainable Buildings Manitoba	• CoW staff time	• Identify key partners for working group, and develop a Terms of Reference for the group • Create and implement a workforce development strategy	# of participants in a program developed through this working group

Zero-Emissions Transportation

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Program #3: The Built Environment					
3.1 Urban planning and land use policies to encourage densification	2022- onward	• CoW	• CoW	• Implement policies that support garden suites, laneway homes and multi-unit homes in residential neighbourhoods	% of new dwelling units in a greenfield location
3.2 Super Blocks + 15-Minute City	2023-onwards	• CoW	• CoW	• Identify and implement a pilot super block in the city • Plan for 15-minute walking sheds including mixed-use, infrastructure, parks and food	% of residents that have access to a full suite of destinations within a 15 minute walk.
3.3 Neighbourhood climate action plans	2022-onward	• CoW • Neighbourhood associations	• CoW	• Develop a climate action plan for each new or revised secondary plan • Ensure the secondary plan is aligned with the City's GHG targets.	# of secondary plans with a climate action plan

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
3.4 Parking strategy	2023- onward	• CoW	• CoW	• Implement $0 parking fees for zero emissions vehicles until 2026 • Remove parking minimums in new construction • Partner with the utilities and other companies to install EV charging stations for on-street and off-street parking	# of ZEVs in Winnipeg

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Program #4: Active Transportation					
4.1 Walking and cycling infrastructure	2022-onwards	• CoW • Winnipeg Trails Association • Green Action Centre • Bike Winnipeg	• CoW staff time • CoW • FCM	• Expand the trail network to allow more trips to be made by separated bike lanes • Develop training on safe cycling for all ages • Organize cycling and walking promotional weeks, including incentives for participation across the city	# km of physically separated bike lanes added mode share for walking and cycling
4.2 Clean air zone	2024	• CoW • Winnipeg Regional Health Authority	• CoW staff time • funding from FCM	• Establish an independent commission to evaluate opportunities for a clean air zone • Evaluate options for either closing off an area or street to vehicles and/or introducing a charge for polluting vehicles.	air pollution indicators

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
4.3 Behaviour change program	2022-onwards	• CoW	• CoW staff time	• Evaluate program including Edmonton's Change for Climate, Smart Commute in the GTA and others • Design and implement a communications and engagement program	# of people engaged
4.4 Flexible work locations	2022-onwards	• Winnipeg Central Business Association • Green Action Centre • local businesses	• CoW staff time	• Adopt zoning and land-use planning policies to support live-work designations • Work with local businesses to develop co-working spaces to allow working closer to home, reducing the need for longer commutes	vehicular commuting mode share

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Program #5: Enhanced Transit					
5.1 Enhanced transit	2022-onwards	• CoW, specifically the transit department	• CoW	• Follow recommendations in the Transit Master Plan to increase transit use, and continue the adoption of zero-emissions buses	transit mode share
5.2 Zero emissions transit	2022-onwards	• CoW, specifically the transit department	• CoW	• Accelerate Winnipeg Transit zero emission bus transition • Expand this program to identify other opportunities for zero-emissions vehicles	# of zero-emissions buses

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Program #6: A Clean Fleet					
6.1 EV charging infrastructure	2022-2025	• CoW • Business Improvement Zones	• Zero Emissions Vehicle Infrastructure Program (ZEVIP) • Investing in Canada Infrastructure Program (ICIP)	• Assess current EV charging infrastructure and identify priority gaps in the system	# publicly accessible EV charging stations # EV charging stations/ km^2 in dense urban areas
6.2 Zero-emissions transportation education program	Ongoing	• CoW • local car dealerships • Manitoba Hydro	• CoW staff time • dealerships for EV trials	• Develop education programs to encourage and incentivise zero-emissions travel, and to address common questions or concerns about EVs	# of residents participating in programs % of new sales that are EVs
6.3 Fleet transformation coalition		• CoW Transit department • Local industry associations • Local car dealerships • Local car and truck mechanics • Economic Development Winnipeg	• CoW staff time	• Identify major fleets in the City • Convene a fleet decarbonisation working group	# of businesses setting fleet decarbonization targets # zero-carbon fleet vehicles in use

Clean Energy for Everyone

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Program #7: A Renewable Energy Economy					
7.1 Renewable energy action group	2022	• Renewable energy businesses • Economic Development Winnipeg	• CoW	• Convene a renewable energy action group with a mandate to identify barriers to renewable energy in the City boundary and strategies to address those barriers.	renewable energy action strategy completed
7.2 Rooftop solar PV	2022: Pilot projects 2024: Full deployment of programs	• CoW • Manitoba Hydro • Community members • Assiniboine Credit Union	• CoW • FCM	• Initiate a community energy mapping exercise to identify suitable locations and opportunities/barriers to implementation. • Pilot a municipal low-interest loan to fund solar installations	kW of generating capacity installed
7.3 Parking lot solar PV	2022: Pilot projects 2024: Full deployment of programs	• CoW • Manitoba Hydro • Local businesses and property owners	• CoW • FCM	• Pilot project for installing solar PV on a parking lot, reporting back with challenges and successes	kW of generating capacity installed
7.4 Household and neighbourhood energy storage	2022: Pilot projects 2024: Full deployment of programs	• CoW • Manitoba Hydro	• CoW • Manitoba Hydro	• Pilot projects for vehicle to grid charging and household energy storage	kw of storage installed
7.5 Community solar garden	2022: Pilot projects 2024: Full deployment of programs	• Renewable energy firms • Community members • Assiniboine Credit Union • Manitoba Hydro	• CoW staff time • Credit Unions	• Issue an Expression of Interest for developers of a solar garden on municipally-owned land	kW of generating capacity installed

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
7.6 Renewable energy cooperatives	2024	• Manitoba Cooperative Association • Cooperatives First • Assiniboine Credit Union	• CoW • Cooperative development fund	• Identify opportunities for solar installations on city-owned facilities • Provide funding for the creation of renewable energy cooperatives	Renewable energy cooperative created # of members in the renewable energy cooperatives
7.7 Zero emissions district energy	2024	• CoW	• CoW • Canada Infrastructure Bank	• Complete a district energy assessment of zero emissions heating systems (geothermal, waste heat from sewer, solar with seasonal storage)	Zero emissions district energy system developed
7.8 Renewable natural gas (RNG)	Ongoing	• CoW	• CoW	• Maximize the capture of biogas in the wastewater treatment system	GJ of RNG generated

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Program #8: Clean Industry					
8.1 Industrial Efficiency Action Team	2022	• CoW • Province of Manitoba • Manitoba Hydro • Manitoba Environmental Industries Association • Economic Development Winnipeg • Canmet Labs (NRCan)		• Convene a low carbon industry working group • Identify opportunities for pilot projects to improve the efficiency of industrial operations	% reduction in GHGs from industrial processes

Waste Management

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Program #9: Zero waste					
9.1 A Circular Economy Strategy	Ongoing	• CoW • Economic Development Winnipeg • Province of Manitoba	• CoW	• Develop and deliver educational programming about waste reduction, and waste sorting • Develop a working group to identify opportunities with local businesses and community members to expand the availability of repair and reselling of goods	# tonnes of waste per capita % waste to landfill
9.2 Landfill GHG Action Group	Ongoing	• CoW • Private landfill operators • Province of Manitoba	• CoW staff time	• Identify key partners for working group, and develop a Terms of Reference for the group • Identify a strategy to maximize landfill gas capture on all landfills as soon as possible	Average % CH4 leakage from landfills
9.3 Zero emissions water and wastewater	Ongoing	• CoW	• CoW	• Identify specific sources of GHG emissions in CoW water and wastewater treatment systems Develop an implementation plan to address emissions sources, including fuel switching, process changes, and industrial efficiencies	GHG emissions by gas from water and wastewater treatment

A Whole City Approach

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Program #10: Carbon management					
10.1 Develop an annual carbon budget	2022-onwards	• CoW	• CoW staff time	• Develop a community-wide carbon budget for the City of Winnipeg, and allocate it by department • Provide staff training on the use and purpose of a carbon budget • Report annually using the Task Force on Climate-Related Financial Disclosure (TCFD) framework	annual carbon budget
10.2 Apply a climate lens for expenditures and policies	2022-onwards	• CoW	• CoW staff time	• Develop a climate lens policy for council approval • Integrate the climate lens into the climate budget process • Provide staff training on the adoption of a climate lens	# of projects evaluated using a climate lens
10.3 Addressing the emissions gap	2026	• CoW	• CoW staff time	• Update the low carbon pathway for the City every five years	low carbon pathway updated

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Program #11: Zero emissions operations					
11.1 Annual GHG and energy reporting	Ongoing	• CoW	• CoW	• Create a climate action dashboard for the carbon budget, inventories and other indicators	annual GHG emissions inventory annual TCFD report published
11.2 An expanded Office of Sustainability	Immediate	• CoW	• CoW staff time	• Develop a management and staffing plan to support immediate implementation of the CEIR next steps	# of staff dedicated to climate action
11.3 A zero-emissions fleet	2022	• CoW	• CoW	• Adopt a policy on zero emissions vehicle procurement	# of zero-emissions vehicles in municipal fleet % of fleet that is zero-emissions
11.4 Zero-emissions buildings	2022-ongoing	• CoW	• CoW staff time • CoW	• Complete an asset-level GHG inventory for CoW assets • Develop a portfolio approach to building-level decarbonization for all existing municipal buildings • Integrate a renewable energy strategy into the portfolio analysis	GHG emissions from municipal buildings

	TIMING	PARTNERS	RESOURCES	NEXT STEPS	REPORTING METRICS
Program #12: Communications					
12.1 Community Climate Advisory Committee	Ongoing	• CoW Others as identified through development of committee	• CoW staff time	• Identify key partners for the Advisory Committee, and develop a Terms of Reference for the group • Develop a workplan for the Advisory Committee	Annual report to Council prepared
12.2 Story-telling	Ongoing	• CoW	• CoW staff time • Communications consultancy	• Develop a communications strategy for the CEIR and climate action in Winnipeg	Climate literacy survey

Appendix D: GPC tables

This table provides the 2016 base year emissions data, categorized according to the Global Protocol for Community-scale Greenhouse Gas Emission Inventories.[1] Using this categorization to update the municipal inventory periodically ensures consistency across inventory years and comparability between global municipal jurisdictions.

Reason for exclusion key

N/A Not applicable; Not included in scope

ID Insufficient data

NR No relevant or limited activities identified

Other Reason provided under Comments

GPC REF NO.	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
I		STATIONARY ENERGY SOURCES						
I.1		Residential buildings						
I.1.1	1	Emissions from fuel combustion within the city boundary	Yes		724,087	14,172	5,179	743,437
I.1.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes		4,744	8	74	4,827
I.1.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes		551	1	9	560
I.2		Commercial and institutional buildings/facilities						
I.2.1	1	Emissions from fuel combustion within the city boundary	Yes		911,899	585	5,661	918,145
I.2.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes		4,273	8	67	4,347

[1] The GPC can be found here: https://ghgprotocol.org/sites/default/files/standards/GHGP_GPC_0.pdf

GPC REF NO.	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
I.2.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes		496	1	8	505
I.3		Manufacturing industry and construction						
I.3.1	1	Emissions from fuel combustion within the city boundary	Yes		231,711	222	1,617	233,551
I.3.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes		4,393	8	69	4,470
I.3.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes		510	1	8	519
I.4		Energy industries						
I.4.1	1	Emissions from energy used in power plant auxiliary operations within the city boundary	No	NR	0	0	0	0
I.4.2	2	Emissions from grid-supplied energy consumed in power plant auxiliary operations within the city boundary	No	NR	0	0	0	0
I.4.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption in power plant auxiliary operations	No	NR	0	0	0	0
I.4.4	1	Emissions from energy generation supplied to the grid	No	NR	0	0	0	0
I.5		Agriculture, forestry and fishing activities						
I.5.1	1	Emissions from fuel combustion within the city boundary	No	NR	0	0	0	0

GPC REF NO.	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
I.5.2	2	Emissions from grid-supplied energy consumed within the city boundary	No	NR	0	0	0	0
I.5.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	No	NR	0	0	0	0
I.6		Non-specified sources						
I.6.1	1	Emissions from fuel combustion within the city boundary	No	NR	0	0	0	0
I.6.2	2	Emissions from grid-supplied energy consumed within the city boundary	No	NR	0	0	0	0
I.6.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	No	NR	0	0	0	0
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	0	0	0	0
I.8		Fugitive emissions from oil and natural gas systems						
I.8.1	1	Emissions from fugitive emissions within the city boundary	Yes		48	44,132	0	44,180
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		1,810,013	3,309	13,339	1,826,661
II.1.2	2	Emissions from grid-supplied energy consumed within the city boundary for on-road transportation	Yes		0	0	0	0

GPC REF NO.	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
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		358,362	728	1,169	360,259
II.2		Railways						
II.2.1	1	Emissions from fuel combustion for railway transportation occurring within the city boundary	No	NR	0	0	0	0
II.2.2	2	Emissions from grid-supplied energy consumed within the city boundary for railways	No	NR	0	0	0	0
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	0	0	0	0
II.3		Water-borne navigation						
II.3.1	1	Emissions from fuel combustion for waterborne navigation occurring within the city boundary	No	N/A	0	0	0	0
II.3.2	2	Emissions from grid-supplied energy consumed within the city boundary for waterborne navigation	No	N/A	0	0	0	0

GPC REF NO.	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
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	0	0	0	0
II.4		Aviation						
II.4.1	1	Emissions from fuel combustion for aviation occurring within the city boundary	No	N/A	0	0	0	0
II.4.2	2	Emissions from grid-supplied energy consumed within the city boundary for aviation	No	N/A	0	0	0	0
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	0	0	0	0
II.5		Off-road						
II.5.1	1	Emissions from fuel combustion for off-road transportation occurring within the city boundary	No	NR	94,554	3,748	608	98,910
II.5.2	2	Emissions from grid-supplied energy consumed within the city boundary for off-road transportation	No	NR	0	0	0	0

GPC REF NO.	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
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		0	224,015	0	224,015
III.1.2	3	Emissions from solid waste generated within the city boundary but disposed in landfills or open dumps outside the city boundary	Yes		0	0	0	0
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	0	0	0	0
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		0	5,214	3,427	8,641
III.2.2	3	Emissions from solid waste generated within the city boundary but treated biologically outside of the city boundary	No	N/A	0	0	0	0
III.2.3	1	Emissions from waste generated outside the city boundary but treated biologically within the city boundary	No	N/A	0	0	0	0
III.3		Incineration and open burning						
III.3.1	1	Emissions from solid waste generated and treated within the city boundary	No	N/A	0	0	0	0

GPC REF NO.	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
III.3.2	3	Emissions from solid waste generated within the city boundary but treated outside of the city boundary	No	N/A	0	0	0	0
III.3.3	1	Emissions from waste generated outside the city boundary but treated within the city boundary	No	N/A	0	0	0	0
III.4		Wastewater treatment and discharge						
III.4.1	1	Emissions from wastewater generated and treated within the city boundary	Yes		0	38,536	4,844	43,380
III.4.2	3	Emissions from wastewater generated within the city boundary but treated outside of the city boundary	No	NR	0	0	0	0
III.4.3	1	Emissions from wastewater generated outside the city boundary	No	N/A	0	0	0	0
IV		INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)						
IV.1	1	Emissions from industrial processes occurring within the city boundary	No	ID	0	0	0	0
IV.2	1	Emissions from product use occurring within the city boundary	No	ID	0	0	0	0
V		AGRICULTURE, FORESTRY AND LAND USE (AFOLU)						
V.1	1	Emissions from livestock within the city boundary	No	NR	0	8,437	182	8,619
V.2	1	Emissions from land within the city boundary	No	NR	0	0	0	0

GPC REF NO.	SCOPE	GHG EMISSIONS SOURCE	INCLUSION	REASON FOR EXCLUSION	CO_2	CH_4	N_2O	TOTAL CO_2E
V.3	1	Emissions from aggregate sources and non-CO2 emission sources on land within the city boundary	No	NR	0	0	0	0
VI		OTHER SCOPE 3						
VI.1	3	Other Scope 3	No	N/A	0	0	0	0