Seizing the opportunity:

The Clean Energy Economy in Durham

PART 2:
THE TECHNICAL PAPER

DURHAM
COMMUNITY
ENERGY
PLAN

SSG SUSTAINABILITY SOLUTIONS GROUP
whatIf?

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Key Energy and Emissions Units

GHG emissions

1 ktCO2e = 1,000 tCO2e

Energy

1 MJ = 0.001 GJ

1 TJ = 1,000 GJ

1 PJ = 1,000,000 GJ

1 GJ = 278 kWh

1 MWh = 1,000 kWh

1 GWh = 1,000,000 kWh

Time Period

A number of charts cover the period of 2016 to 2050. Where actions are involved, the time period considered is 2018 to 2050 to ensure that actions do not begin prior to the current year. In other cases, where five-year increments are used, 2011 and 2051 are also presented.

Introduction

This document is the technical summary of the Durham Community Energy Plan (DCEP).

1. Modelling Approach

The relationship between land-use planning, the form of the built environment, transportation systems, energy consumption and GHG emissions is complex and varies from one municipality to the next. While there are common themes and specific actions that likely make sense in every context, in order to relate potential outcomes of actions to targets and policies – and to understand the financial implications – a model is generally required.

Our analysis applies CityInSight, a bottom-up, stock rollover model that projects energy demand as result of representing the evolution of energy-consuming activities in a city and the energy supply to address the demand.

CityInSight estimates the changes in investments, fuel expenses and other operating expenses of low-carbon pathways relative to a reference or business-as-planned scenario. CityInSight combines changes in investments, fuel costs and operating expenses to estimate the annual net cost of a pathway.

CityInSight does not model the effects of price on supply and demand; it is not a partial or general equilibrium economic model, nor is it an optimization model. It is not designed to project macroeconomic impacts or to determine which clean energy pathway is “best” in terms of the narrow criterion of cost-effectiveness. However, CityInSight illustrates the costs and benefits of different pathways with estimates of changes in investment, operating and energy expenditures.

CityInSight incorporates the accounting framework of the Global Protocol for City-Scale GHG Emissions Inventories.

Table 1. Characteristics of CityInSight model

CHARACTERISTIC	DESCRIPTION
Integrated	Designed to account for and to model all sectors that relate to energy and emissions at a city scale while describing the relationships between sectors.
Stocks and flows	For any given year various factors shape this picture of energy and emissions flows, including: the population and the energy services it requires; commercial floorspace; 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 makes an explicit mathematical relationship between these factors – some contextual and some part of the energy consuming or producing infrastructure – and the energy flow picture. Some factors are modelled as stocks – counts of similar things, classified by various properties. For example, population is modelled as a stock of people classified by age and gender. Population change over time is projected by accounting for: the natural aging process, inflows (births, immigration) and outflows (deaths, emigration). The fleet of personal use vehicles, an example of a service technology, is modelled as a stock of vehicles classified by size, engine type and model year with a similarly classified fuel consumption intensity. As with population, projecting change in the vehicle stock involves aging vehicles and accounting for major inflows (new vehicle sales) and major outflows (vehicle discards). This stock-turnover approach is applied to other service technologies (e.g. furnaces, water heaters) and also harvesting technologies (e.g. electricity generating capacity).

CHARACTERISTIC	DESCRIPTION
Scenario-based	Once calibrated, CityInSight enables the creation of scenarios to explore different possible futures. Each scenario can consist of either one or a combination of policies, actions and strategies.
Spatial	The configuration of the built environment determines the ability of people to walk and cycle, accessibility to transit, feasibility of district energy and other aspects. CityInSight therefore includes a full spatial dimension that can include as many zones as are deemed appropriate. The spatial component to the model can be integrated with City GIS systems, land-use projections and transportation modelling.
Accounting framework	CityInSight is designed according to the accounting framework of the GHG Protocol for Cities, the international standard for emissions inventories for cities.
Economic impacts	The model 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. The model generates marginal abatement curves to illustrate the costs and/or savings of policies, strategies and actions. CityInSight also accounts for the impact of policies, strategies and actions on household incomes and public and business expenditures.

In order to explore energy futures for the Region of Durham, scenarios were developed and then modelled using the CityInSight model. The modelling process involved five steps:

1. The development of a baseline for the year 2016, which is calibrated against observed data from the utilities and other sources;
2. The development of a BAU scenario;
3. The modelling of actions;
4. The creation of low carbon scenarios which integrate the actions; and
5. The comparison of the Region's pathway with its GHG targets.

Low carbon scenario development

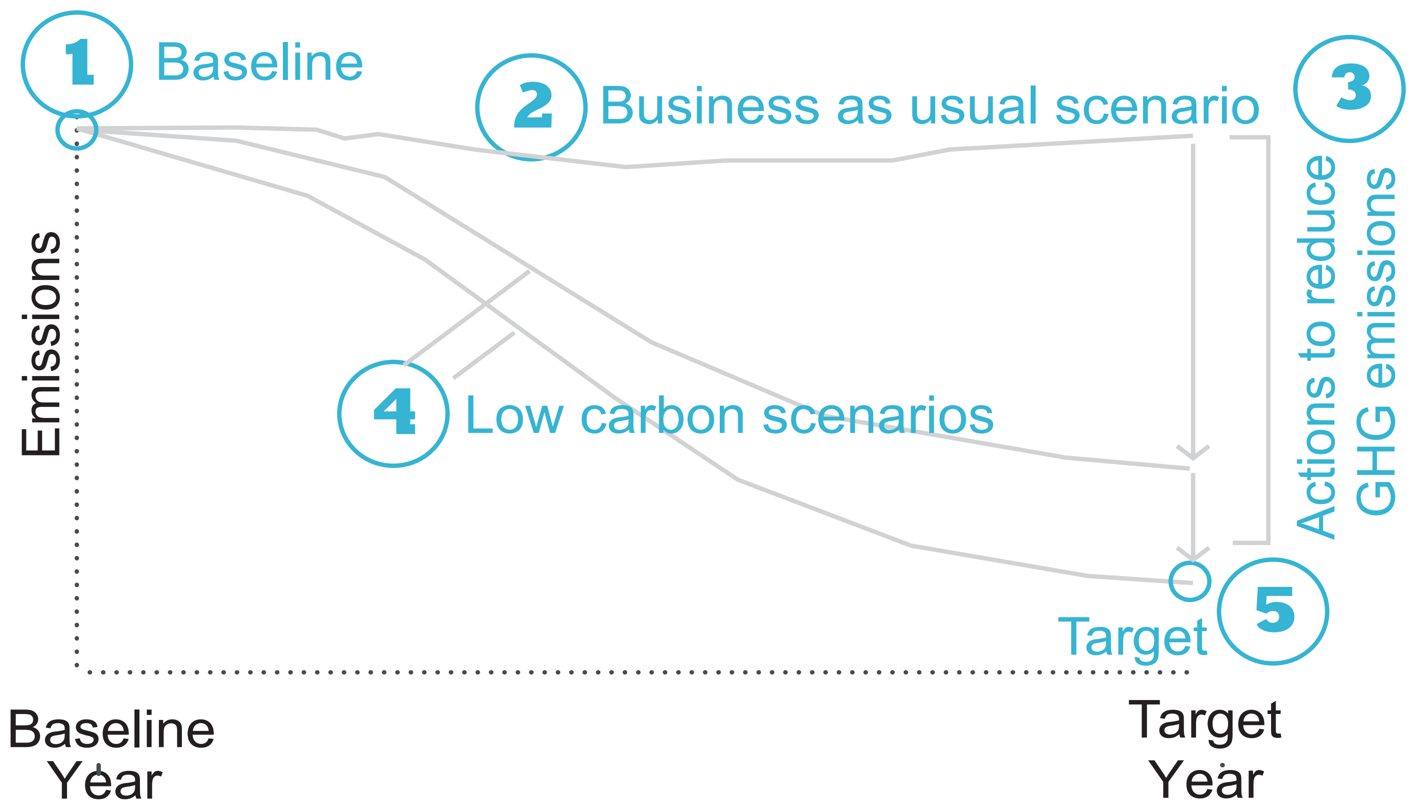

Figure 1. The development of low carbon scenarios, represented visually

The Baseline Year – GHG and Energy Inventory

The year 2016 is used as the baseline year within the model. The modelling approach requires the calibration of a base year system state (initial conditions) using as much observed data as possible in order to develop an internally consistent snapshot of the Region. The census is a key source of data and at the time of modelling, the last census year for which data was available was 2016. Additionally, the Transportation Tomorrow Survey and the long-range transportation modelling conducted by the Region were available for that year.

Identifying Actions

The first part of the actions development process involved extensive research of low carbon actions and best practices to reduce emissions at the municipal level, including consideration of the Pickering-Ajax-Whitby Integrated Regional Resource Plan (2016). The initial list was reviewed by the Steering Committee, and a filtering process was undertaken to identify actions that were explicitly not relevant or applicable to the context of the Region, or that the Region was already undertaking. This initial list of actions was completed prior to the modelling of the baseline and BAU. The process was therefore agnostic as to whether the implementation of the action would have a significant impact on emissions reduction in the Region or not.

2. The Scenarios

Following the development of the actions, five scenarios were identified, defined using a quadrant approach. The horizontal axis of the quadrant represents at one end ongoing deployment of existing technologies and at the other end, ambitious adoption of low carbon options. The vertical axis describes different forms of land-use patterns, from greenfield development on one side to intensification on the other. The first scenario, or the reference scenario, is an extrapolation of current patterns out until 2050. The subsequent four scenarios are defined by the four quadrants.

Following the definition of the scenarios, modelling assumptions and parameters were developed for each action to reflect the current energy and low carbon dimensions. The low carbon actions were informed by literature and what other cities are undertaking. A separate modelling exercise was undertaken to identify the current development and urban intensification parameters.

The Low Carbon Actions

Actions were identified in the sectors that influence energy and GHG emissions, including buildings, energy and transport sectors. Actions addressed the themes of enhanced energy performance in new construction, retrofits of existing buildings, additional renewable energy both on buildings and on a larger scale, electrification of vehicles, and enhanced mode shifting to walking, cycling and transit.

Table 2. Summary of assumptions in the three actions

		BAU	BAP	LCP
New buildings – buildings codes & standards				
1	New residential dwellings	Extrapolation of 2016 patterns, unless noted	Apply projected increases in OBC (15% improvement every five years)	Incrementally increase the number of net zero new homes to 100% by 2030
2	New commercial, institutional and industrial buildings			Incrementally increase the number of buildings that achieve Passive-house levels of performance to 100% by 2030
Existing buildings – retrofitting				
3	Retrofit homes built prior to 1980		211 homes in 2019 climbing to 400 by 2030, then held constant: average savings per house 1,500 kWh per year (electricity only)	By 2050, 98% of pre-1980 dwellings retrofit starting in 2019, with retrofits achieving thermal and electrical savings of 50%
4	Retrofit homes built after 1980 but before 2017		Increase slightly over background retrofit levels	By 2050, 98% of dwellings built between 1980 and 2017 retrofit, with retrofits achieving average thermal and electrical savings of 40%; savings will be greater for older buildings than newer buildings
5	Retrofits of commercial and industrial buildings		No change	By 2050, 98% of pre-2017 buildings with retrofits achieving average thermal and electrical savings of 40%; savings will be greater for older buildings than newer buildings

		BAU	BAP	LCP
Renewable energy generation (on-site, building scale)				
6	Installation of heat pumps		Baseline share of heat pumps for heating is continued for new construction	Air source heat pumps are added to 40% of residential buildings and 30% of commercial buildings by 2050. Ground source heat pumps are added to 20% of residential and 25% of commercial buildings by 2050.
7	Solar PV – net metering		By 2050, 10% of all buildings have solar PV systems which provide on average 30% of consumption for building electrical load for less than 5 storeys; 10% for multi-unit and commercial buildings	By 2050, 80% of all buildings have solar PV systems which provide on average 30% of consumption for building electrical load for less than 5 storeys; 10% for multi-unit buildings greater than 5 storeys and commercial buildings
8	Solar hot water		By 2050, scale up to 20% of all residential buildings, and 10% of commercial buildings by 2050; addresses 50% of hot water load	Scale up to 80% of residential buildings by 2050, and 50% of commercial buildings by 2050. Addresses 50% of hot water load
Low or zero carbon energy generation (commercial scale)				
9	Solar PV – ground mount commercial scale		0.5 MW per year between 2018 and 2050	5 MW per year between 2018 and 2050

		BAU	BAP	LCP
10	District energy	District energy in Ajax (biomass); UOIT (natural gas CHP): Lakeridge Health cogen system	Same as BAU	Existing district energy is carbon neutral; new systems are added in locations with sufficient heat density as well as village centres in the north of the region; district cooling will also be incorporated; fuel is split between geothermal and biogas
11	Energy storage		100 MW added by 2050	580 MW added by 2050
12	Wind		50 MW by 2050	300 MW by 2050
13	Renewable natural gas		No change	Renewable natural gas is introduced according to per capita allocation of 2030 potential generation
			Transit	
14	Expand transit		Transit expanded according to existing plans	Boost transit mode share guided by targets in 2017 Transportation Master Plan
15	Electrify transit		100% electric transit system by 2050 (regional and inter-regional)	100% electric transit system by 2030 (regional and inter-regional)
			Active	
16	Increase/improve cycling & walking infrastructure		Walking and cycling mode share remain constant	Mode shift 50% of trips less than 1 km to walking by 2050; 50% of trips between 1 and 5 km to cycling by 2050
17	Increased rideshare		Rideshare mode share held constant until 2050	Double the percentage of trips that are rideshare by 2050
18	Car-free zones		None	No personal vehicular trips in dense vehicular centres post-2040

		BAU	BAP	LCP
Private/personal use				
19	Electrify municipal fleets		25% electric by 2030	100% of the fleet is electric by 2030
20	Electrify personal vehicles		Electric vehicle projection in accordance with the updated Long Term Energy Plan. Assume 15% of stock is EV by 2035.	100% of new passenger vehicles are electric beginning in 2030
21	Electrify commercial vehicles		25% of the vehicle fleet is electric by 2050	All commercial vehicles are electric by 2050
Industrial				
22	Industrial efficiencies		No change	Increase process motors and electrical efficiency by 50% by 2050

Land-use Analysis

Land-use projections have not previously been completed out until 2050 for the Region, so a land-use analysis has been undertaken. It should be noted that the exercise is completed solely for the purpose of this project and its energy and emissions analysis, and bears no relation to the Provincial Lands Needs Assessment methodology, an exercise that is underway at the time of writing. Projections out until 2031 are informed by the June 26, 2015 Region Official Plan Consolidation; projections between 2031 and 2050 are estimates developed specifically for the DCEP. The steps involved in developing the land-use projections are as follows:

Step 1. Map out the baseline year's population, employment, and land use zone by zone.

Data is compiled on the numbers, sizes, locations, and types of buildings across the Region for the year 2011 using the Municipal Property Assessment Corporation and guided by the Regional Official Plan.

Step 2. Determine the capacity for new development within each zone.

A land-use analysis is completed for each zone using GIS (digital mapping) in order to estimate how much capacity for new development existed in each zone. This capacity analysis process accounts for land already allocated to existing buildings, roads, key natural heritage features and Greenbelt lands. The amount of undeveloped land within each zone is identified and categorized according to its designation in the Regional Official Plan and Area Municipal Official Plans (i.e. employment areas, living areas, urban growth centres, etc.), and whether lands are within the built boundary settlement areas or outside of them (greenfield areas). Each designation is assigned an allowance for maximum densities of dwellings and commercial floorspace, as well as the proportions and types for each (i.e. single family units, row houses, apartments), as specified within the Regional Official Plan and Municipal Plans. Figure 2 illustrates the mix of dwellings for greenfield and developed areas.

A subsequent step involves reviewing the results with Regional and Municipal representatives. Finally, verification of existing conditions is undertaken for a selection of zones to ensure that the identified capacities were reasonable.

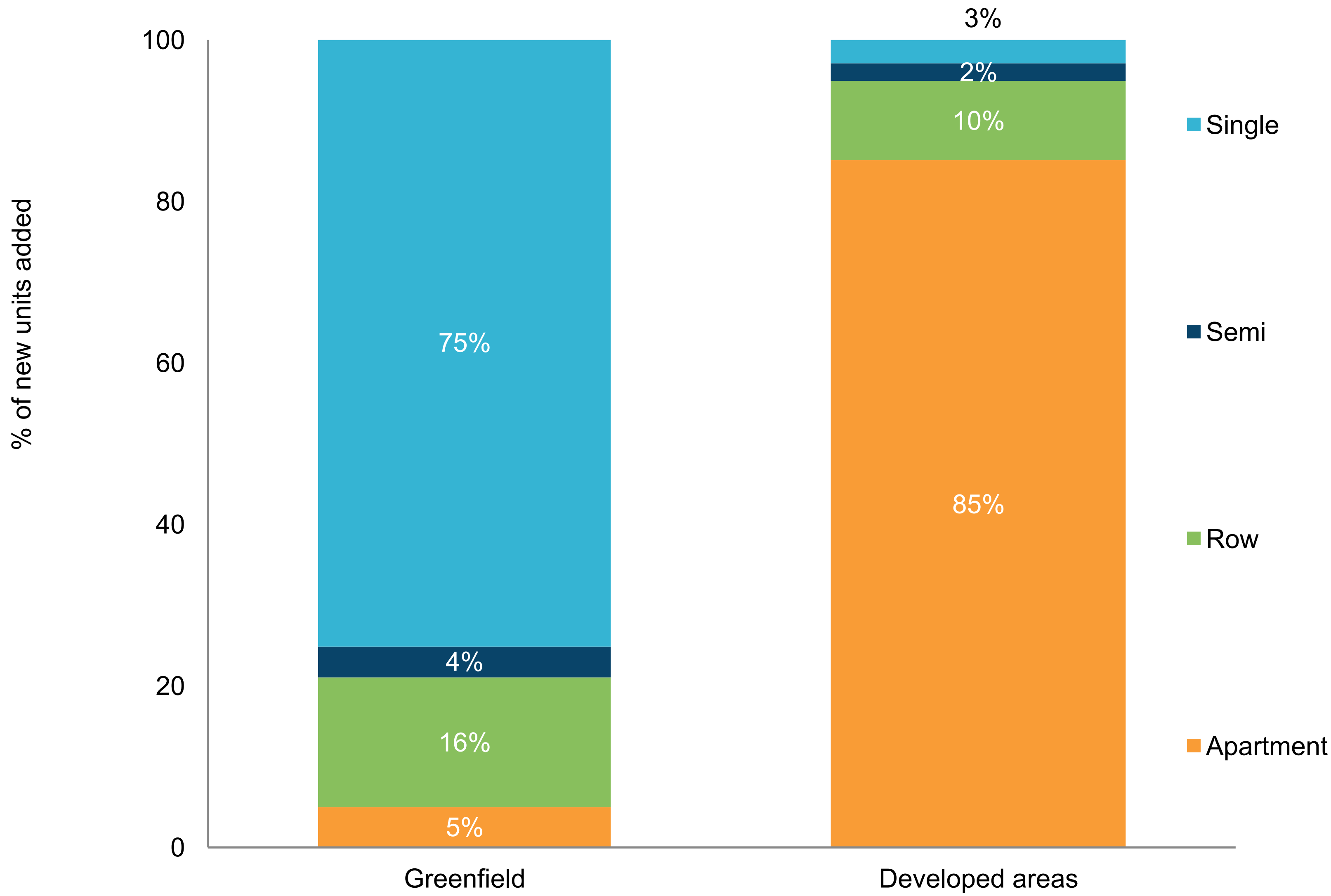

Figure 2. Assumed unit mix for new development in greenfield and developed areas in the Region of Durham, 2018-2050

Step 3. Assign new development to each zone year by year until 2050.

Once the maximum potential for new dwellings and non-residential floorspace is determined for each zone, the model requires an indication of how much development is estimated to occur within each, and when. Projections for jobs and population from the Regional Official Plan by municipality out until 2031, data on planned and new development from municipal building permits and plans of subdivision for certain municipalities, and regional targets for new construction occurring within versus outside of the Provincial Built Boundary are used to inform scheduling and location of future development. The results are again reviewed with Regional and Municipal representatives, who also provided feedback on the model's allocations for the 2031–2050 period beyond the Regional Official Plan's 2031 projections.

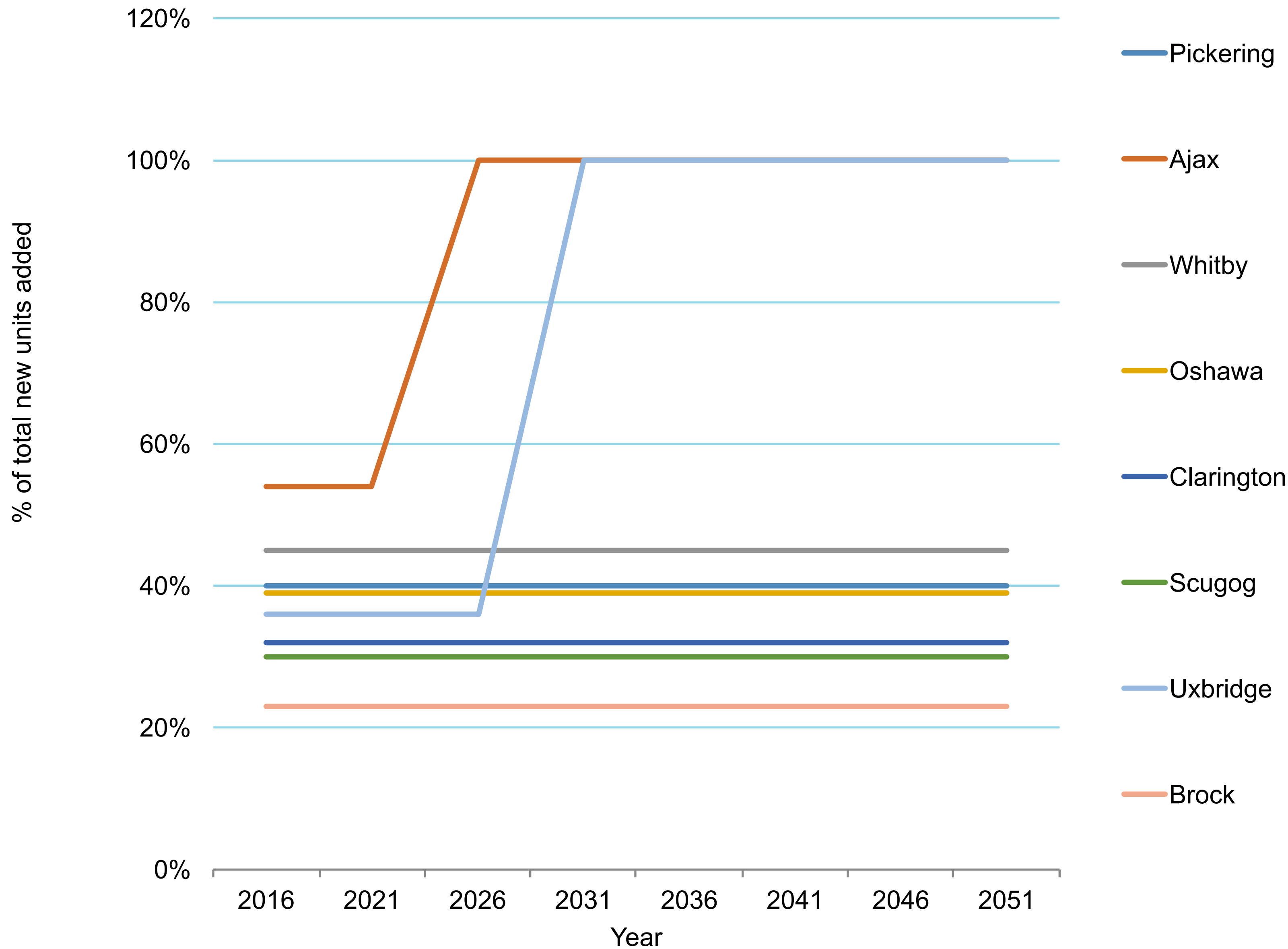

Figure 3. Assumed fraction of new units being allocated to Region of Durham municipalities within the Provincial Built Boundary for the BAU and BAP scenarios, 2016–2050

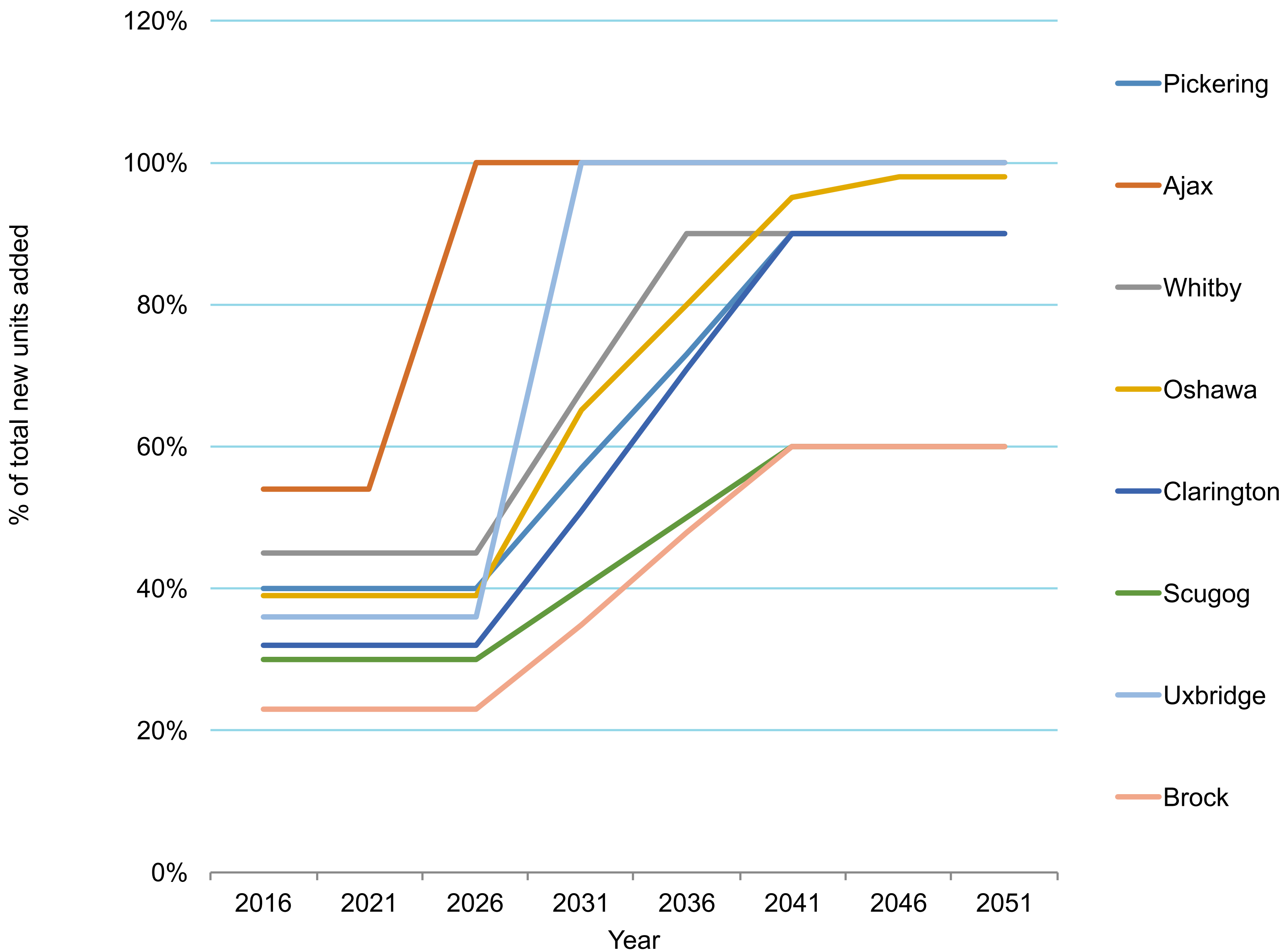

Figure 4. Assumed fraction of new units being allocated to Region of Durham municipalities within the Provincial Built Boundary for the LCP scenario, 2016–2050

Figure 5 shows the dwelling mix for greenfield development in the LCP scenario. In most areas the share of apartments and rows increase over time; Seaton is assumed to achieve this mix immediately due to specific planning policy for the area, as indicated in Figure 6.

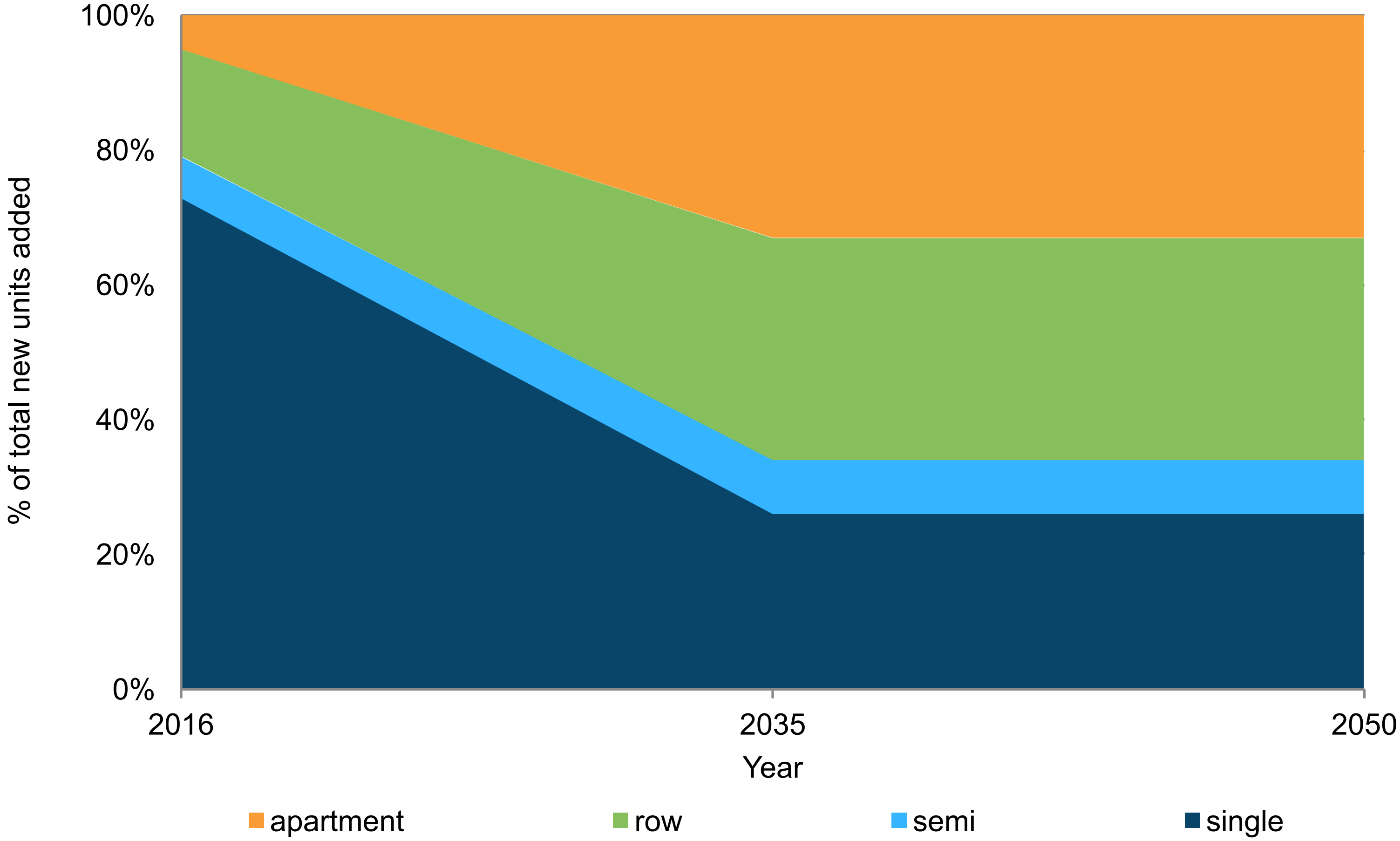

Figure 5. Dwelling unit mix for greenfield development in the LCP scenario, other than Seaton

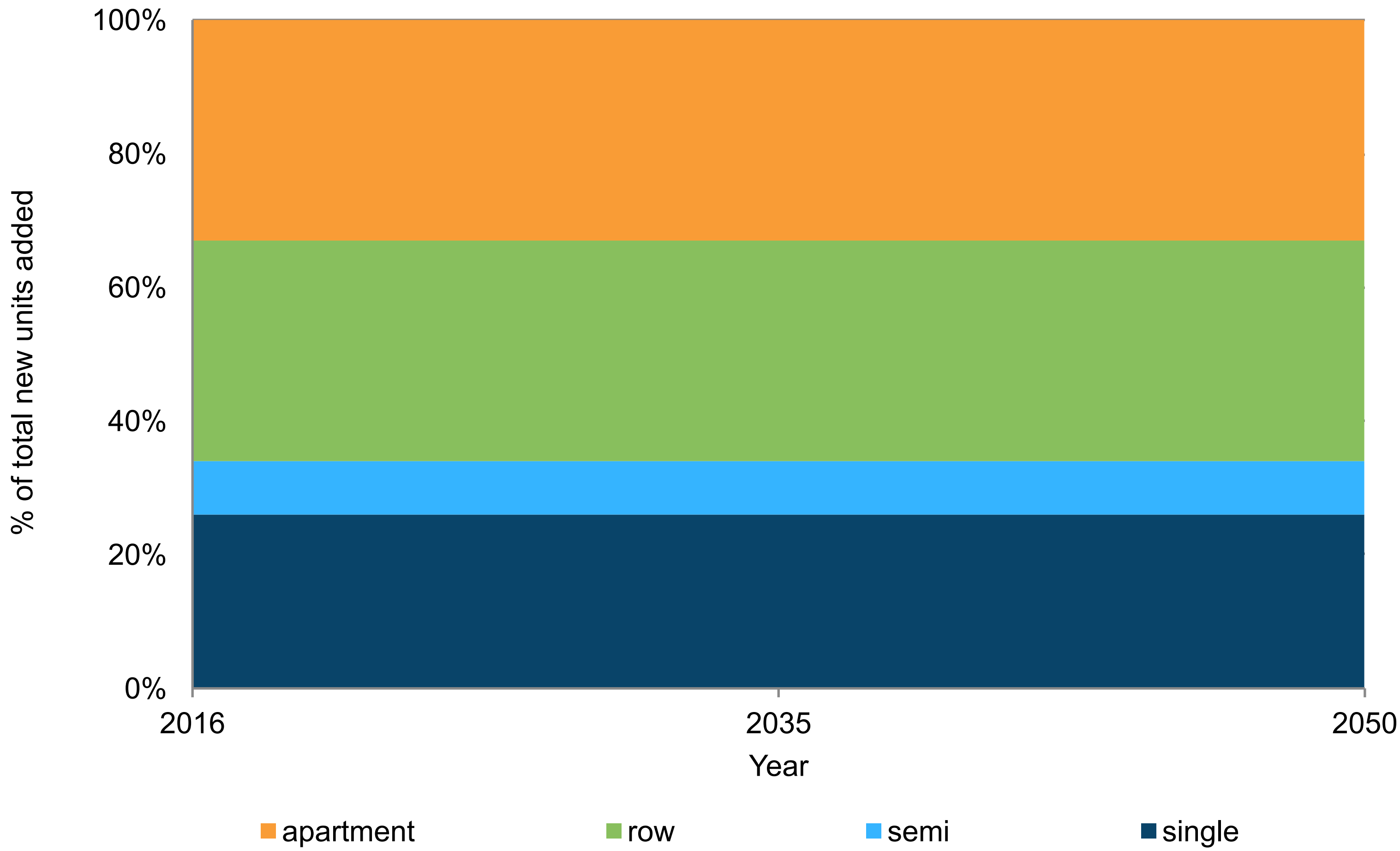

Figure 6. Dwelling unit mix for Pickering (Seaton) greenfield development in the LCP scenario

3. The Results of the Low Carbon Pathway

Energy

In the BAU scenario, energy consumption for the Region is projected to increase by 30% by 2050, from 97 million GJ in 2016 to 123 million GJ. This increase is modest, given the projected doubling in population. Drivers of the increased efficiency on a per capita basis include the reduced heating degree days, improved fuel efficiency in vehicles, the increased adoption of electric vehicles and increased requirements for energy performance in the building code. The LCP scenario results in a decline of nearly 37% in energy to 61 million GJ.

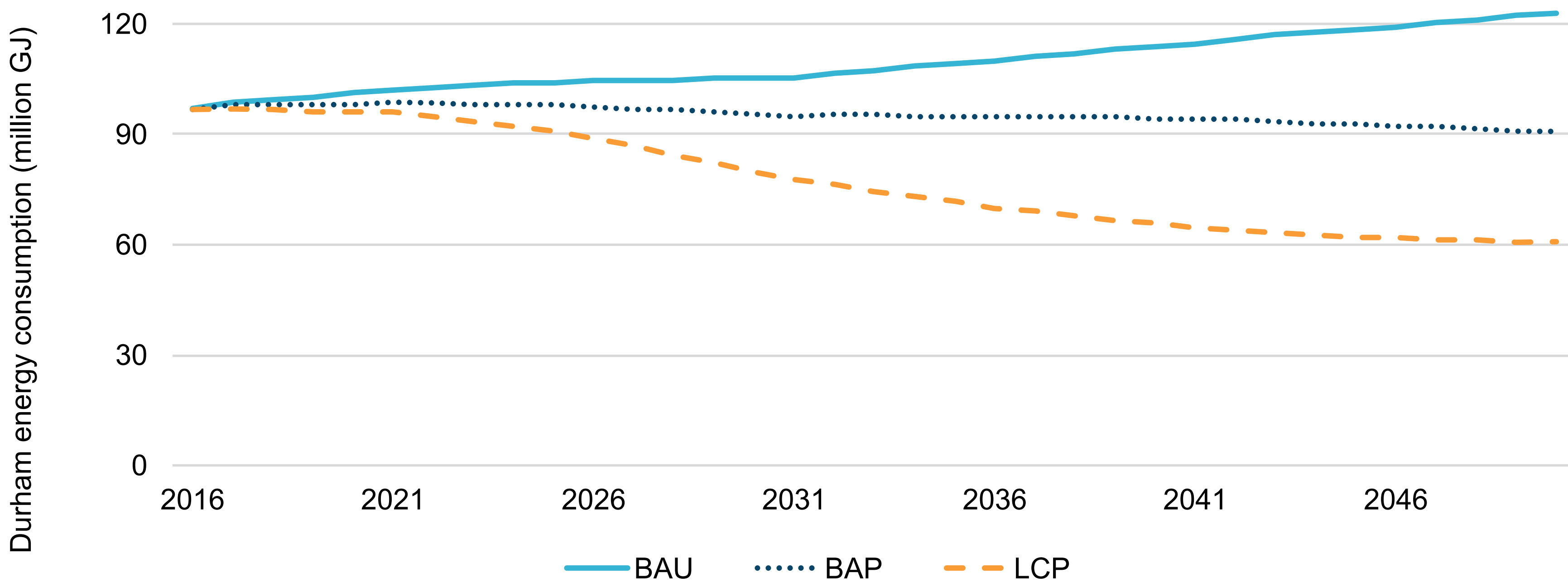

Figure 7. Annual energy consumption (GJ) by scenario, 2016–2050

An illustration of the energy mix in 2016 versus the four scenarios in 2050 indicates an overall decline in natural gas and gains in the “other” category, which includes renewable natural gas. Diesel and gasoline have been eliminated in the low carbon scenario.

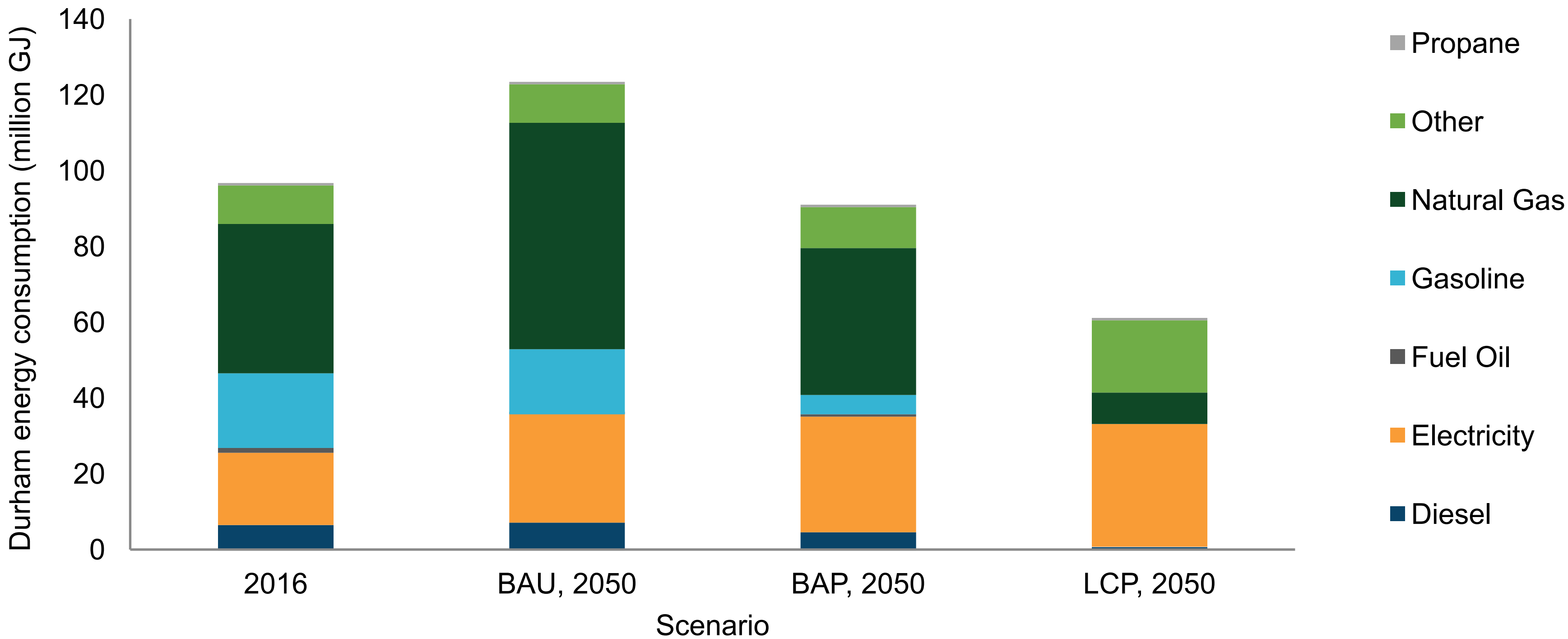

Figure 8. Annual energy consumption by fuel, 2016 baseline vs 2050 for each scenario

A similar picture by end use shows that energy use in the industrial sector declines moderately, while space heating declines significantly due to both decreased thermal demand (heating degree days) and improved building envelope. Transportation energy consumption declines by nearly 70% in the LCP over the BAU scenario.

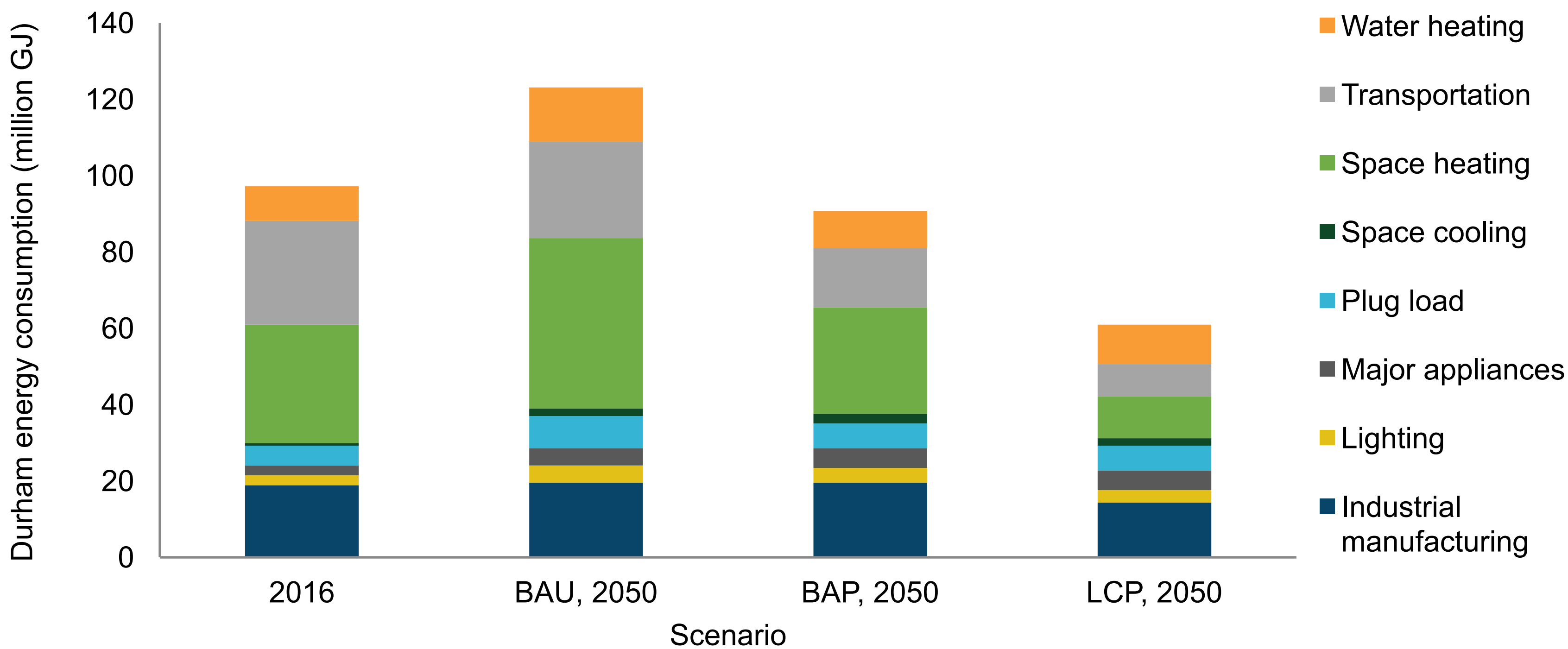

Figure 9. Annual energy consumption by end use, 2016 baseline vs 2050 for each scenario

An analysis of the BAP year over year shows the decline of gasoline and the gain of electricity, as electric vehicles come online. Natural gas consumption is relatively flat, despite a doubling of the population, as a result of the decreased thermal load and improved building performance.

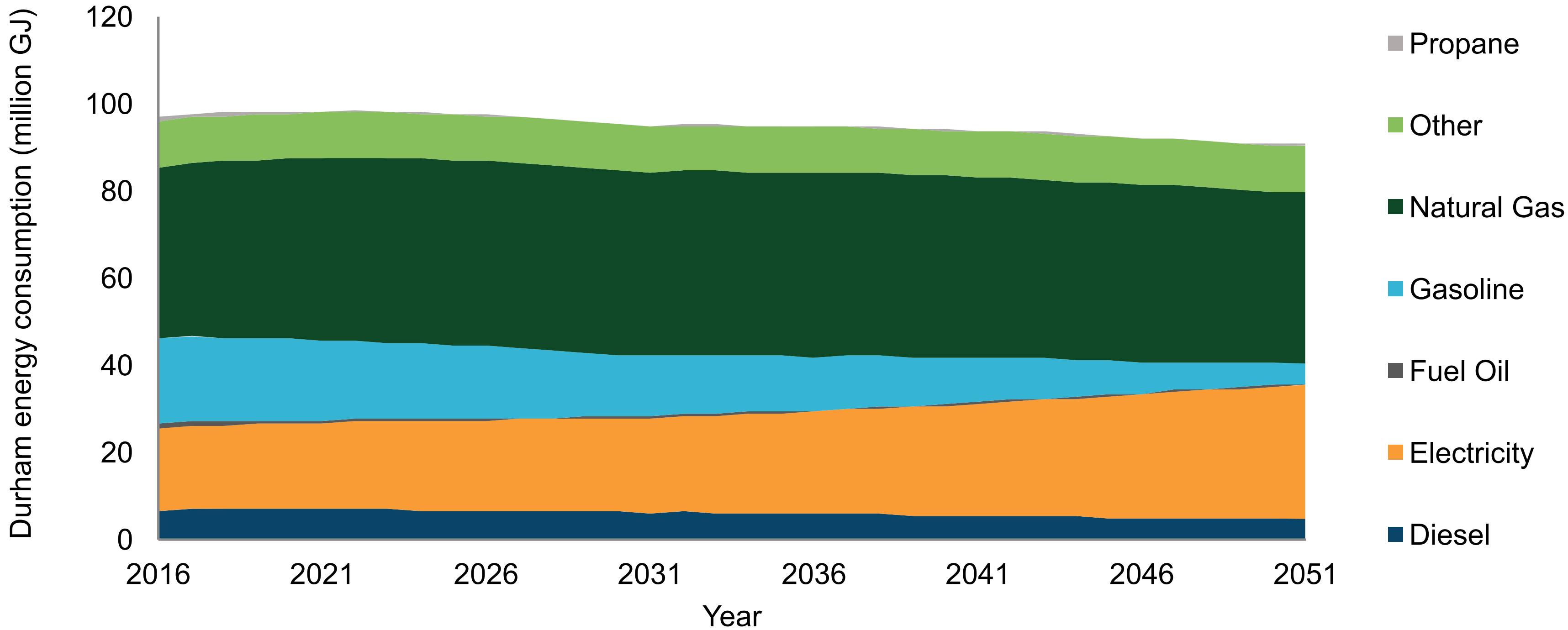

Figure 10. Annual energy consumption by fuel, BAU (2016–2050)

In the LCP scenario, gasoline and diesel are phased out more rapidly, replaced by electricity. Extensive building retrofits drive down natural gas consumption, some of which is replaced by renewable natural gas ("other" category) and electricity.

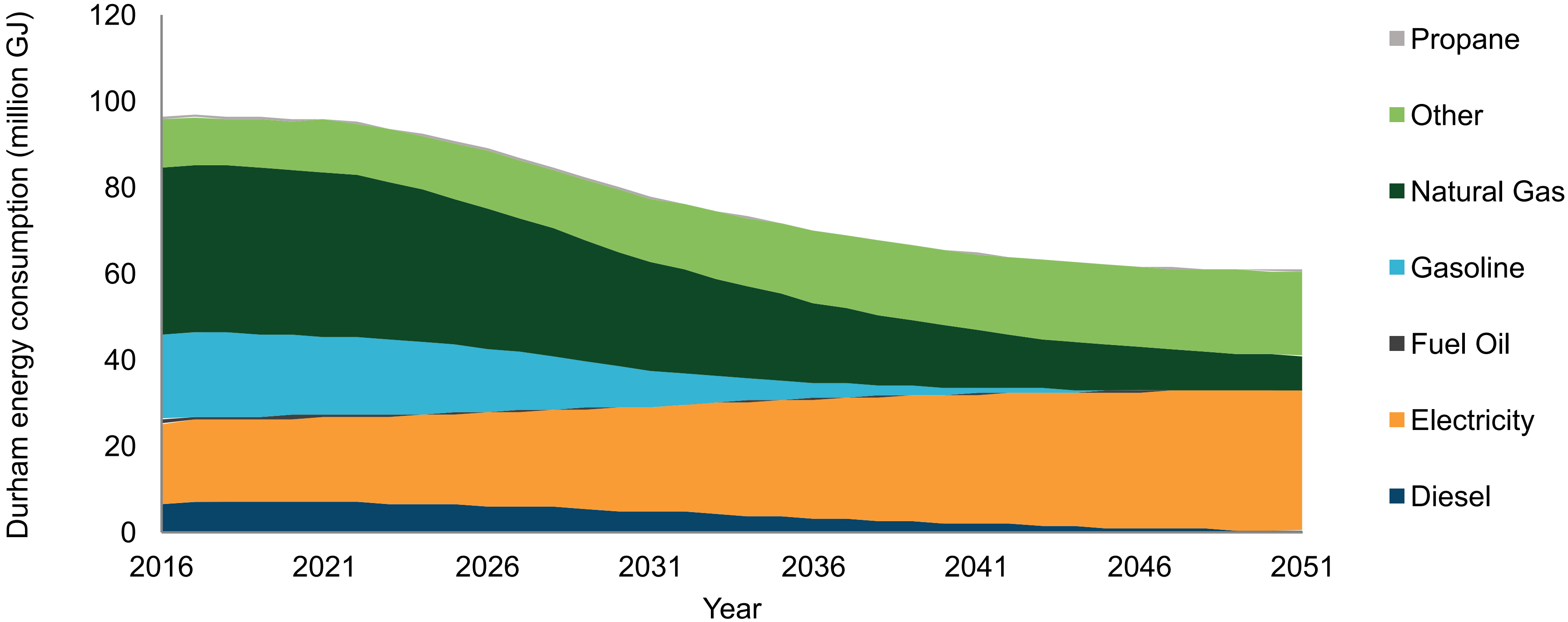

Figure 11. Annual energy consumption by fuel, LCP (2016–2050)

When represented by sector, energy savings are most apparent in the transportation and space heating sectors, whereas other sectors grow more proportionally to a doubling of the population.

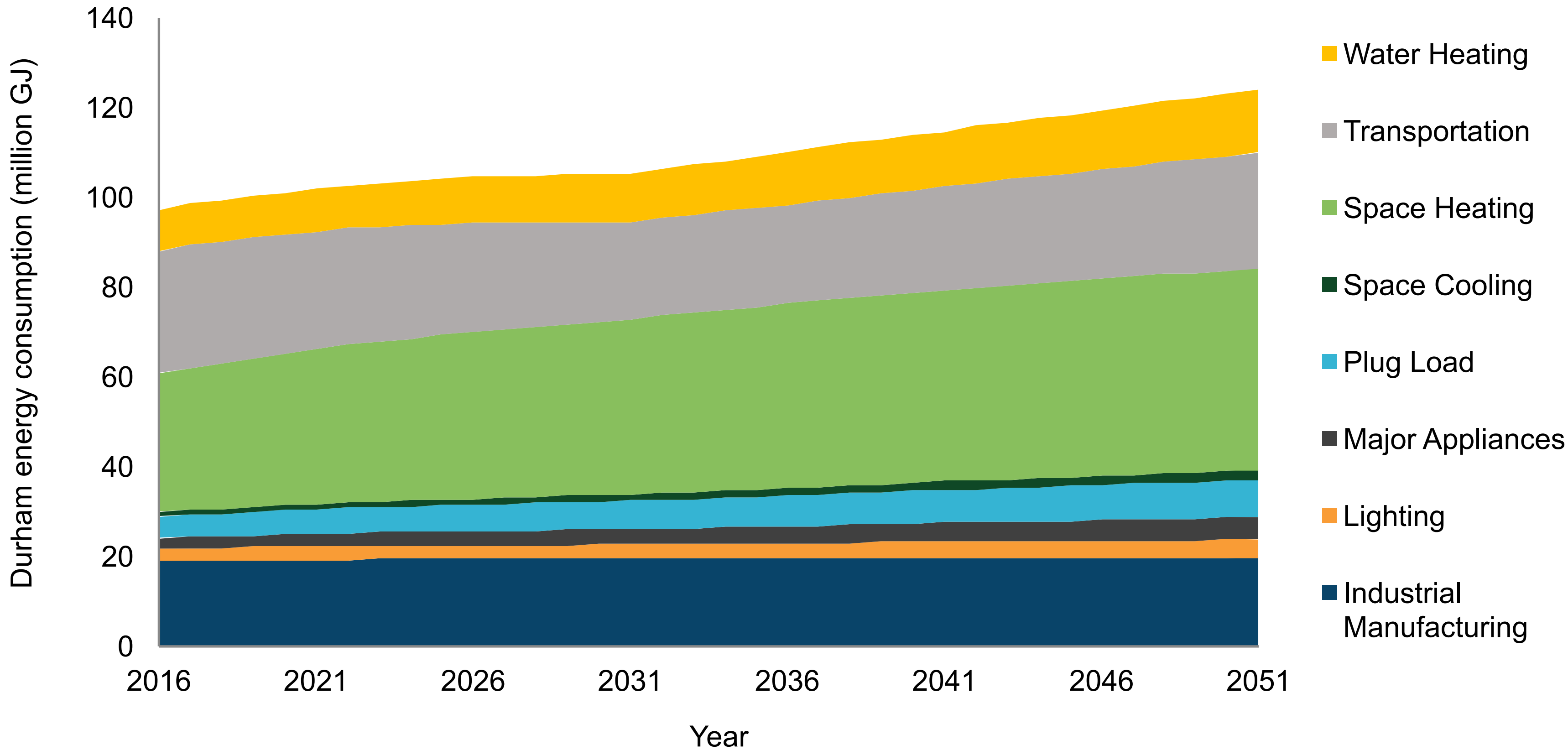

Figure 12. Annual energy consumption by end use, BAU (2016–2050)

In the LCP scenario, the major reductions are evident in the space heating and transportation categories, with smaller decreases in the other end-use categories

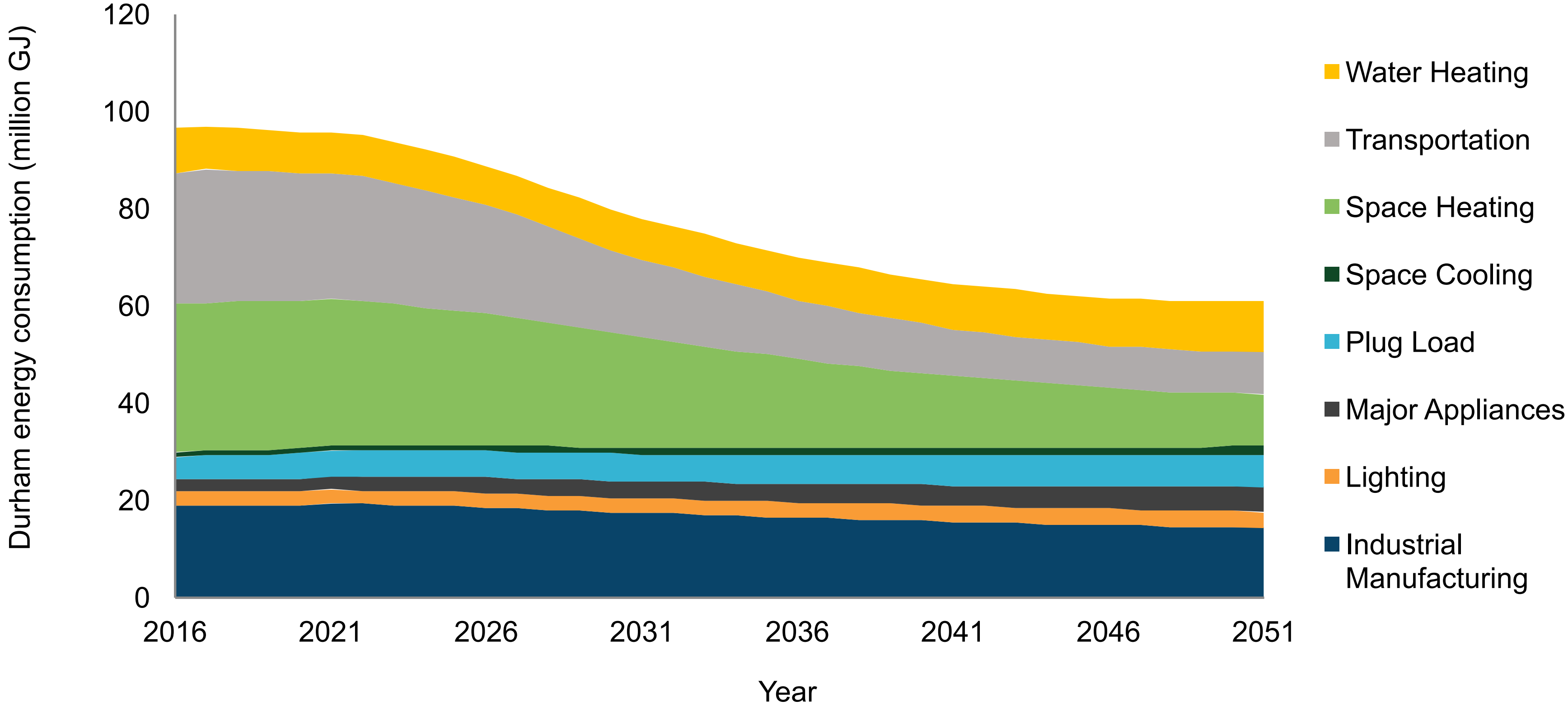

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Figure 13. Annual energy consumption by end use, LCP (2016–2050)

Sankey diagrams provide a comprehensive snapshot of energy use for the Region for one year, tracing energy from its fuel source to the sector it's used in and finally if it is transformed into useful energy or conversion losses. The bands are scaled to represent, for example, the amount of energy consumed in a sector. By comparing bands between different scenarios, one can see how the mix of fuels is being transformed or efficiency gains are being achieved. The ratio between useful energy and conversion losses is an indicator of how much energy is "wasted"; a high ratio of conversion losses is an indicator that much of the energy being processed is being lost, which increases the cost and environmental impact of providing the relevant energy service.

In 2016, conversion losses were approximately 43% of the total energy consumed; in the BAU, this declines to 37% and in the LCP the conversion losses are 24%. The Sankey diagrams illustrate a decline in natural gas by two thirds between 2016 and the 2050. Electricity is fairly constant between 2016 and 2050 in the LCP, with efficiency efforts offsetting fuel switching from natural gas and gasoline to electricity in the building and transportation sectors.

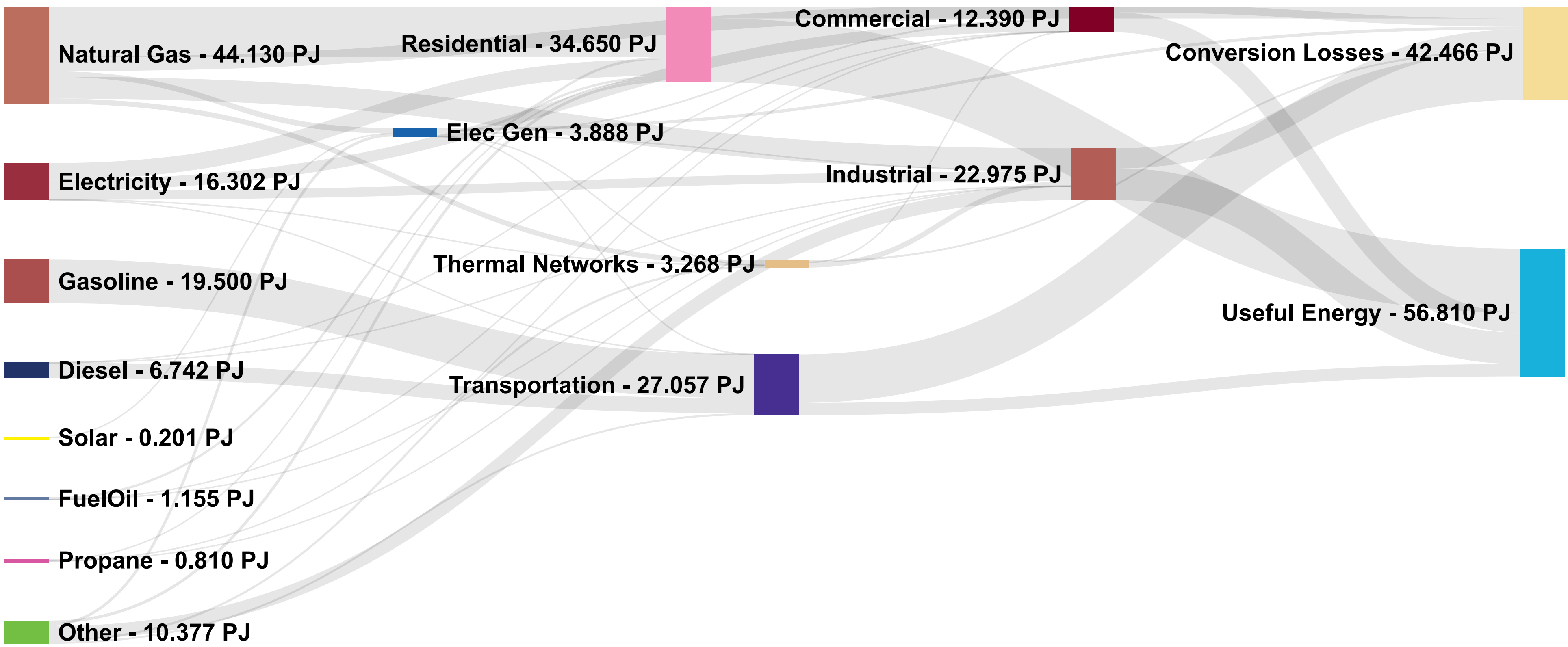

Figure 14. Energy Sankey, 2016

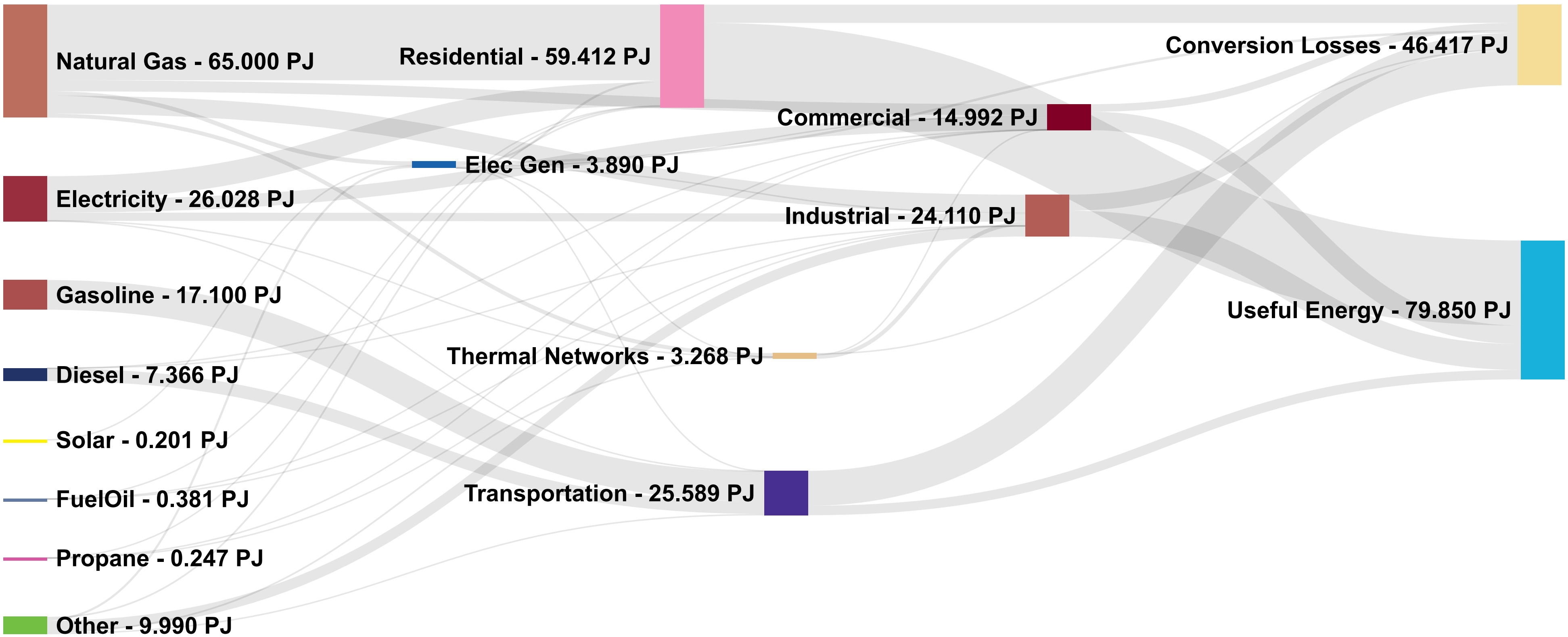

Figure 15. Energy Sankey, BAU, 2050.

Thermal networks (district energy) nearly triples in size between the BAU and LCP in 2050, whereas solar generation increases by a factor of 60. Overall the energy system becomes more distributed and less reliant on natural gas and grid electricity, with the addition of increased local renewable generation and renewable natural gas.

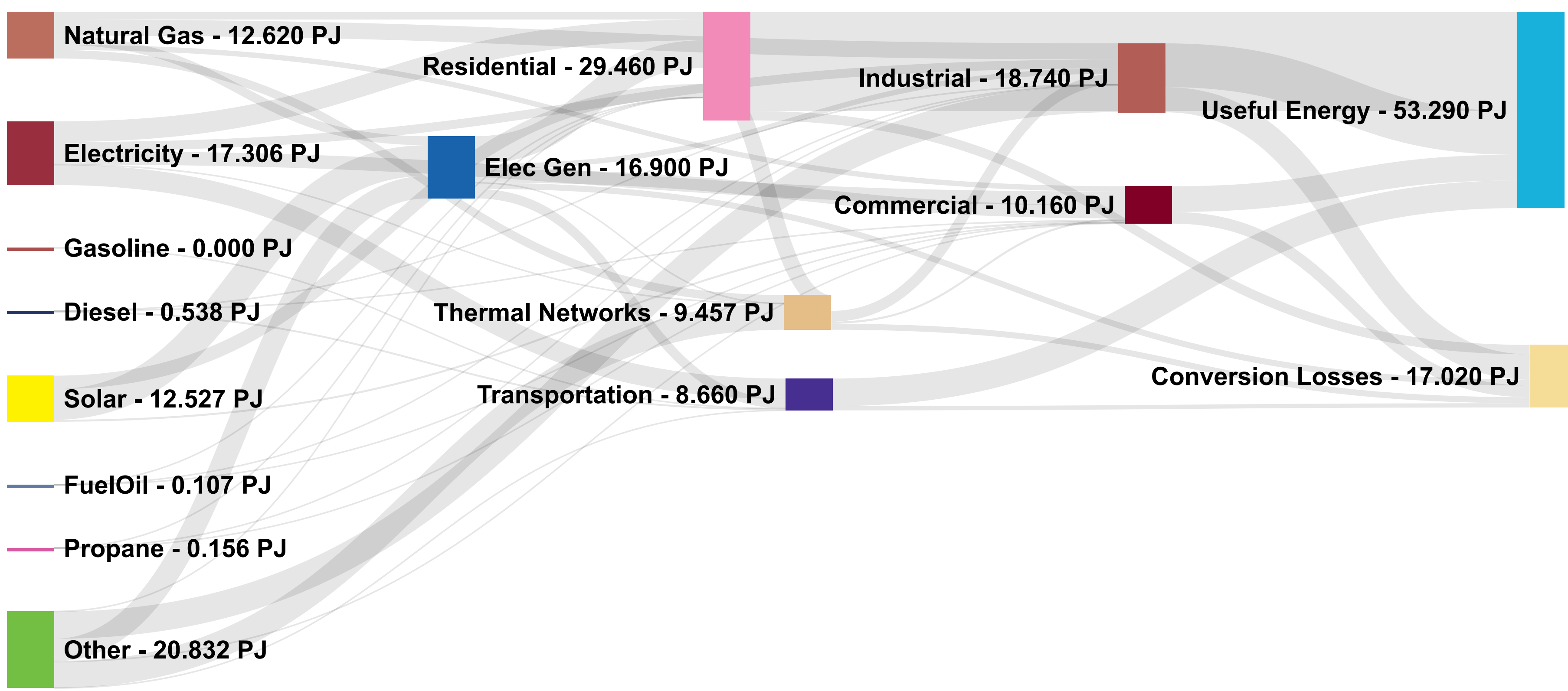

Figure 16. Energy Sankey, LCP, 2050

Emissions

GHG emissions reductions are more significant than energy savings, and in the LCP scenario GHG emissions drop by 66% compared to 2016, despite a doubling of the population. A comparison between 2016 and 2050 for each of the scenarios illustrates the GHG emissions from different fuels. The remaining emissions in the LCP scenario are from coke and coal (other), waste (other), natural gas and electricity.

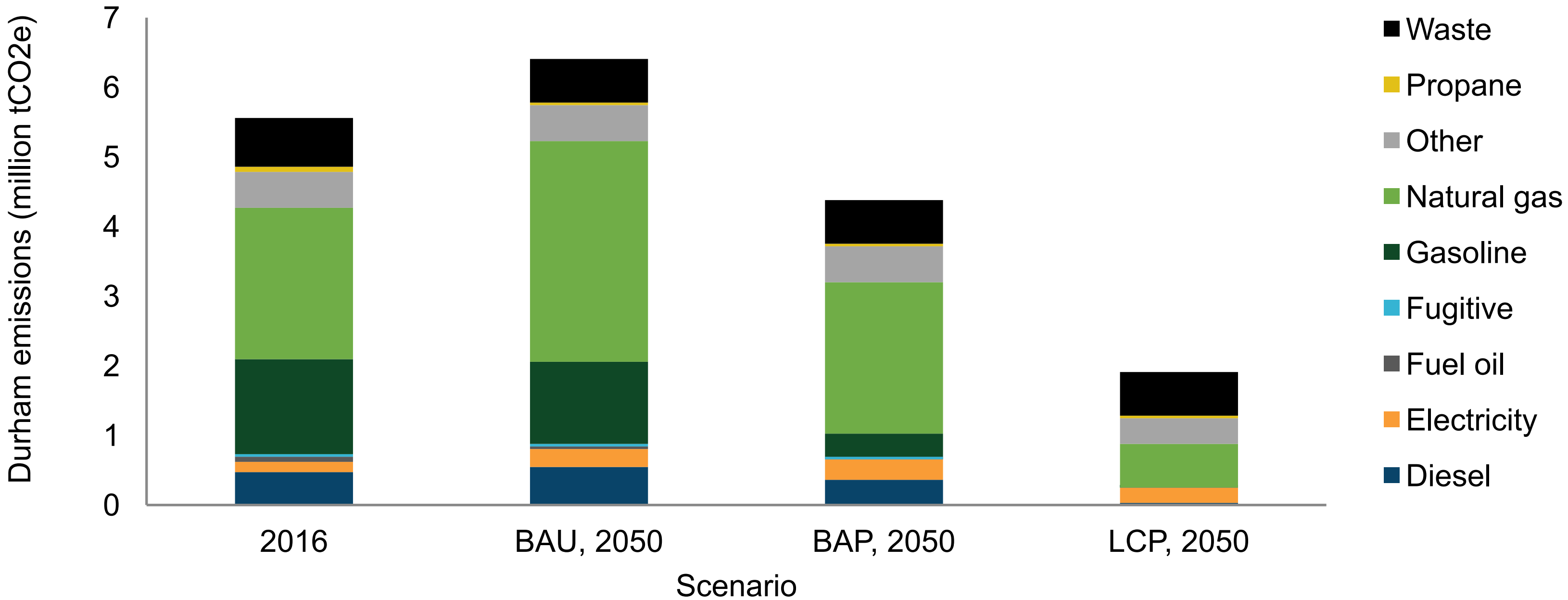

Figure 17. Annual GHG emissions by fuel, 2016 vs 2050 for each scenario

A comparison by sector shows that the remaining emissions in the low carbon sector are concentrated in the industrial sector, with some emissions resulting from waste, and to a lesser degree, residential and commercial buildings. The emissions from waste are as a result of combustion of plastics and other residual solid waste (methane emissions).

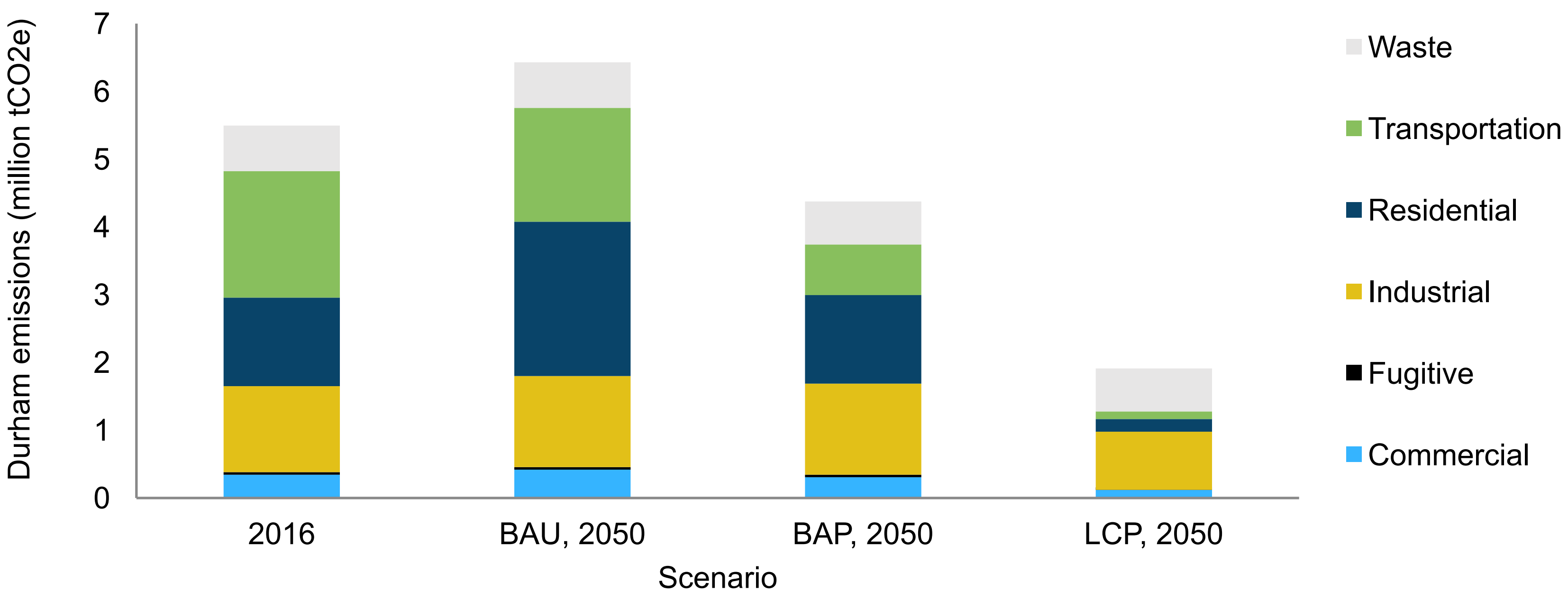

Figure 18. Annual GHG emissions by sector, 2016 vs 2050 for each scenario

GHG emissions climb by 17% between 2016 and 2050 in the BAU scenario, with increases in every sector. Residential GHG emissions increased by 74%, as a result of the population increase.

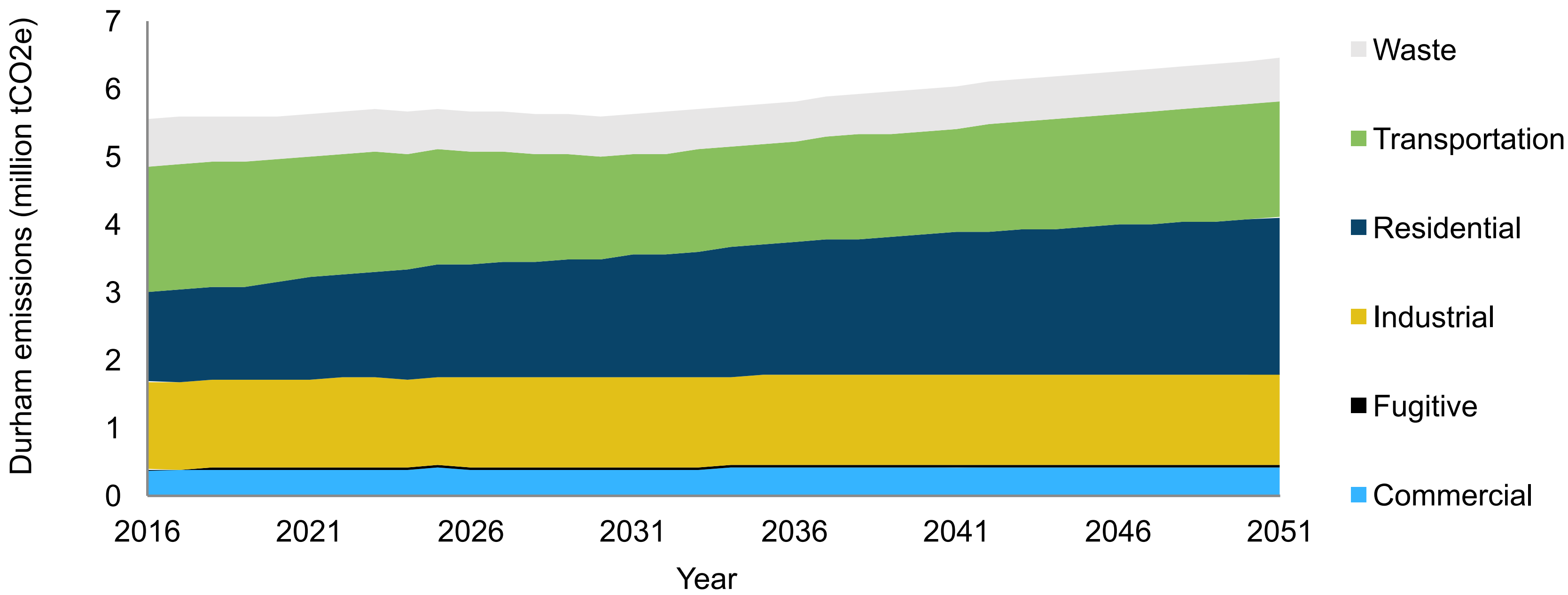

Figure 19. Annual GHG emissions by sector, BAU (2016–2051)

The most significant GHG reductions occur in the transportation sector in the LCP scenario, followed by residential, with smaller gains in the commercial sector. Total emissions decline from 5.5 $MtCO_2e$ in the BAU in 2016 to 1.9 $MtCO_2e$ in the LCP scenario.

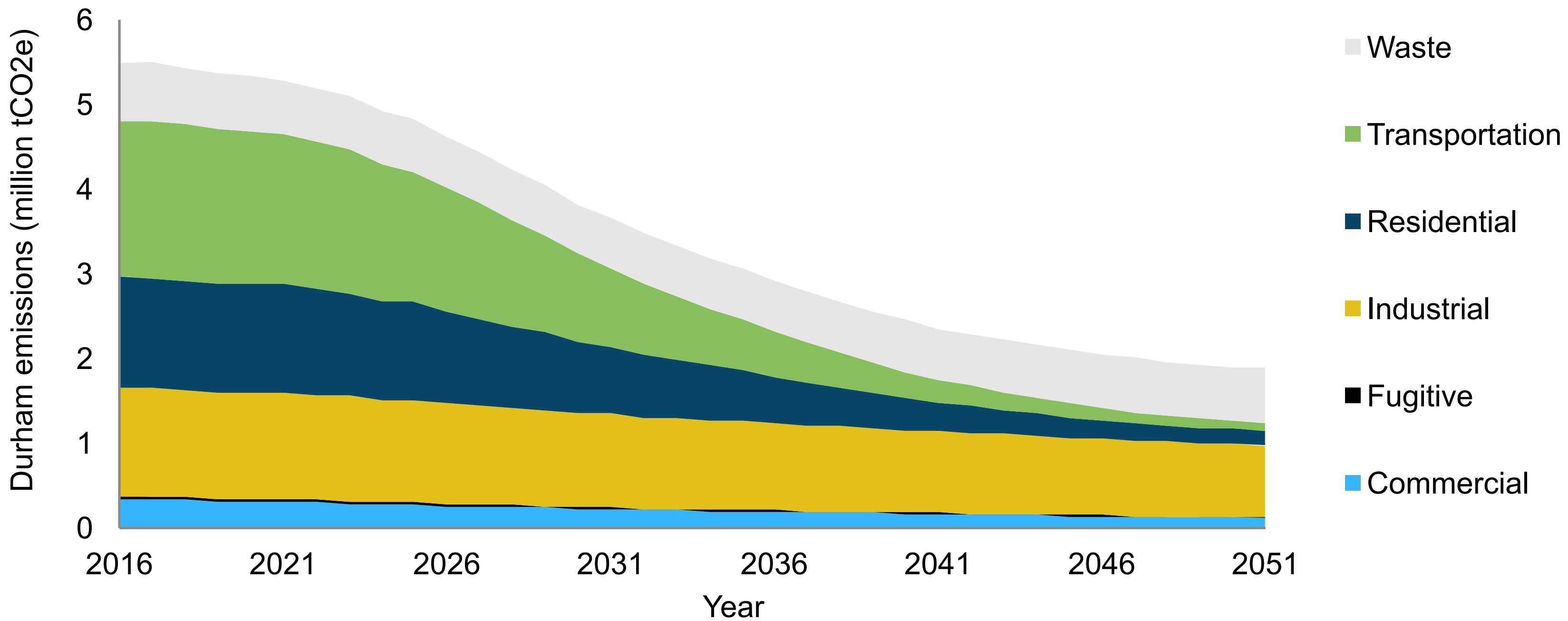

Figure 20. Annual GHG emissions by sector, LCP (2016–2051)

When considered in terms of fuels, natural gas is the most significant source of emissions, accounting for 40% of the total in 2016, followed by gasoline a 25%. The “other” category refers to emissions from coke and coal.

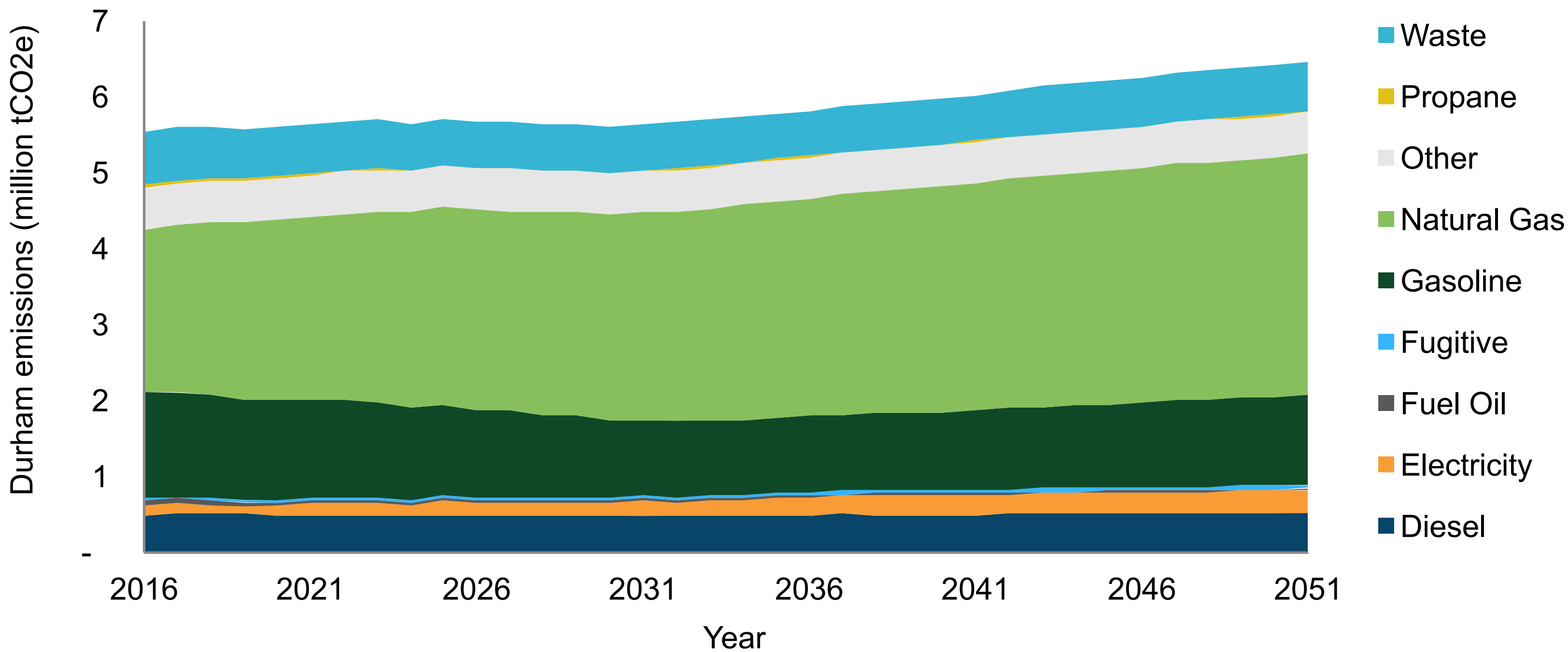

Figure 21. GHG emissions by fuel, BAU (2016–2051)

The decline in emissions from gasoline is notable in the LCP scenario, as is a slightly less drastic decline in emissions from natural gas, as a result of fuel-switching and energy conservation measures.

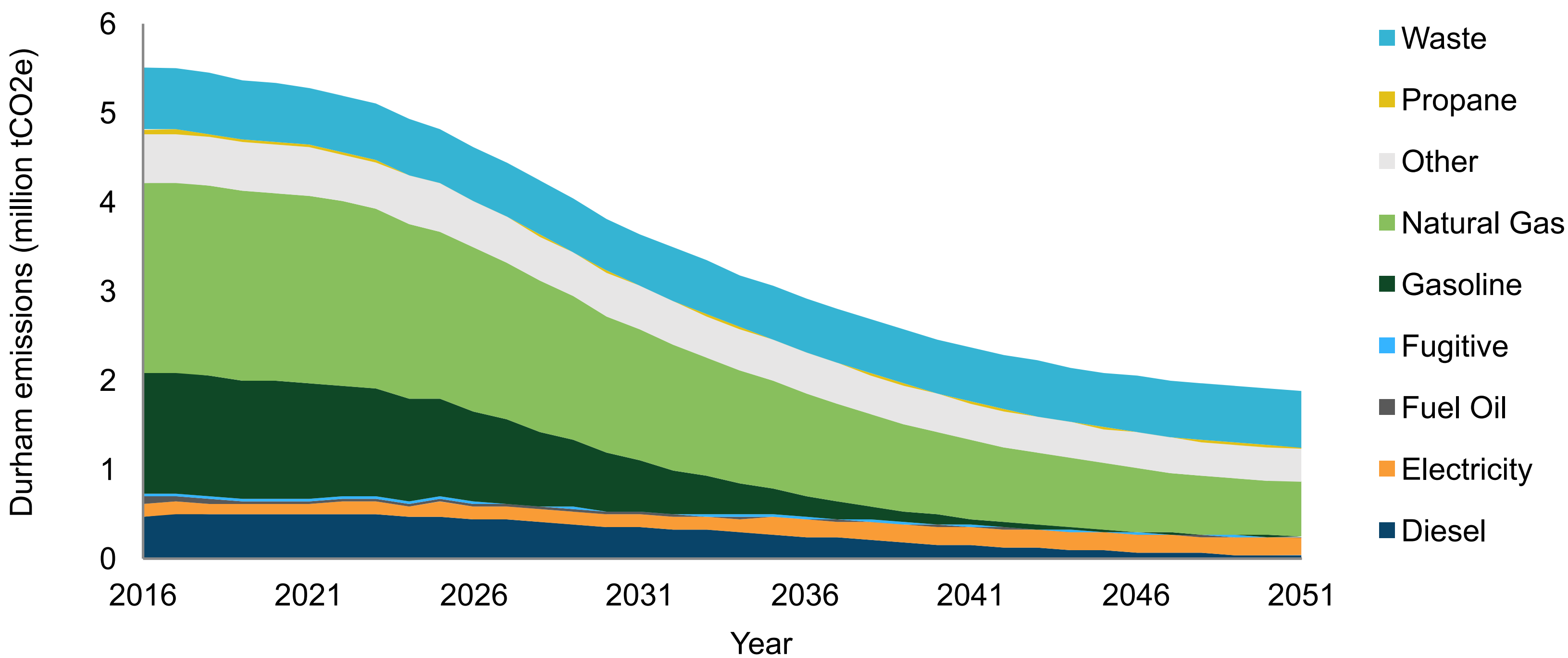

Figure 22. Annual GHG emissions by fuel, LCP (2016–2051)

Transportation

The vehicular mode share declines significantly between the BAU and LCP scenarios as a result of increased land-use intensification and actions related to active transportation in the LCP. By 2050, the mode share for internal trips falls from 92% of trips by single vehicles in the BAU to 63% for single vehicles in the LCP. Internal trips are trips that remain within the boundaries of the Region.

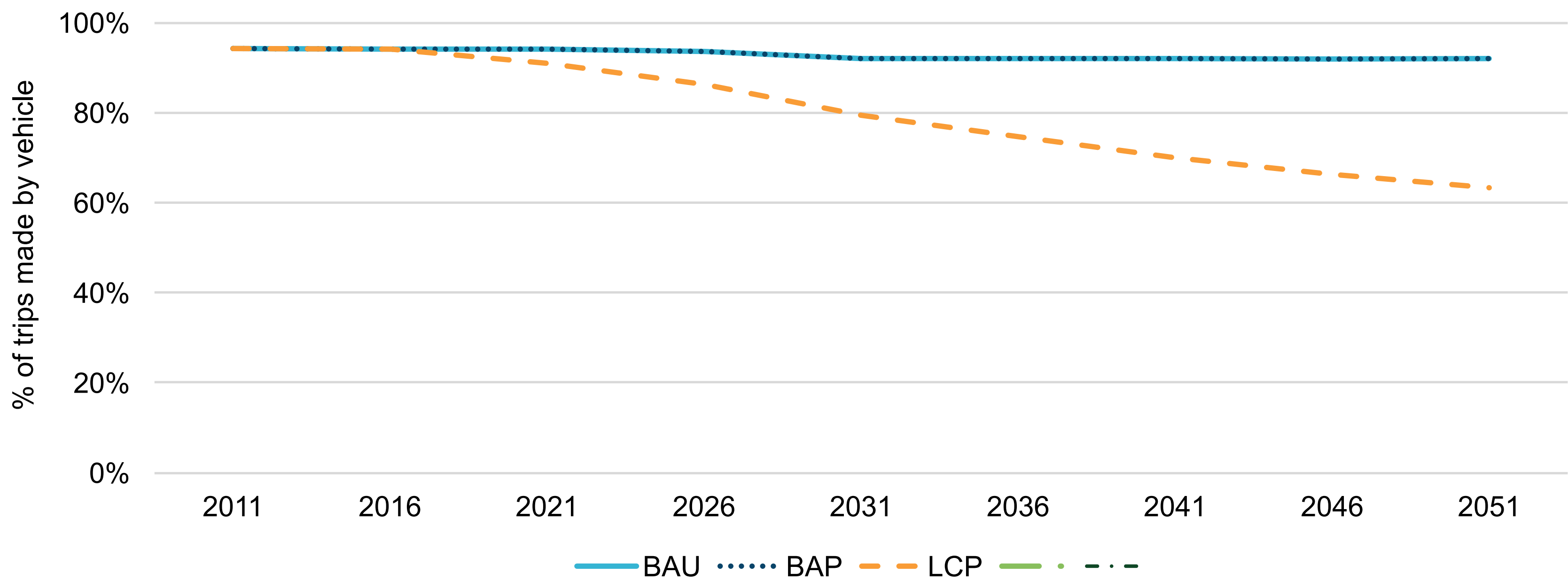

Figure 23. Annual vehicular mode share by scenario (2016–2051)

Overall mode share for internal trips indicates that the shares are nearly constant in the BAP, but active modes make significant gains in the LCP scenario, with transit increasing from 2% to 7%, and active modes increasing from 4% to 29% of trips. The increase in population accentuates these gains, as there are many more trips overall in 2050 than in 2016.

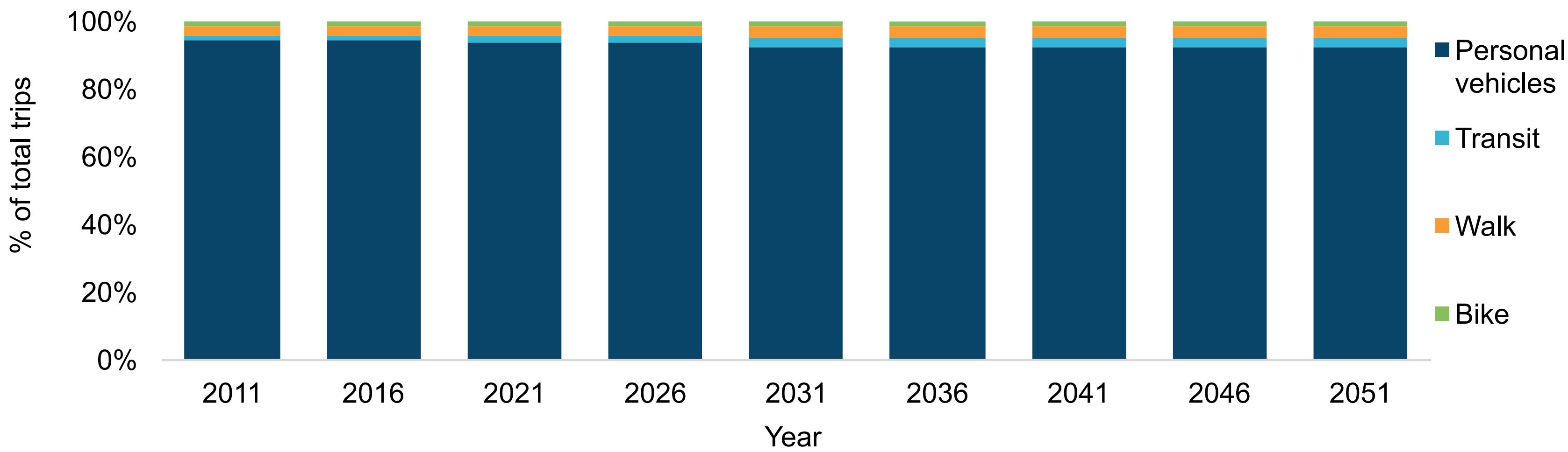

Figure 24. Mode share for internal trips, BAU (2011–2051)

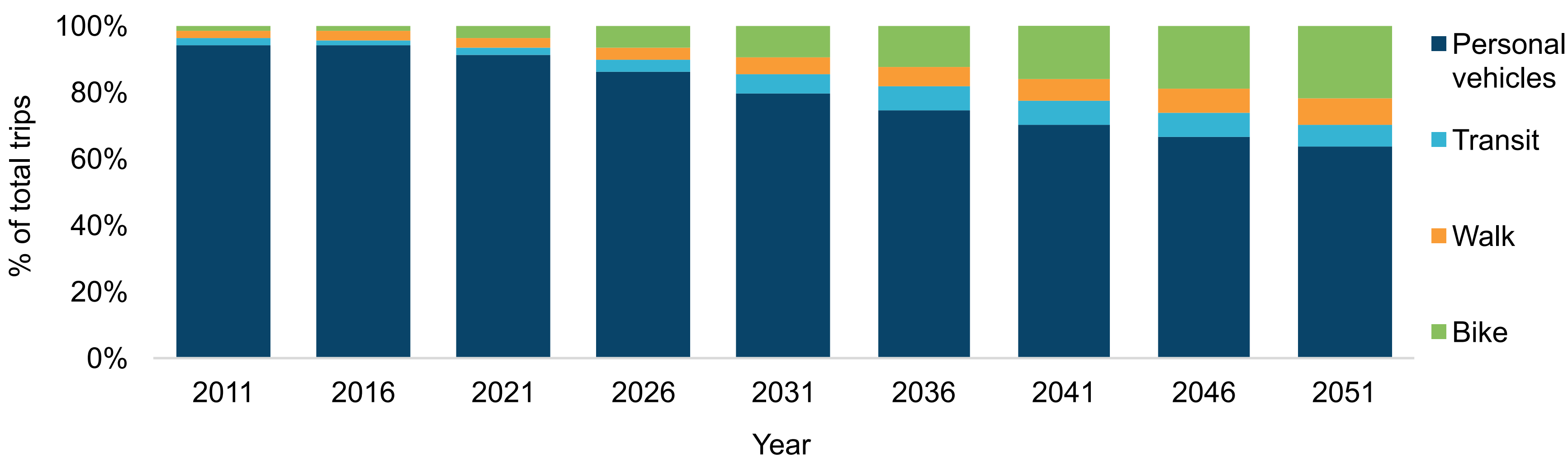

Figure 25. Mode share for internal trips, LCP (2011–2051)

Fuel use in the scenarios demonstrates a complete technological transformation in the transportation sector. Whereas in 2016, fuel use is primarily gasoline (73%) with some diesel, in the LCP, it is almost entirely electricity (98%). The BAP scenario assumes one third electricity by 2050.

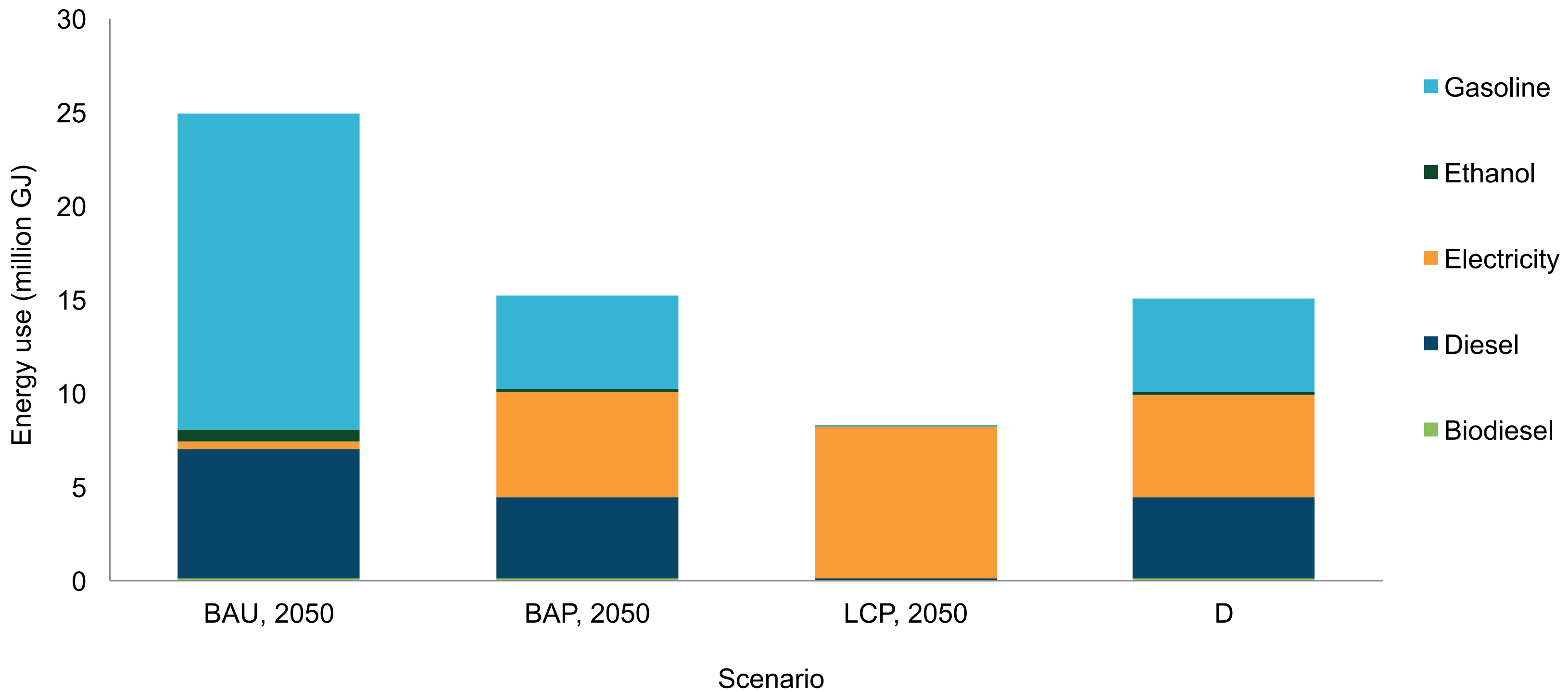

Figure 26. Transportation energy by fuel, 2016 vs 2050 for all scenarios

When considered by vehicle type, total energy consumption is relatively similar in each scenario. The share of energy from cars falls from 33% in 2016 to 22% in the LCP scenario, whereas light trucks account for 50% of the energy in 2016, climbing to 56% by 2050.

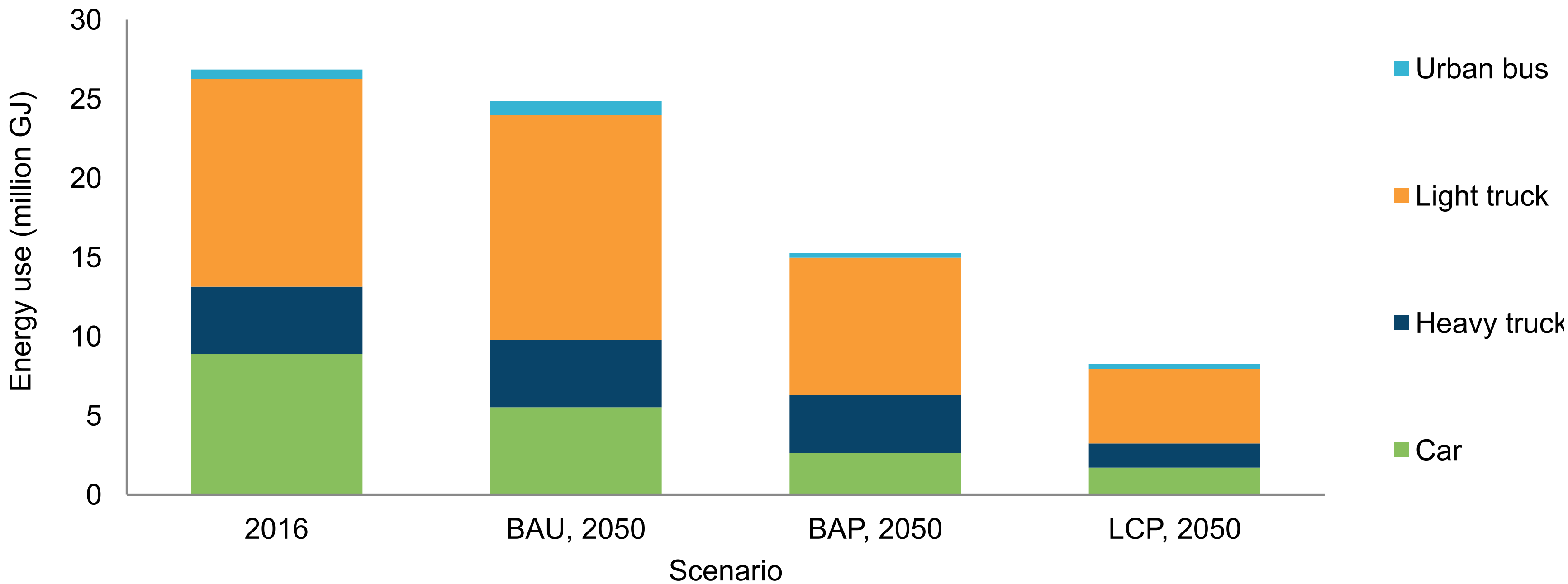

Figure 27. Transportation energy by vehicle, 2016 vs 2050 for all scenarios

In the BAU scenario, gasoline consumption declines until 2030 as a result of the federal fuel efficiency standards and then population increases start to increase fuel consumption as efficiency gains flatten off. Diesel consumption is relatively flat across the time period.

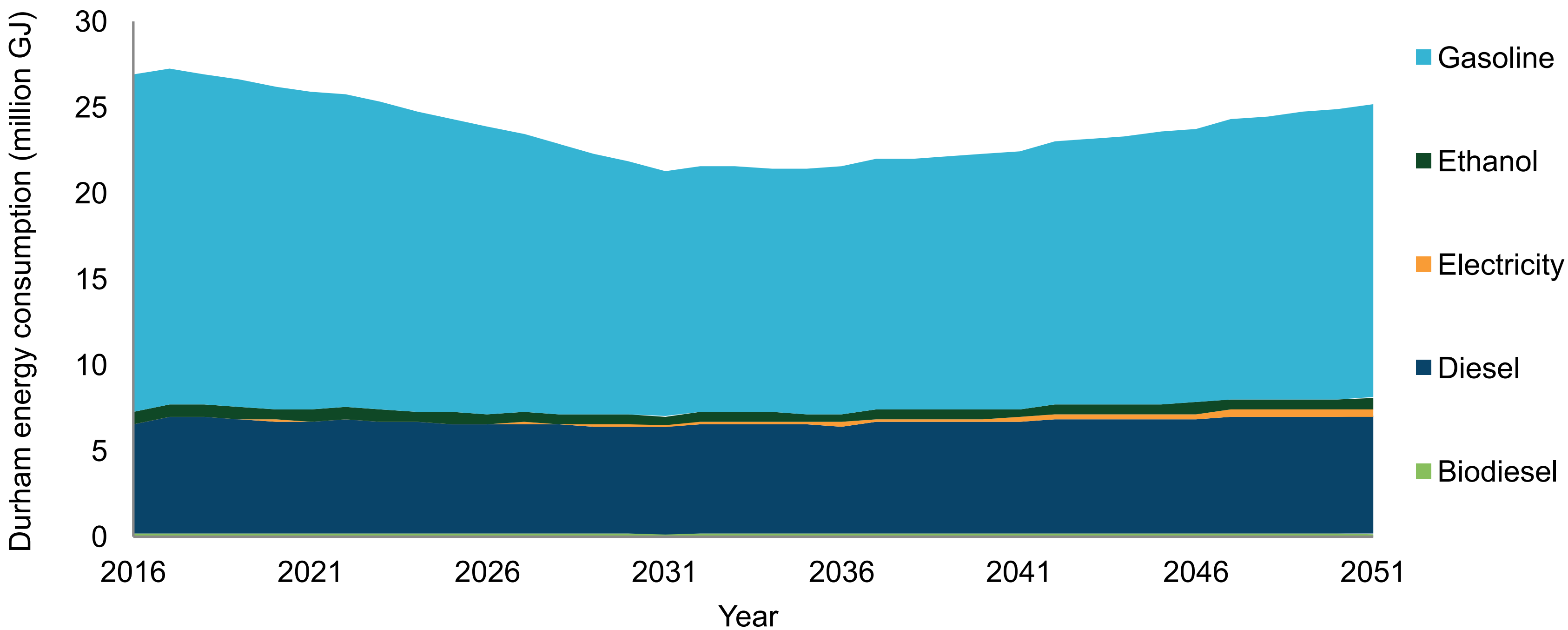

Figure 28. Annual transportation energy by fuel, BAU (2016–2051)

In the LCP scenario, energy use overall declines by 70% as a result of the improved efficiency of electric engines over internal combustion engines and mode shifting away from the private vehicle. By 2045, nearly 100% of energy consumed for transportation purposes is electric.

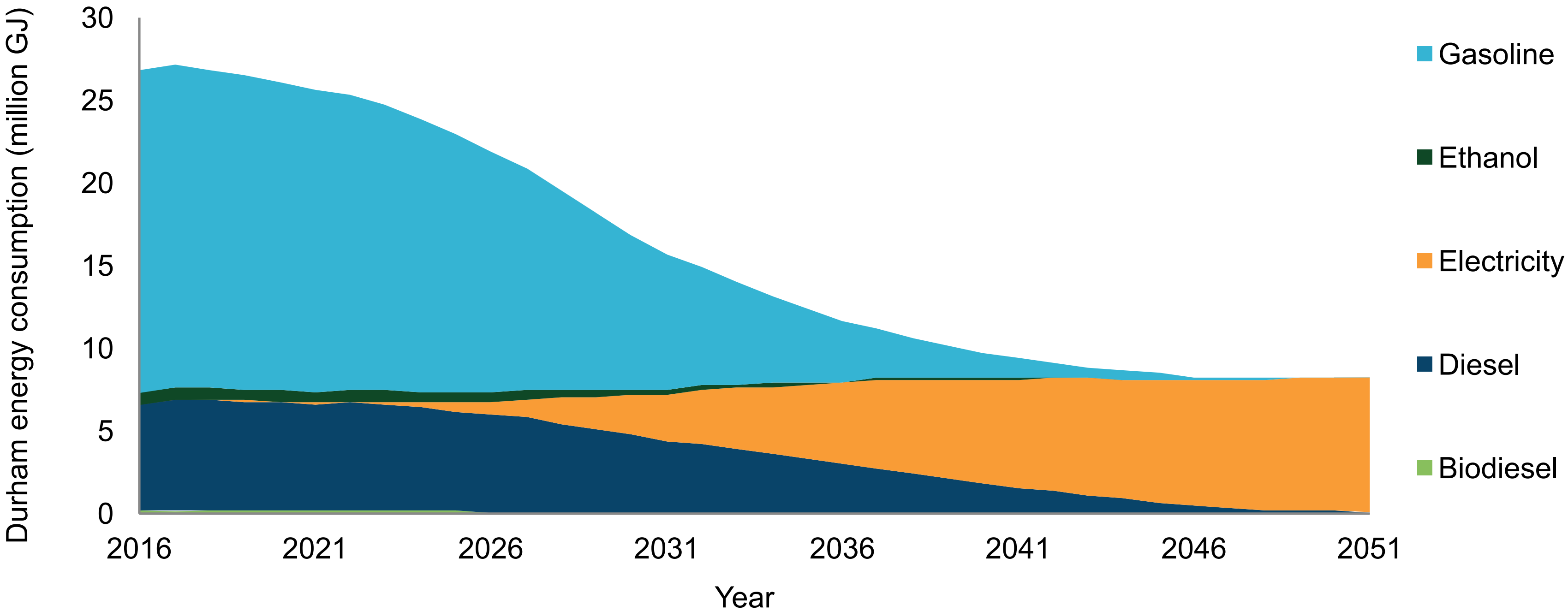

Figure 29. Annual transportation energy by fuel, LCP (2016–2051)

By vehicle type, energy consumption is dominated by light trucks (including sport utility vehicles) in the BAU scenario and by 2050, the portion of energy used by cars declines slightly as they become more efficient at a faster rate than other sectors. Energy consumption of heavy trucks is relatively flat.

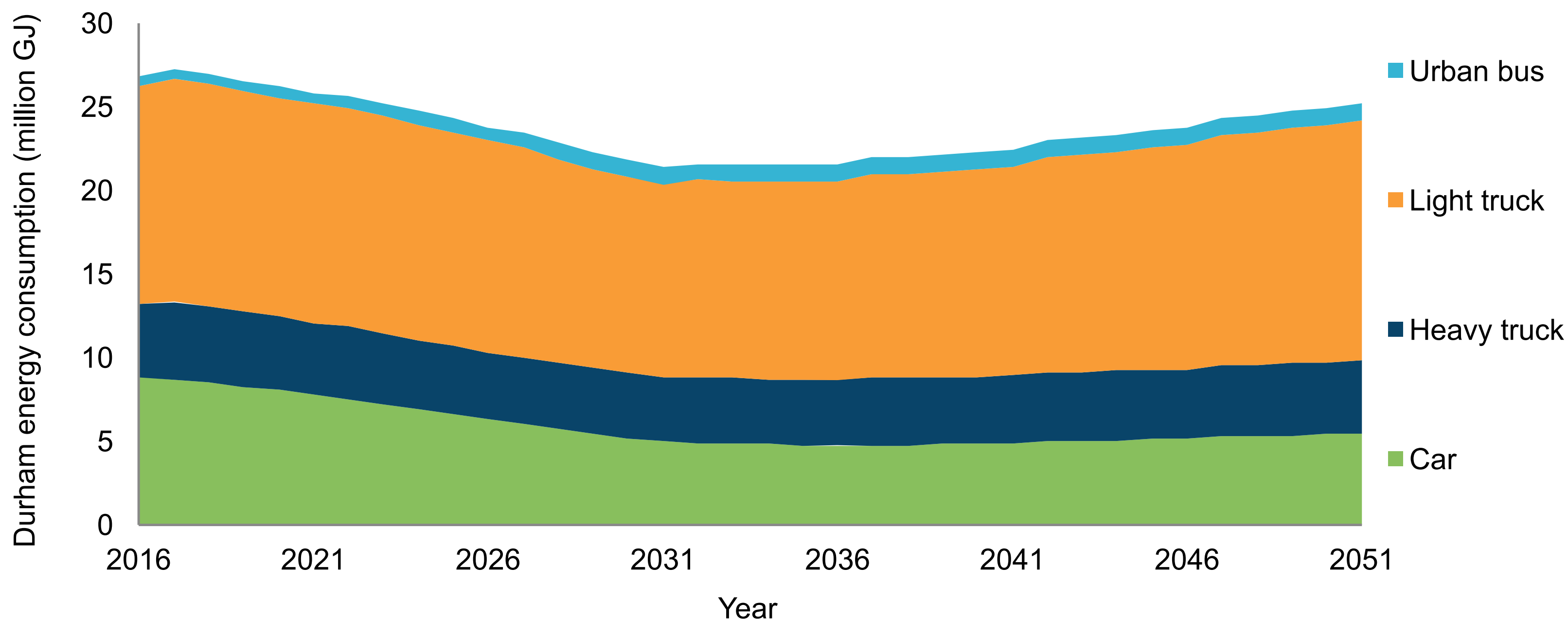

Figure 30. Annual transportation energy by vehicle type, BAU (2016–2051)

In the LCP scenario, the more rapid introduction of electric vehicles decreases overall electricity consumption early on, and across every vehicle type.

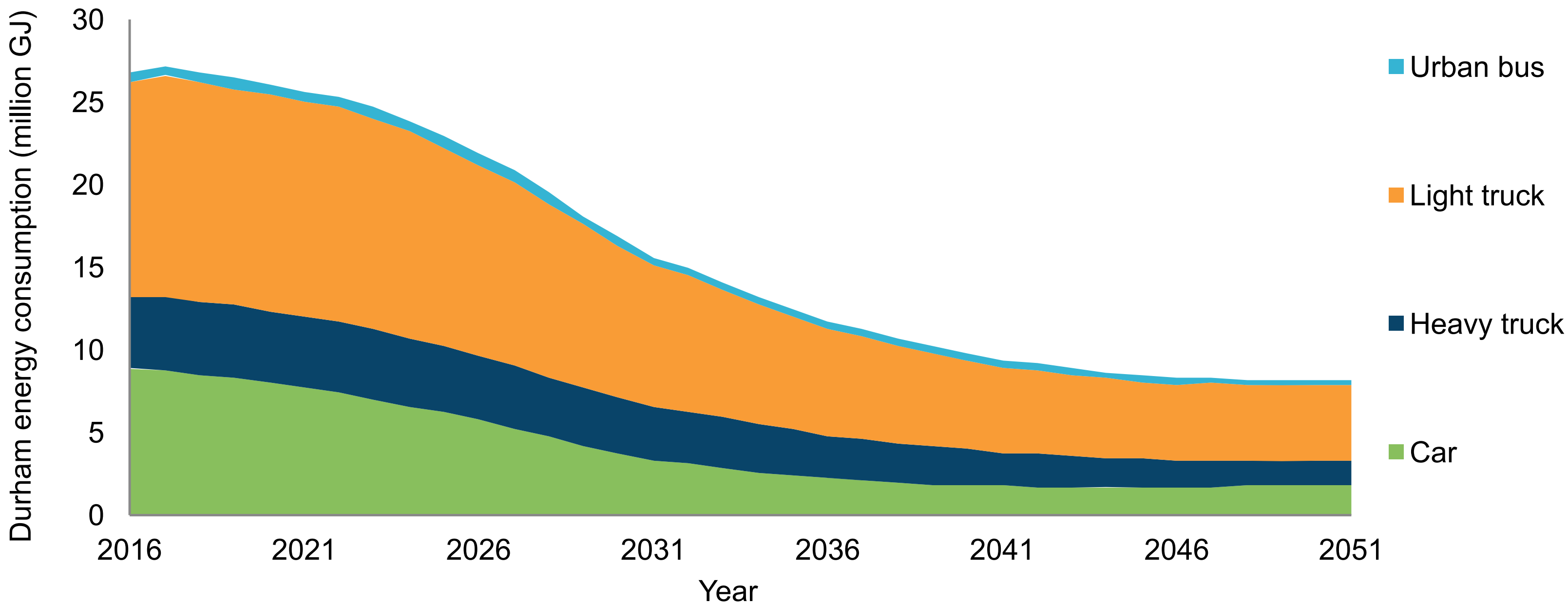

Figure 31. Annual transportation energy by vehicle type, LCP (2016–2051)

4. Financial Analysis Summary

The actions in the low carbon pathway require capital expenditures that result in savings in fuel and electricity costs, operation and maintenance costs, and that result in new sources of revenue from carbon markets and local energy generation. It is a classic case of pay now to save later -- incremental expenditures (as compared with the business-as-usual case) in buildings, vehicles and other energy-related equipment and infrastructure increase costs in the short term in return for long term savings.

As described in more detail below, incremental investments in the low carbon pathway, as compared to the business-as-usual scenario, quickly ramp up to about $1 billion per year in the 2020's. By 2050, the cumulative investment in the low carbon pathway reaches $31 billion with a present value in 2018 of $19.2 billion. As noted earlier, this incremental investment in the LCP occurs against a background level of investment in buildings, vehicles, and energy using equipment and infrastructure that currently totals over $5 billion per year in Durham, and by 2050 accumulates to $165 billion, with a present value of more than $100 billion, using a discount rate of 3%.

On the other side of the ledger are the fuel and electricity cost savings, the monetary value of the carbon reductions from carbon pricing, some specified savings in operation and maintenance costs, and revenue from locally generated energy generation.

The largest contribution to the value of the LCP comes from lower energy bills; by 2050, fuel and electricity expenditures in Durham are $1.4 billion per year lower than in the business-as-usual scenario. Cumulative savings reach $20 billion by 2050, with a present value of $10.1 billion.

Carbon pricing effectively increases the value of fuel and electricity savings, and especially fuel savings, modestly in the first half of the program but more significantly in the later years as the effective carbon price increases. In 2050, the annual carbon “premium” from the LCP reaches $520 million and the cumulative premium over the 2018–2050 period totals $7 billion, with a present value in 2018 of $3.5 billion.

The low carbon pathway includes investments in local energy generation facilities in Durham that generate a steadily growing stream of revenue that reaches $365 million per year by 2050 and a cumulative total $6.4 billion with a present value in 2018 of $3.4 million.

Finally, the low carbon investments also result in lower operation and maintenance costs for all sorts of energy using equipment, partly as the result of the lower demands placed on equipment as the result of more efficient buildings and infrastructure, but more importantly as the result of the lower maintenance costs associated with electric motors as compared to internal combustion engines. These maintenance savings grow strongly in the latter years of the program when electric vehicles are also growing quickly, and by 2050 reach $520 million per year with a cumulative value over the 2018-2050 period of $6.9 billion (net present value of $3.2 billion).

The above five categories of investments, energy savings, carbon credits, O&M savings, and energy generation revenue are summarized in Figure 32 below. On an annual basis, the increased capital expenditures exceed the savings and revenues until the break-even point in the mid 2030’s and then the net benefits begin to exceed the annual investment by an ever widening margin. By 2050, the annual net payback from the plan reaches $2.7 billion per year. By that point the cumulative investment reaches $31 billion as compared to the cumulative benefits of $40.2 billion. As illustrated in Figure 33, the Low Carbon Pathway has a positive net present value in 2018, with energy savings, O&M savings, carbon premiums and local generation revenue more than offsetting the incremental capital investments in the program. Because a greater portion of the savings and revenues occur later in the program as compared to the investments, they are more heavily discounted than the investments. This is a high level summary that includes all the costs and all the benefits of all the measures in the Low Carbon Pathway, over a range of cost effectiveness.

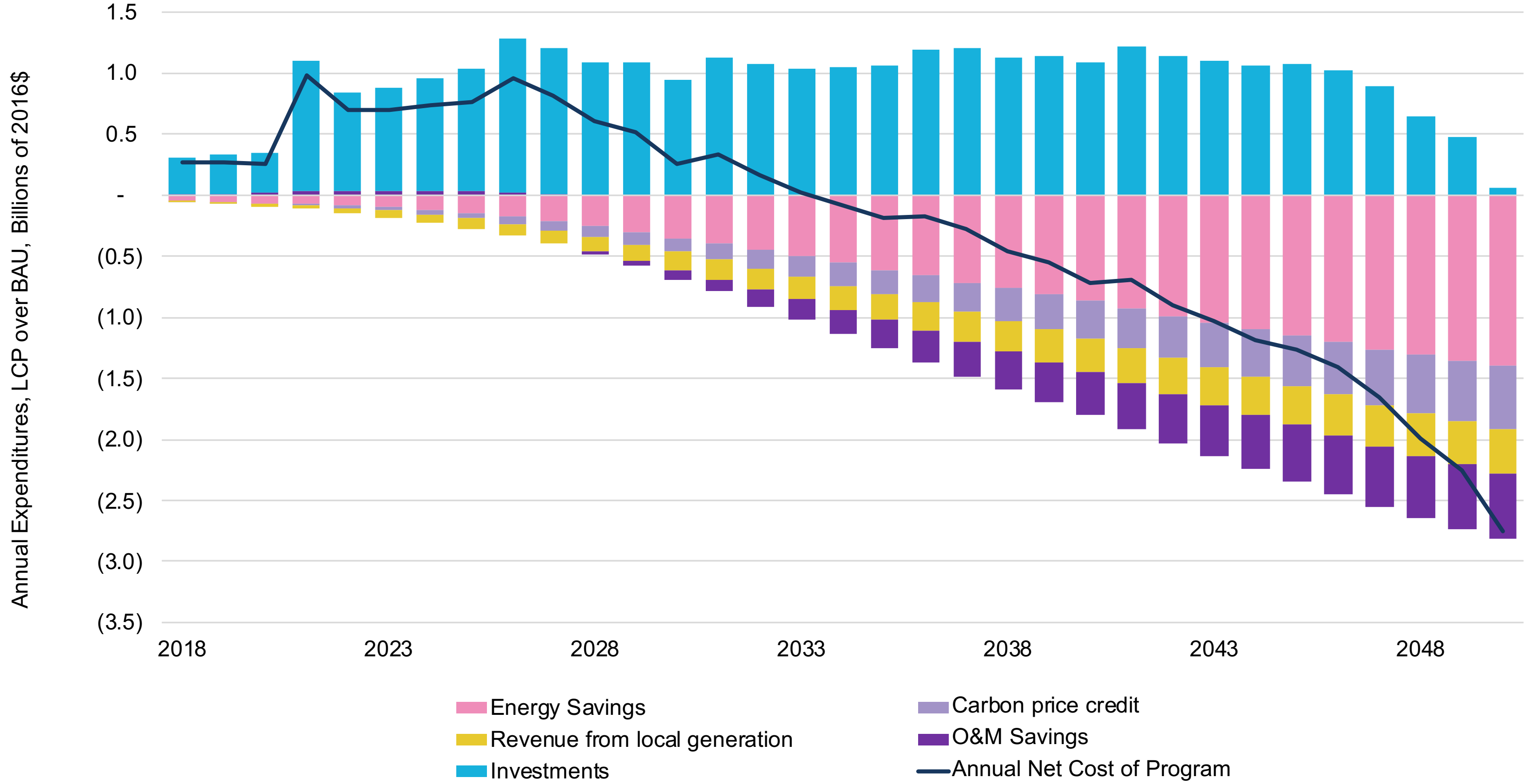

Figure 32. Expenditures, savings and revenues from the LCP, relative to business-as-usual. (Values are presented as costs in this figure, so expenditures are shown above the line and savings and revenue are below the line.)

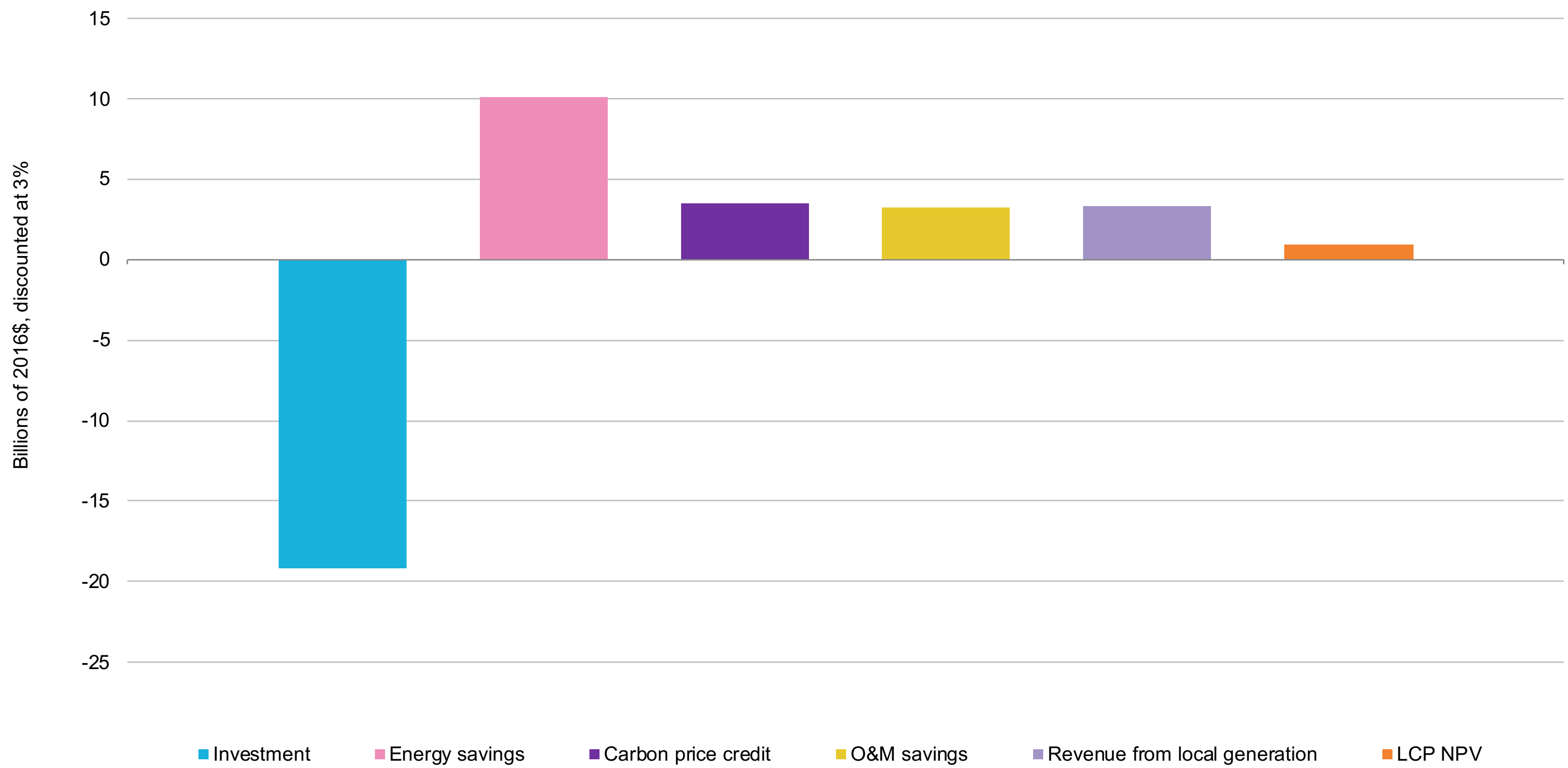

Figure 33. Net present value of expenditures, savings and revenues from the LCP. (This figure shows present value, so costs are shown below the line, and revenues and savings above the line.)

Investments and Expenditures

Total expenditures were evaluated in each of the three scenarios, including capital investments, operating costs (including for fuel and electricity), carbon credits, O&M savings, and revenues from investments in local generation. Table 3 summarizes the categories of expenditures evaluated.

Table 3. Categories of expenditures evaluated

CATEGORY	DESCRIPTION
Residential buildings	Cost of dwelling construction; operating and maintenance costs (non-fuel)
Residential equipment	Cost of appliances and lighting, heating and cooling equipment
Personal use vehicles	Cost of vehicle purchase; operating and maintenance costs (non-fuel)
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; operating and maintenance costs (non-fuel)
Commercial equipment	Cost of lighting, heating and cooling equipment
Commercial vehicles	Cost of vehicle purchase; operating and maintenance costs (non-fuel)
Non-residential fuel	Energy costs
Non-residential emissions	Costs resulting from a carbon price on GHG emissions from dwellings 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

CATEGORY	DESCRIPTION
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. This is treated as a negative expenditure in the analysis.

Capital Investments

The capital costs of the LCP scenario are shown in Figure 34, represented as the incremental additional investments required to implement the actions in the plan. Typically, the incremental investments are positive, but in the case of personal and commercial vehicles there is an exception that arises. In the latter half of the scenario, the electric vehicles that are implemented in the low carbon pathway are projected to cost less than the combustion engine vehicles they replace, thus generating capital savings that are shown in Figure 34 as negative incremental capital costs that are growing quickly in the last few years of the program.

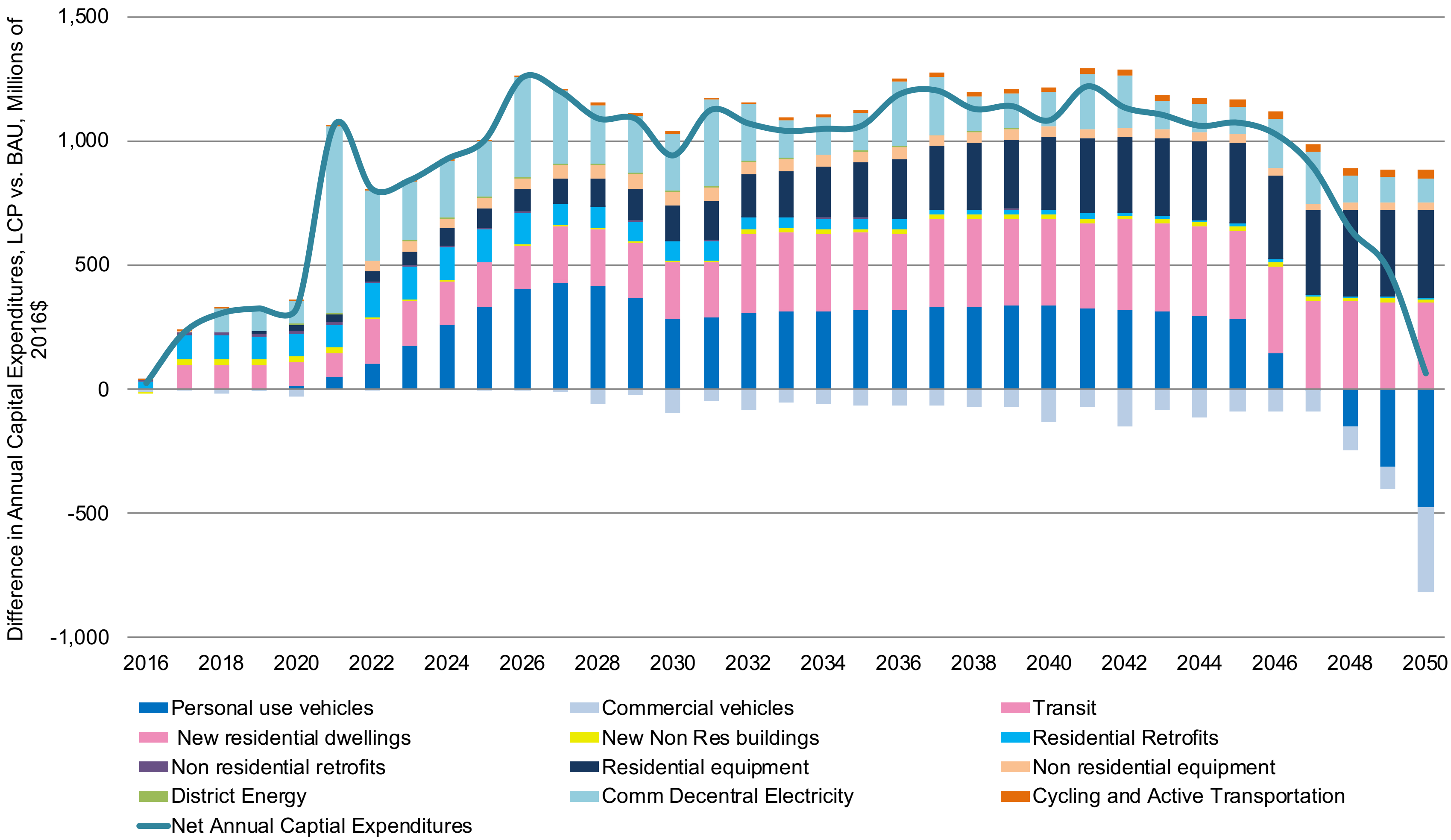

Figure 34. DCEP scenarios, annual incremental capital expenditures, LCP over BAU (2016–2050)

Fuel and Electricity Costs

The fuel and electricity costs for all three scenarios are shown in Figure 35.

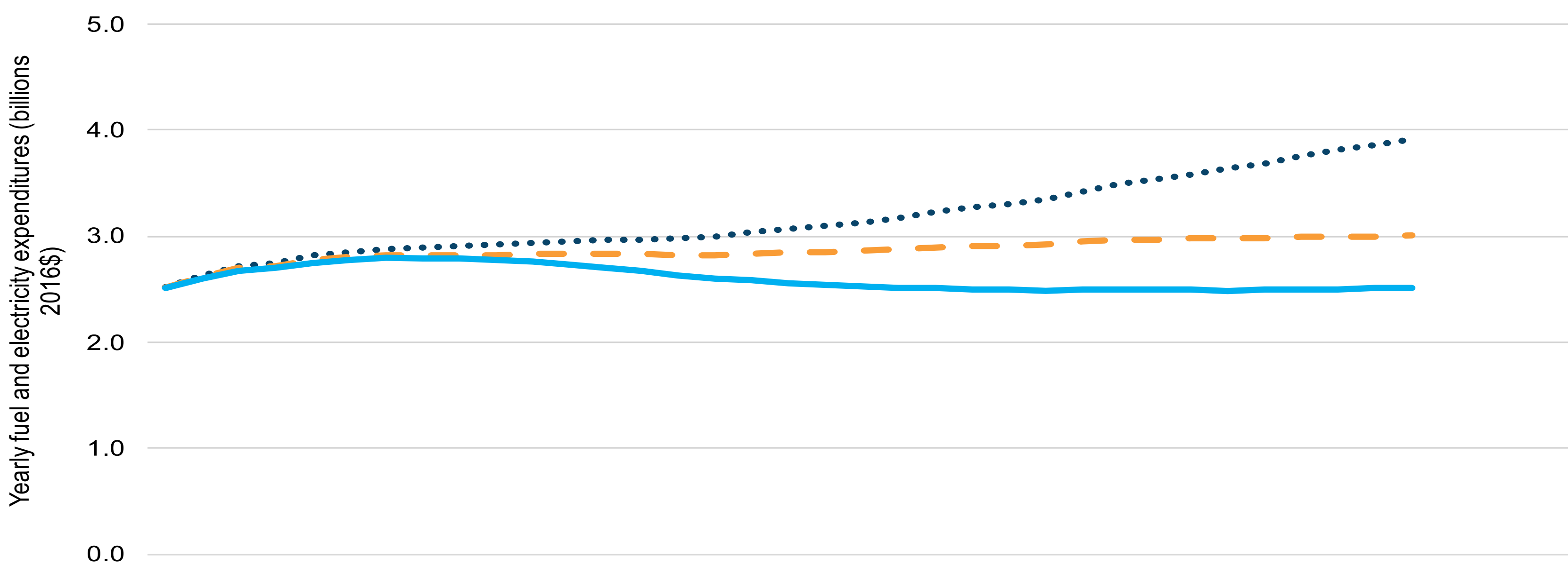

Figure 35. Total annual energy expenditures, all scenarios

In 2018, Durham households, businesses and other organizations paid out $2.5 billion for fuel and electricity. Transportation fuels (gasoline and diesel) account for 45% of this total and electricity costs comprise 36%. Because natural gas is so much cheaper than gasoline and electricity, it contributes only 10% to total energy expenditures in the region, even though it provides 41% of Durham's total energy requirements. In the business-as-usual scenario, energy prices are projected to increase, but ongoing improvements in the efficiency of vehicles and buildings offsets some of the increase so that real growth in total energy spending is 1.1% per year, reaching $3.9 billion by 2050.

In the BAU scenario, the share of expenditures on electricity continues to increase towards 2050, whereas natural gas is relatively flat and gasoline decreases significantly.

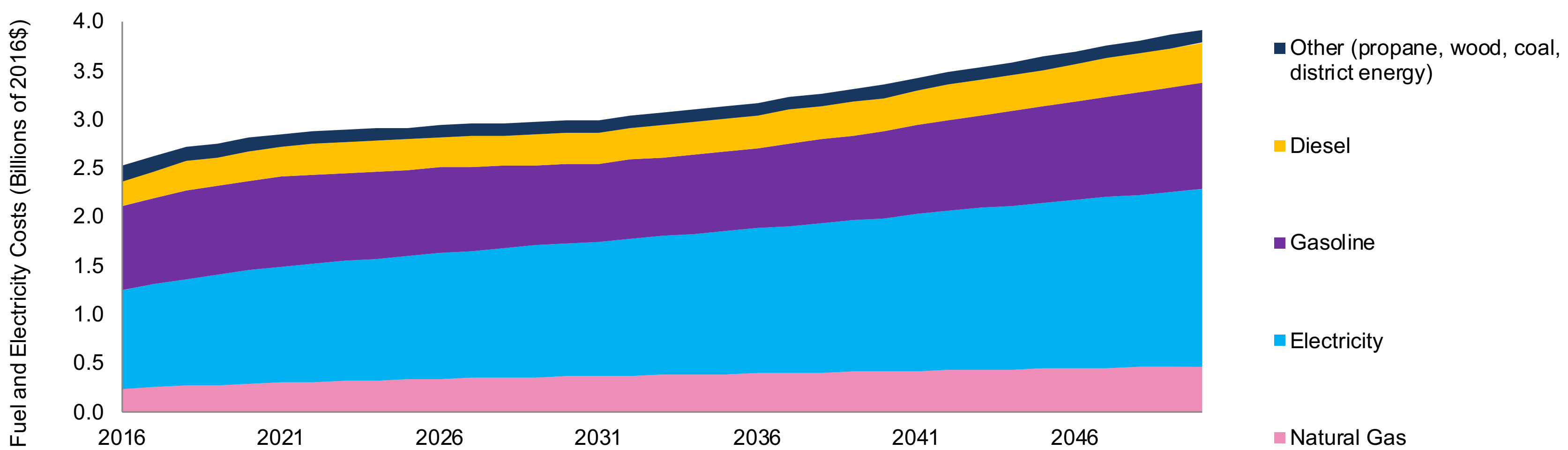

Figure 36. Total annual energy expenditure by fuels, BAU, 2016–2050

In the LCP scenario, nearly 100% of the expenditures are on electricity, with a sliver on natural gas.

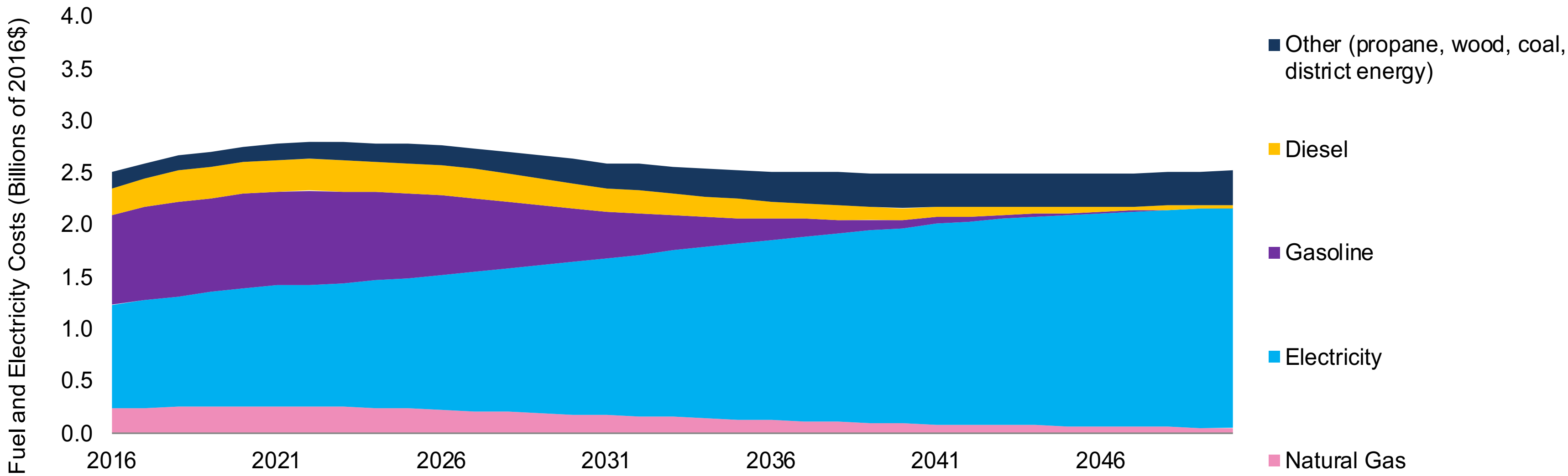

Figure 37. Total annual energy expenditures by fuel, LCP, 2016–2050

Details of Incremental Costs and Saving

Figure 38 provides a detailed year-by-year breakdown of the investments, fuel and electricity savings, carbon premiums, O&M savings, and generation revenue in the low carbon pathway, relative to business-as-usual. This is a more detailed portrayal of the information provided above in Figure 32. As noted in the summary at the beginning of this section, the LCP scenario requires a stream of investments in the range of $1 billion per year and results in a steadily growing stream of energy costs savings, emissions credits and local energy generation revenue.

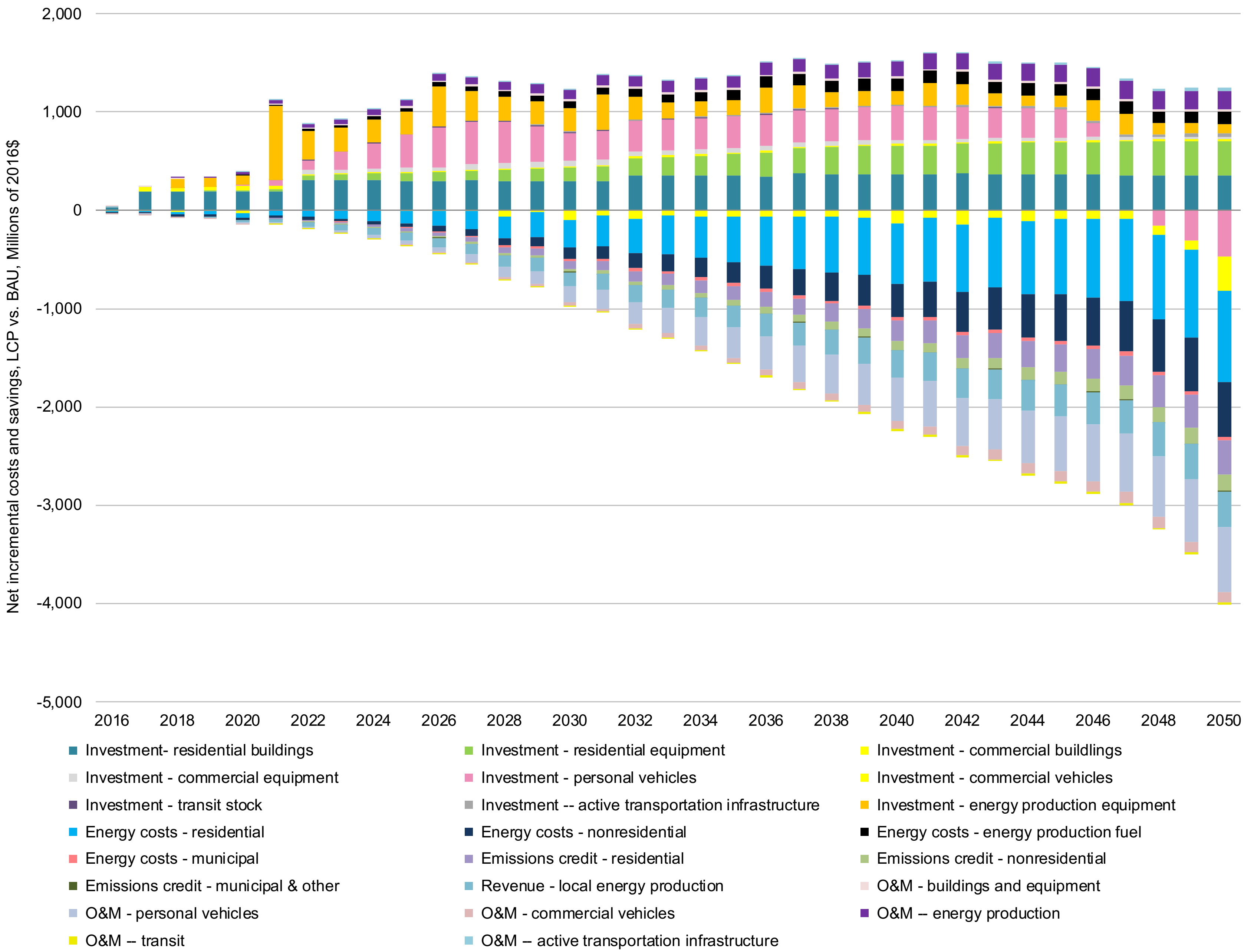

Figure 38. DCEP scenarios, annual incremental expenditures, LCP over BAU (2016–2050)

Context

The incremental investments to put Durham on the low carbon pathway – about $1 billion per year – compare with the $2.5 billion per year that is already being spent on fuel and electricity, a figure that is projected to grow to $3.9 billion per year in the business-as-usual outlook. They represent an even smaller percentage of the baseline levels of investment in Durham for buildings, vehicles and other energy-using equipment. In 2018, Durham households, businesses and other organizations will spend $1.8 billion on new cars and $351 million on commercial vehicles, $1.3 billion on new homes and $1 billion on renovations of existing homes, $709 million on new commercial buildings, and at least another $140 million on other energy-using equipment and infrastructure. In addition, the operations and maintenance of all these buildings, vehicles, equipment and infrastructure totals another $2 billion per year. Combined with the fuel and electricity expenditures, this brings total energy-related spending in Durham to over $9 billion, a figure that is on track to reach $14 billion per year by mid-century, and a cumulative total between now and 2050 of $374 billion. In the LCP scenario, this total would be $4 billion higher, just one percent more than business-as-usual. Add in the carbon price premium and the new revenue from local generation and the total net cost of the Low Carbon Pathway drops below the business-as-usual case by $5 billion before discounting and to about the same overall net cost as business-as-usual after discounting.

Employment

Capital expenditures result in new employment opportunities. Employment factors for each sector are used to translate each million dollars of activity into full-time equivalents. The low carbon scenario is estimated to generate 210,000 person years of employment between 2018 and 2050, or an average of 6,500 per year compared to the BAU.

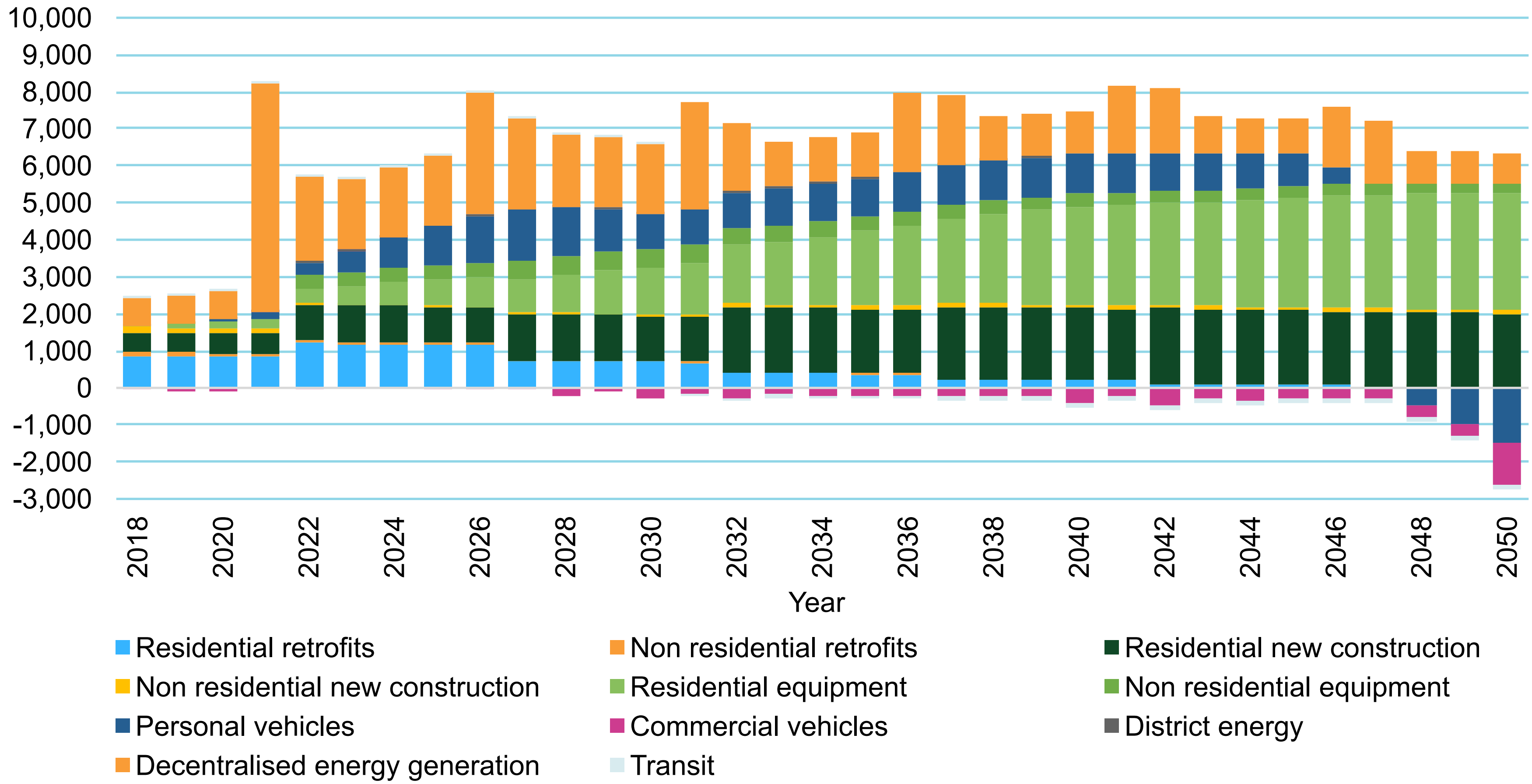

Figure 39. Employment impacts of the LCP scenario

The LCP scenario is estimated to generate 210,000 person years of employment between 2018 and 2050, or an average of 6,500 per year.

Abbreviations

BAP	Business as planned scenario
BAU	Business as usual scenario
CO2	Carbon dioxide
CO2E	Carbon dioxide equivalents
CDD	Cooling degree days
CEP	Community Energy Plan
CH4	Methane
DE	District energy
DCEP	Durham Community Energy Plan
DRT	Durham Regional Transit
GHG	Greenhouse gas emissions
GPC	Global Protocol for Community Scale Greenhouse Gas Emissions Inventories
GWP	Global warming potential
HDD	Heating degree days
LCP	Low carbon pathway scenario
LIC	Local improvement charge
MCA	Multi-criteria analysis
MTO	Ministry of Transportation
NPV	Net present value
OBC	Ontario Building Code
PV	Photovoltaics
RNG	Renewable natural gas
SCC	Social cost of carbon
VKT	Vehicle kilometres travelled

5. Appendices

Appendix 1: Data, methods and assumptions

The modelling for the baseline year 2016, and BAP scenario out to 2050 are completed using CityInSight.

About CityInSight

CityInSight is an integrated energy, emissions and finance model developed by Sustainability Solutions Group (SSG) and whatIf? Technologies Inc. (whatIf?).

It is an integrated, multi-fuel, multi-sector, spatially disaggregated energy systems, emissions and finance model for cities. The model enables bottom-up accounting for energy supply and demand, including renewable resources, conventional fuels, energy consuming technology stocks (e.g. vehicles, appliances, dwellings, buildings) and all intermediate energy flows (e.g. electricity and heat).

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

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

Table 4. Characteristics of CityInSight

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

Model Structure

The major components of the model, and the first level of modelled relationships (influences), are represented by the blue arrows in Figure 40. Additional relationships may be modelled by modifying inputs and assumptions, specified directly by users, or in an automated fashion by code or scripts running “on top of” the base model structure. Feedback relationships are also possible, such as increasing the adoption rate of non-emitting vehicles in order to meet a particular GHG emissions constraint.

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

Stocks and flows

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

Some factors are modelled as stocks – counts of similar things, classified by various properties. For example, population is modelled as a stock of people classified by age and gender. Population change over time is projected by accounting for: the natural aging process, inflows (births, immigration) and outflows (deaths, emigration). The fleet of personal use vehicles, an example of a service technology, is modelled as a stock of vehicles classified by size, engine type and model year, with a similarly classified fuel consumption intensity.

CityInSight
Major Components & Relationships Influence Diagram

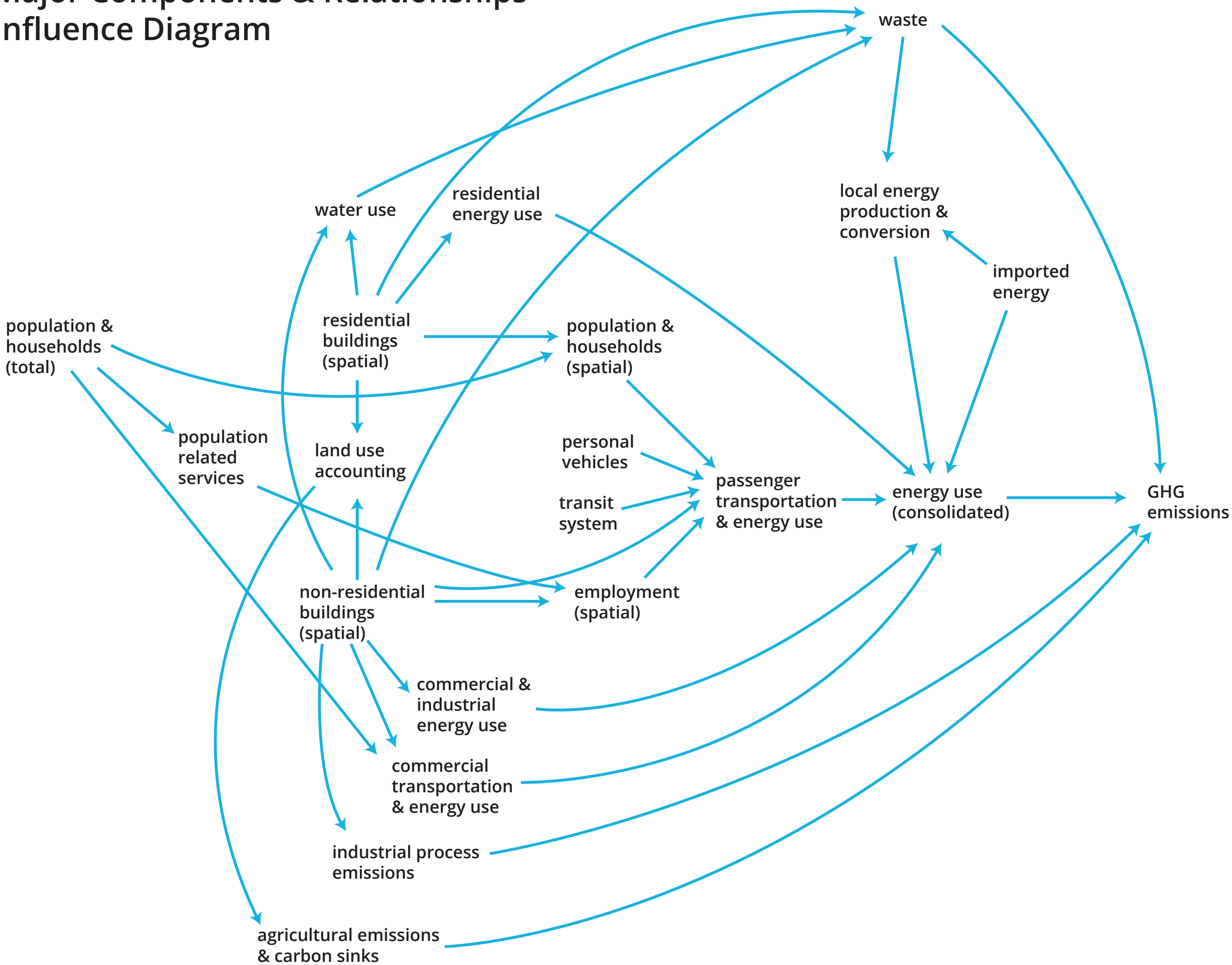

Figure 40. Representation of CityInSight's structure

As with population, projecting change in the vehicle stock involves aging vehicles and accounting for major inflows (new vehicle sales) and major outflows (vehicle discards). This stock-turnover approach is applied to other service technologies (e.g. furnaces, water heaters) and also harvesting technologies (e.g. electricity generating capacity).

Sub-models

POPULATION AND DEMOGRAPHICS

City-wide population is modelled using the standard population cohort-survival method, disaggregated by single year of age and gender. It accounts for various components of change: births, deaths, immigration and emigration. The age structured population is important for analysis of demographic trends, generational differences and implications for shifting energy use patterns.

RESIDENTIAL BUILDINGS

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

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

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

NON-RESIDENTIAL BUILDINGS

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

SPATIAL POPULATION AND EMPLOYMENT

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

Passenger Transportation

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

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

WASTE

Households and non-residential buildings generate solid waste and wastewater, and the model traces various pathways to disposal, compost and sludge including those which capture energy from incineration and recovered gas. Emissions accounting is performed throughout the waste sub-model.

ENERGY FLOW AND LOCAL ENERGY PRODUCTION

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

FINANCE AND EMPLOYMENT

Energy-related financial flows and employment impacts (though not shown explicitly in Figure 40) are captured through an additional layer of model logic. Calculated financial flows include the capital, operating and maintenance cost of energy-consuming stocks and energy-producing stocks, including fuel costs. Employment related to the construction of new buildings, retrofit activities and energy infrastructure is modelled.

Modelling Process

Data request and collection

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

Setting up the model

POPULATION AND EMPLOYMENT

Population and employment data is sourced directly from the Region to 2031, and spatially allocated to residential (population) and non-residential (employment) buildings. Population and employment is allocated spatially primarily to enable indicators to be derived from the model, such as emissions per household, and to drive the BAP energy and emissions projections (buildings, transportation, waste).

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

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

ZONE SYSTEM

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

The population, employment and floorspace forecasts, as well as baseline and projected transportation modelling results, were provided by the Region of Durham at the transportation zone level to the year 2031. The Region uses an established transportation zone system to allocate population and employment for planning purposes.

As such, the transportation zone system for the Region of Durham was adopted as CityInSight's zone system, the primary spatial unit of analysis.

BUILDINGS

Buildings data, including building type, building footprint area, number of storeys, total floorspace area, number of units, and year built, was sourced from the Region of Durham's Municipal Property Assessment (MPAC) data for 2016.

Using the spatial attributes of the MPAC data, buildings were allocated to specific zones, based on the zone system for the Region of Durham.

Subsequently, buildings were classified using a detailed set of building archetypes: 30+ archetypes for residential and 50+ archetypes for non-residential. These archetypes capture footprint, height and type (eg. single family home, semi-attached home), enabling the creation of a "box" model of buildings, and an estimate of surface area for all buildings.

Residential buildings

The model multiplies the residential building surface area by an estimated thermal conductance (heat flow per unit surface area per degree day) and the number of degree days to derive the energy transferred out of the building during winter months and into the building during summer summer months. The energy transferred through the building envelope, the solar gain through the building windows, and the wild heat gains from equipment inside the building constitute the space conditioning load to be provided by the heat systems and the air conditioning. The initial thermal conductance estimate is a provincial average by dwelling type from the Canadian Energy System Simulator (CanESS).[1]

Non-residential buildings

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

Starting values for output energy intensities and equipment efficiencies for other residential and non-residential end uses are also provincial averages from CanESS. All parameter estimates are further adjusted during the calibration process (see Buildings calibration).

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

TRANSPORTATION

Data from the GTA-wide 2011 Transportation Tomorrow Survey[2] (TTS) is analyzed with respect to passenger trips to, from and within the Region of Durham; at the time of the analysis the 2016 TTS data was not available, so 2011 is used. The TTS zone system and the city's traffic

1 Canadian Energy Systems Analysis Research. *Canadian Energy System Simulator*. http://www.cesarnet.ca/research/caness-model.
2 http://www.transportationtomorrow.on.ca/

zone system is identical, and therefore the same as the zone system used for the Durham CityInSight.

Several key model parameters are calculated from the TTS data: trip generation rates, origin-destination patterns for trip distribution within the city, shares for external (inbound and outbound) trips, and mode share assumptions for each origin-destination zone pair and external trips.

WASTE

Solid waste stream composition and routing data (landfill, composting, recycling) is sourced from the Region. The base carbon content in landfill is estimated based on historical waste production data. Total methane emissions are estimated using the first order decay model, with the methane generation constant and methane correction factor set to default, as recommended by and based on values from IPCC Guidelines for landfill emissions.3

Calibration

BUILDINGS CALIBRATION

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

TRANSPORTATION CALIBRATION

Unlike utility-reported stationary energy consumption totals (e.g. electricity, natural gas) transportation fuel sales data is not a preferred control total for municipal transportation activity and energy analysis, due to the uncertainty of estimating point of fuel consumption based on retail point of fuel purchase. Therefore, calibration of the passenger transportation model is anchored with the household survey informing the spatial travel demand model and the results compared for reasonableness against indicators such as average annual VKT per

3 Landfill emissions: *IPCC Guidelines Vol 5*. Ch 3, Equation 3.1

vehicle. For medium-heavy duty commercial vehicle transportation, the diesel fuel sales[4] for Durham are used as a control total – along with an assumed retail/non-retail ratio – due to the absence of other data sources for local commercial transportation activity.

The modelled stock of personal vehicles (by size, fuel type, efficiency, vintage) is informed by the CanESS model.

The transit vehicle fleet, VKT and fuel consumption is modelled on data provided by the Region.

The modelled 2016 spatial transportation-driver variables – population, employment, non-residential floorspace – are applied to the transportation model with parameters estimated from the 2011 TTS data. This is intended to reflect the transportation impacts of recent growth and development.

Baseline

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

4 Kent Group Ltd.

Business as planned

ABOUT THE BAP

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

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

THE BAP PROCESS

The BAP scenario is established through developing assumptions as follows:

- Incorporating existing quantitative projections directly into the model when available. This includes:

a. From the Region:

b. Population and employment projections by zone until 2031;

c. From other technical sources:

  - Ontario building code and new building energy performance standards
  - Electricity grid emissions factor
  - Climate projections for heating/cooling degree days
  - Vehicle efficiency standards
  - Electric vehicle uptake projections

- Where quantitative projections are not carried through to 2050 (eg. completed to 2031), the projected trend is extrapolated to 2050.
- Where specific quantitative projections are not available, projections are derived using proxy or related data, and continuing with the existing trend; this included:

  - Building floorspace projections, derived using the population and employment projections and allocating new dwellings based on existing persons per unit (for residential), and floorspace (m2) per employee/job (for non-residential space).
  - Waste projections, derived using population projections and applying existing waste production rates (tonnes waste/person).
  - The BAP methodology and assumptions for the major model components are summarized. Further details and sources of data can be found in *BAP data and assumptions*.

Table 5. Key assumptions

	DATA/ ASSUMPTION	SOURCE	SUMMARY APPROACH/METHODOLOGY
DEMOGRAPHICS			
Population & employment			
Population & employment		Region of Durham; population & employment projections to 2031.	Population and employment projections by zone to 2050 are applied and spatially allocated in the model. 2016 population number includes estimated census undercount. Post-2031 projections and spatial allocation are not available from the Region or Area Municipalities. The population and employment trends for 2017–2031 are extrapolated to get totals for 2050. Spatial allocation of post-2031 population and employment are distributed according to similar patterns of growth exhibited between 2017 and 2031.

	DATA/ ASSUMPTION	SOURCE	SUMMARY APPROACH/METHODOLOGY
BUILDINGS			
New buildings growth			
Building growth projections	No data from the Region or other. Derived by the model.		Buildings floorspace (residential & non-residential) by zone to 2050 is derived using the population and employment projections provided by the City. New residential floorspace (households/dwellings) is derived by allocating new dwellings based on the existing persons per unit. New dwellings by type are allocated to zones: - if zone already has dwellings, the existing dwelling type share is used for new builds - if zone does not have dwellings, existing dwelling type share from nearby zones is used for new builds - if population in a zone is projected to decrease, dwellings are removed - greenfield vs. infill designation is based on the Neptis Foundation GIS data New non-residential floorspace is derived by allocating new non-residential floorspace according to gross floor area per employee/job. New non-residential floorspace by type is allocated to zones - if zone already has employment, the existing employment sector shares are used along with gross floor area per employee - if zone does not have any employment, the employment shares from nearby zones are used along with gross floor area per employee - if employment in a zone decreases, non-residential buildings are removed - greenfield vs. infill designation is based on the Neptis Foundation GIS data

	DATA/ ASSUMPTION	SOURCE	SUMMARY APPROACH/METHODOLOGY
New buildings energy performance			
Residential	New construction 15% more efficient every 5 years starting in 2018.	City of Toronto. Toronto Green Standard Version 2. Toronto Atmospheric Fund. Internal analysis. Received through email correspondence.	Toronto Green Standard (TGS) analysis by The Atmospheric Fund (TAF) indicates that by 2017, the Ontario Building Code (OBC) will be the equivalent of TGS v2 Tier 1. The modelling approach assumes that OBC evolution will follow TGS evolution with a 5-year lag. Based on modelled energy use intensity improvements, the incremental performance improvement for TGS v2 Tier 1 and TGS v3 Tier 1 are 13–15% and 20–40%, respectively. The modelling for all new construction assumes a 15% improvement every 5 years.
Multi-residential	New construction 15% more efficient every 5 years starting in 2018.		
Commercial & Institutional	New construction 15% more efficient every 5 years starting in 2018.		
Industrial	New construction 15% more efficient every 5 years starting in 2018.		
Existing buildings energy performance			
Residential	Existing building stock efficiency unchanged; efficiency held constant from 2016–2050.		Baseline efficiencies for each building type are derived in the model through calibration with observed data; for existing buildings, no improvements in efficiency are applied.
Multi-residential			
Commercial & Institutional			
Industrial			

	DATA/ ASSUMPTION	SOURCE	SUMMARY APPROACH/METHODOLOGY
End use			
Space heating	Fuel shares for end use unchanged; held from 2016–2050.	Canadian Energy Systems Analysis Research. Canadian Energy System Simulator. http://www.cesarnet.ca/research/caness-model	Within the model, the starting point for fuel shares by end use is an Ontario average value for the given building type, which comes from CanESS. From there, the fuel shares are calibrated to track on observed natural gas and electricity use. Once calibrated, end use shares are held constant through the BAP.
Water heating			
Space cooling			
Projected climate impacts			
Heating & cooling degree days	Heating degree days (HDD) decrease and cooling degree days (CDD) increase from 2016–2050.	SENES Consultants (2014). Durham Region's Future Climate (2040–2049) Summary	To account for the influence of projected climate change, energy use was adjusted according to the number of heating and cooling degree days. The projection only includes the time periods of 2000–2009 and 2040–2049 so a trend line was interpolated between those two periods.

	DATA/ ASSUMPTION	SOURCE	SUMMARY APPROACH/METHODOLOGY
Grid electricity emissions			
Grid electricity emissions factor	2016: 50.8 gCO2e/ kWh 2050: 76.4 gCO2e/ kwh 2016: CO2: 28.9 g/kWh CH4: 0.007 g/kWh N2O: 0.001 g/kWh 2050: CO2: 37.4 g/kWh CH4: 0.009 g/kWh N2O: 0.001 g/kWh	National Energy Board. (2016). Canada's Energy Future 2016. Government of Canada. Retrieved from https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016pt/nrgyftrs_rprt-2016-eng.pdf	Electricity generation input variables are sourced from CanESS and are set on the basis of a combination of NEB's Energy Future 2016 projected electricity generation capacity for Ontario, and IESO capacity factors that specify the planned deployment of that capacity
ENERGY GENERATION			
Local energy generation			
Solar PV		Region provided data.	Generation is derived assuming solar capacity is available 8,760 hr/year and using a capacity factor of 0.16. Solar capacity in 2016 is held constant to 2050.

	DATA/ ASSUMPTION	SOURCE	SUMMARY APPROACH/METHODOLOGY
TRANSPORTATION			
Transit			
Expansion of transit	Transit expansion assumed according to regional projections. 2016–2031.		Transit share reflects regional projections as included within origin-destination matrices provided by the Region.
Electric vehicle transit fleet	No electrification of transit vehicle fleet assumed 2016–2050.		No electrification of transit vehicle fleet assumed 2016–2050.
Active			
Cycling & walking infrastructure	No expansion of active transportation infrastructure assumed in BAP.		No change in active transportation mode share assumed 2016-2050.
Private & commercial vehicles			
Vehicle kilometres travelled	Derived by the model.		Vehicle kilometres travelled projections are driven by buildings projections. The number and location of dwellings and non-residential buildings over time in the BAP drive the total number of internal and external person trips. Person trips are converted to vehicle trips using the baseline vehicle occupancy. Vehicle kilometres travelled is calculated from vehicle trips using the baseline distances between zones and average external trip distances.

	DATA/ ASSUMPTION	SOURCE	SUMMARY APPROACH/METHODOLOGY
Vehicle fuel efficiencies	Vehicle fuel consumption rates reflect the implementation of the U.S. Corporate Average Fuel Economy (CAFE) Fuel Standard for Light-Duty Vehicles, and Phase 1 and Phase 2 of EPA HDV Fuel Standards for Medium- and Heavy-Duty Vehicles.	EPA. (2012). EPA and NHTSA set standards to reduce 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 http://www.nhtsa.gov/fuel-economy	Fuel efficiency standards are applied to all new vehicle stocks starting in 2016.
Vehicle share	Personal vehicle stock share changes between 2016 and 2050. Commercial vehicle stock unchanged 2016–2050.	CANSIM and Natural Resources Canada's Demand and Policy Analysis Division.	The total number of personal use and corporate vehicles is proportional to the projected number of households in the BAP.

	DATA/ ASSUMPTION	SOURCE	SUMMARY APPROACH/METHODOLOGY
Electric vehicles		Government of Ontario. (2013). Long Term Energy Plan.	Incrementally increase EVs in personal use vehicle stock starting in 2016 so that by 2020, EVs constitute 4% of all new personal use vehicles. By 2035, the personal use vehicle stock will include over 11,000 electric vehicles (based on LTEP projections of 1 million EVs in Ontario by 2035, pro-rata to Durham population).
WASTE			
Waste generation	Existing per capita waste generation rates unchanged.		Waste generation per capita held constant from 2016–2050.
Waste diversion	Existing waste diversion rates unchanged.		Waste diversion rates held constant from 2016–2050.
Waste treatment	Existing waste treatment processes unchanged.		No change in waste treatment processes assumed 2016–2050.

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

Population, employment and buildings

The BAP energy and emissions profile is generated through:

- Applying the population and employment projections into the future, provided by the Region;
- Identifying new residential floorspace (households/dwellings) to house the projected population; this is derived by allocating new dwellings based on the existing persons per unit;
- Identifying new non-residential floorspace to accommodate projected employment; this is derived by allocating new non-residential floorspace according to gross floor area per employee/job;
- New residential and non-residential floorspace is spatially allocated according to existing and projected growth/land-use plans.

People drive the requirement for energy services; more people equates to a greater requirement for energy. However, energy efficiency can be improved and low or zero carbon energy sources can be introduced. In 2016, the Region of Durham's population was 720,505 people[5], following a period of rapid growth for more than 20 years. The Province of Ontario projects that this growth will continue until 2031. CityInSight's demographic model was used to continue the Province's trend until 2050. By 2050, the population reaches 1,391,379 people, nearly doubling the 2016 population.

5 The population in the modelling result varies slightly in comparison with the 2016 census result because the Official Plan projections have not been adjusted to reflect the lower growth rates in the 2016 census.

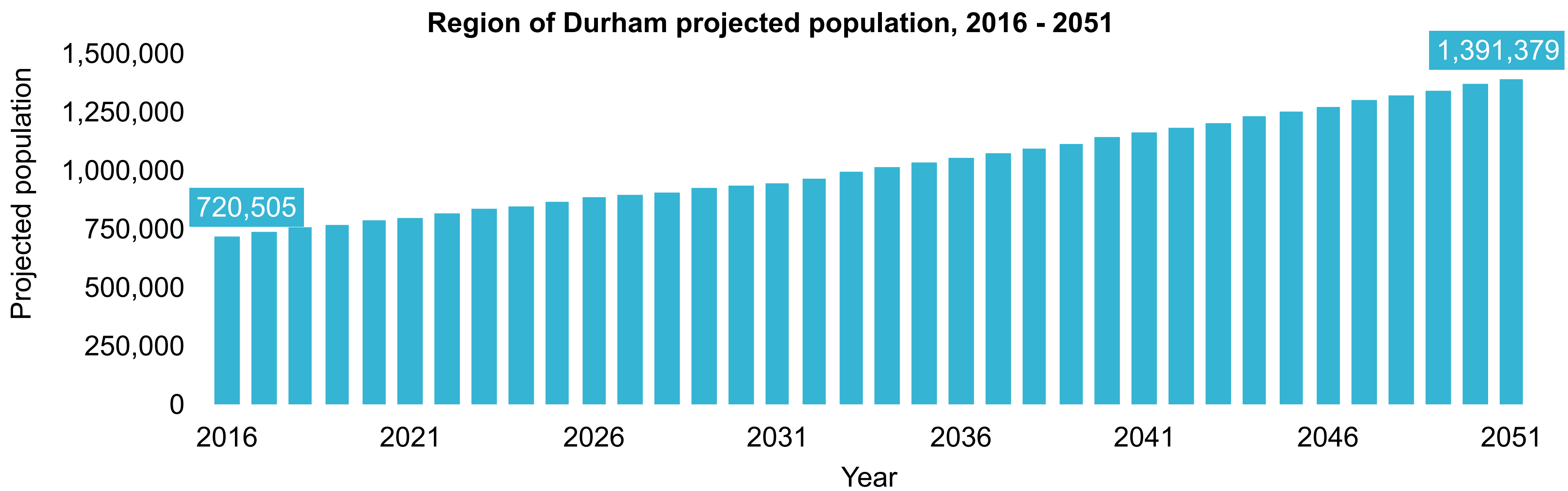

Figure 41. Projected population, 2016–2050

Employment in Durham is also projected to almost double, increasing from 230,697 jobs in 2016 to 403,261 jobs in 2050.

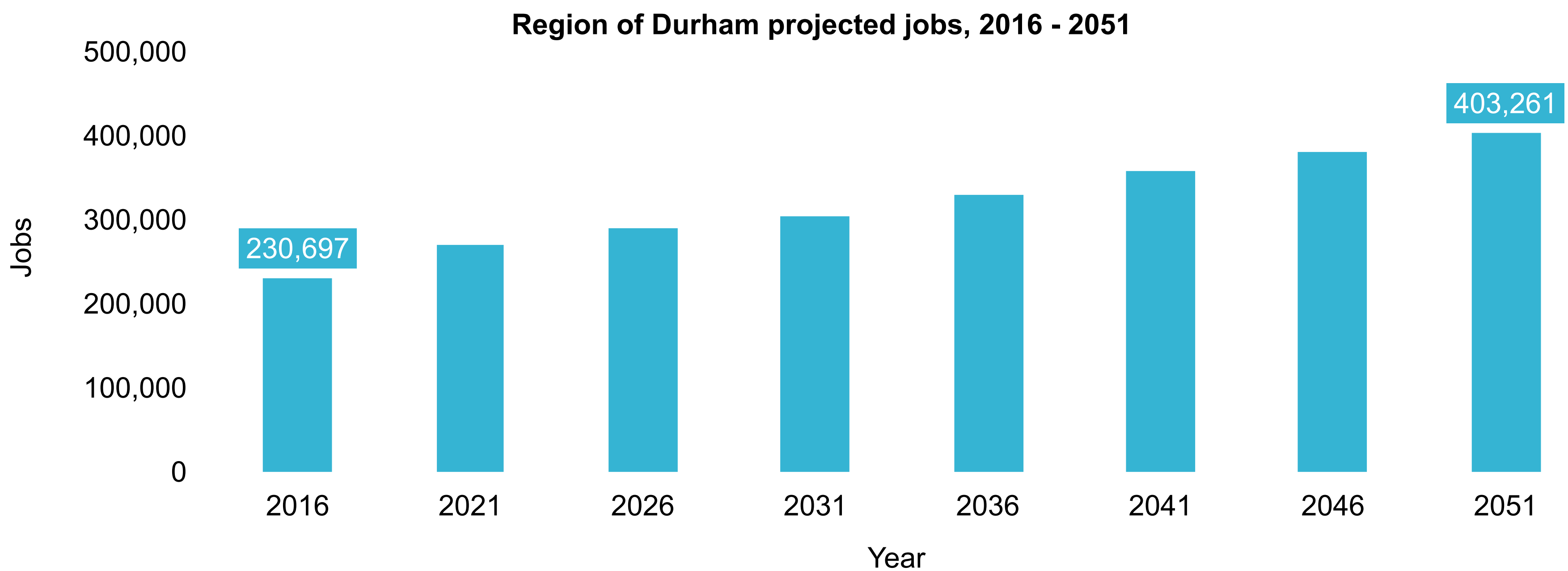

Figure 42. Projected employment, 2016–2050

In 2016, Durham had 241,616 households and by 2050, the total is projected to be 503,758. The number of people per household declines from just under 3 people per household to 2.75 people per household by 2050.

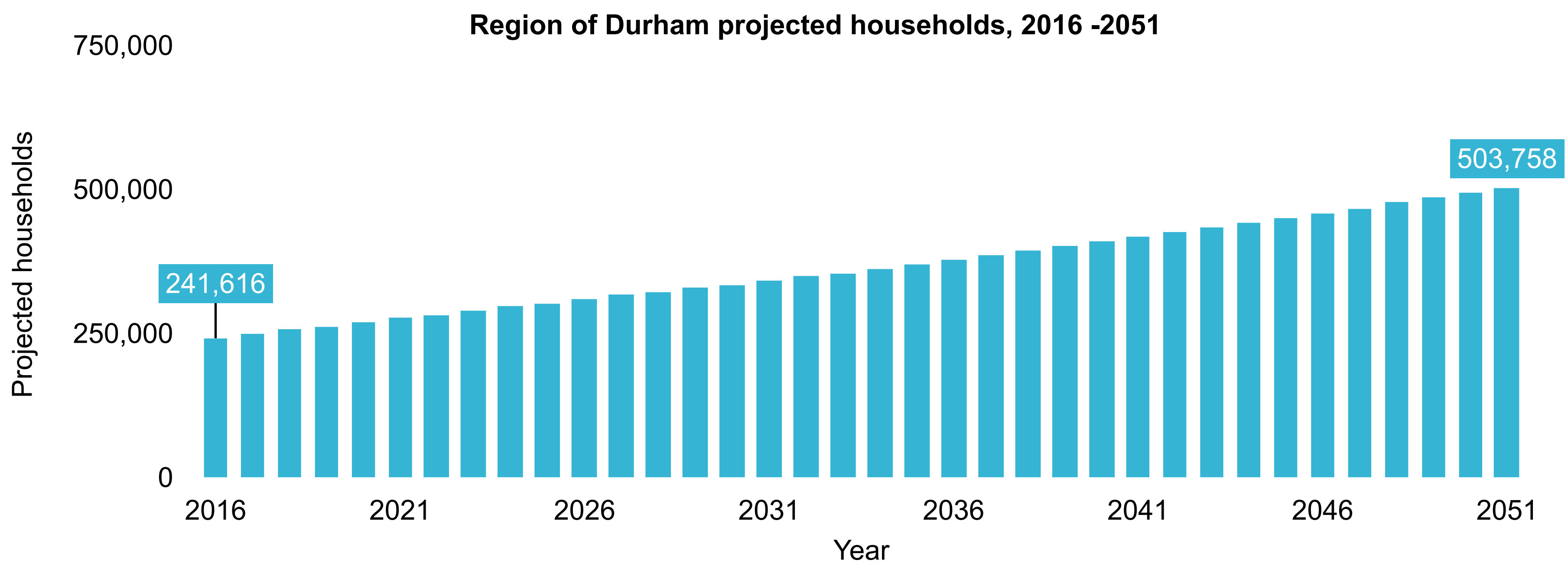

Figure 43. Projected households, 2016–2050

Buildings performance

New construction: Toronto Green Standard (TGS) analysis by The Atmospheric Fund (TAF) indicates that by 2017, the Ontario Building Code (OBC) will be the equivalent of TGS v2 Tier 1. The modelling approach assumes that OBC evolution will follow TGS evolution with a 5-year lag. Based on modelled energy use intensity improvements, the incremental performance improvement for TGS v2 Tier 1 and TGS v3 Tier 1 are 13–15% and 20–40%, respectively. The modelling for all new construction assumes a 15% improvement every 5 years.

Existing buildings: The efficiency of the existing building stock was assumed to remain unchanged; efficiency was held constant from 2016–2050. Retrofits were introduced at the rate of 200 residential dwellings, climbing to 400 by 2030 at which point the rate was held constant. Average savings were 1,500 kWh per household.

Climate projections

To account for the influence of projected climate change, energy use is adjusted according to the number of heating and cooling degree days. A projection developed for the City of Toronto by SENES Consultants Ltd. is applied. Because the projection only includes the time periods of 2000–2009 and 2040–2049, a trend line is interpolated between those two periods (Figure 44). This projection indicates a decrease in heating degree days (HDD), and an increase in cooling degree days (CDD) as the climate continues to warm towards 2050. A decrease in the number of heating degree days (the number of degrees that a day's average temperature is below 18^{o} Celsius, at which buildings need to be heated) results in a reduction in the amount of energy required for space heating. This increase is partially offset by an increase in the number of cooling days (the temperature at which buildings start to use air conditioning for cooling), which results in an increase in energy usage.

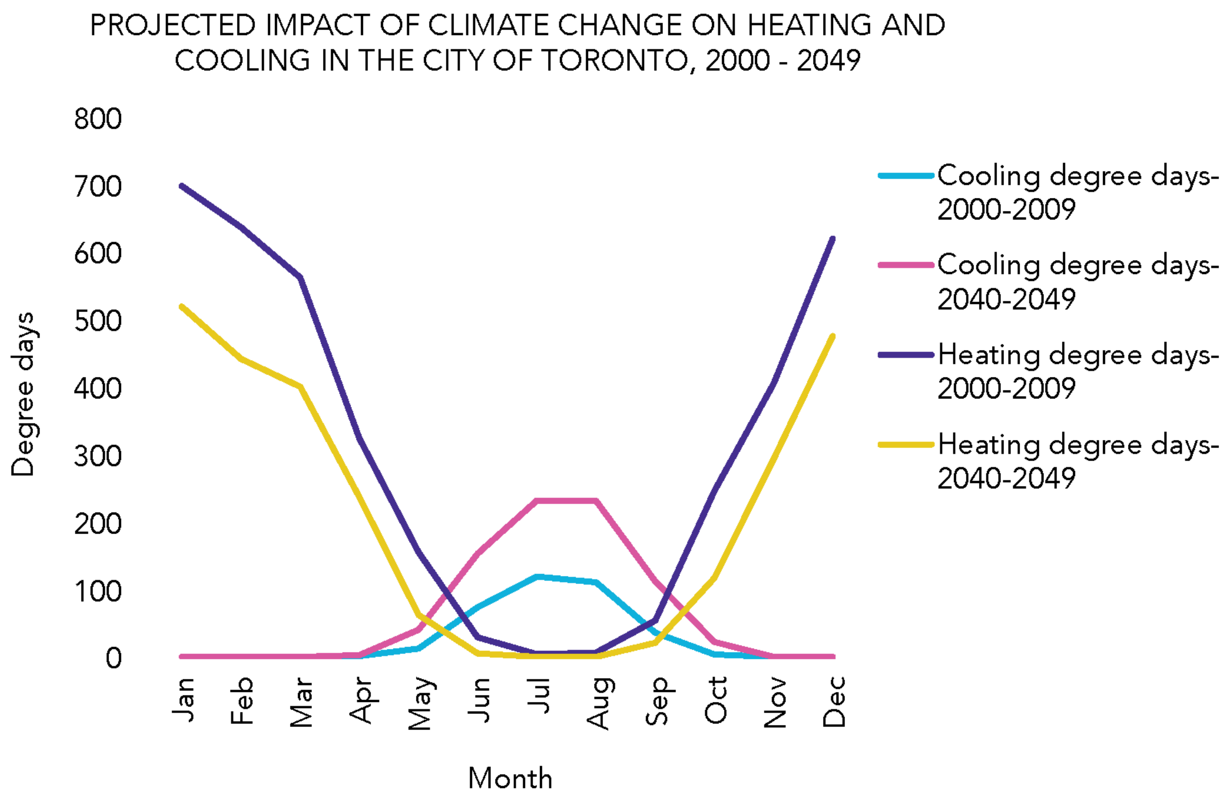

Figure 44. Projected heating and cooling degree days in 2000–2009 and 2040–2049

Grid emissions

For the BAP scenario, the electricity generation input variables are set on the basis of a combination of NEB's Energy Future 2016 projected electricity generation capacity for Ontario, and IESO capacity factors that specify the planned deployment of that capacity. This scenario assumes: the Pickering generation units are decommissioned between 2022 and 2024, while refurbishments of the remaining nuclear facilities mostly occur in the 2020s; wind, solar and natural gas increase in capacity from 2016 to 2025; from 2016 onwards there is a slight increase in carbon intensity as nuclear loses some of its share; and, post 2035 fossil fuel based electricity generation (natural gas) is maintained at 2035 levels, and all increases in capacity, required due to increases in demand, is non-fossil fuel based, resulting in a constant carbon intensity post 2035 (Figure 45). The resulting Ontario grid carbon intensity closely aligns with the emission and generation projection of Outlook B presented in the 2016 IESO Ontario Planning Outlook (OPO)6.

6 http://www.ieso.ca/en/sector-participants/planning-and-forecasting/ontario-planning-outlook

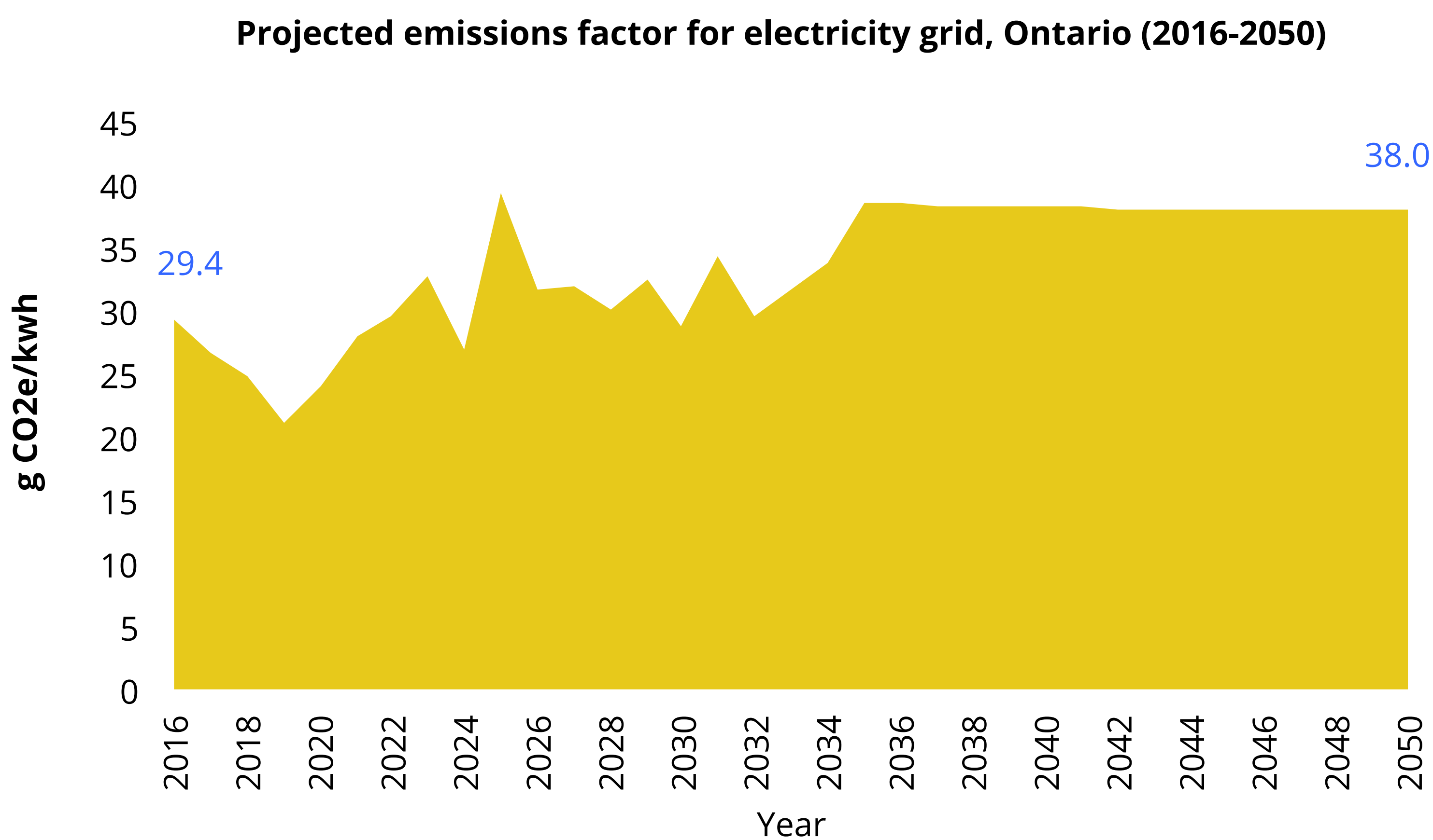

Figure 45. Projected emissions factor for electricity grid, Ontario (2016–2050)

Transportation

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

For vehicle stocks, the BAP assumes the introduction of electric vehicles, according to projections from the Long Term Energy Plan. The composition of the corporate vehicle stock is held constant from the model baseline. The total number of personal use and corporate vehicles is proportional to the projected number of households in the BAP.

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

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

Waste

Emissions projections for waste are derived using projected population growth and existing rates of waste produced per capita. The projection assumes no reduction in the rates of per capita waste production and no improvement in treatment facilities.

Financial

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

Table 6. Energy costs projections, 2016 and 2050

ENERGY COSTS ($/MJ)		2016	2050	% INCREASE (2016–2050)
Residential	Natural Gas	$0.009	$0.010	17%
Residential	Electricity	$0.042	$0.048	14%
Residential	Fuel Oil	$0.029	$0.037	28%
Commercial	Natural Gas	$0.006	$0.008	23%
Commercial	Electricity	$0.035	$0.042	20%
Commercial	Fuel Oil	$0.025	$0.034	33%
Commercial	Propane	$0.015	$0.018	26%
Industrial	Natural Gas	$0.006	$0.007	27%
Industrial	Electricity	$0.032	$0.039	20%
Industrial	Diesel	$0.016	$0.024	54%
Industrial	Fuel Oil	$0.016	$0.024	54%
Industrial	Propane	$0.019	$0.027	41%
Vehicles	Natural Gas	$0.009	$0.010	17%
Vehicles	Electricity	$0.042	$0.048	14%
Vehicles	Gasoline	$0.036	$0.049	36%
Vehicles	Diesel	$0.035	$0.048	39%

Table 7. Carbon price projections

YEAR	$/TCO2E (2016$)
2018	10
2019	20
2020	30
2021	40
2022	50
2023	52
2024	53
2025	55
2026	56
2027	58
2028	60
2029	61
2030	63
2031	65
2032	67
2033	69
2034	71

YEAR	$/TCO2E (2016$)
2035	73
2036	76
2037	78
2038	80
2039	83
2040	85
2041	88
2042	90
2043	93
2044	96
2045	99
2046	102
2047	105
2048	108
2049	111
2050	114

Table 8. Key assumptions

CATEGORY	DESCRIPTION	COMMENT
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, Emission Factors for Natural Gas.
Electricity	2016: CO_2: 28.9 g/kWh CH_4: 0.007 g/kWh N_2O: 0.001 g/kWh 2050: CO_2: 37.4 g/kWh CH_4: 0.009 g/kWh N_2O: 0.001 g/kWh	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	Environment and Climate Change Canada. *National Inventory Report 1990–2015: Greenhouse Gas Sources and Sinks in Canada.* Part 2. Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Diesel	g/L CO_2: 2690.00 CH_4: 0.07 N_2O: 0.21	Environment and Climate Change Canada. *National Inventory Report 1990–2015: Greenhouse Gas Sources and Sinks in Canada.* Part 2. Table A6–12 Emission Factors for Energy Mobile Combustion Sources

CATEGORY	DESCRIPTION	COMMENT
Fuel oil	Residential g/L CO_2: 2560 CH_4: 0.026 N_2O: 0.006 Commercial g/L CO_2: 2753 CH_4: 0.026 N_2O: 0.031 Industrial g/L 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

CATEGORY	DESCRIPTION	COMMENT
Propane	g/L Transport CO2: 1515.00 CH4: 0.64 N2O: 0.03 Residential CO2: 1515.00 CH4 : 0.027 N2O: 0.108 All other sectors CO2: 1515.00 CH4: 0.024 N2O: 0.108	Environment and Climate Change Canada. *National Inventory Report 1990–2015: Greenhouse Gas Sources and Sinks in Canada.* Part 2. Table A6–3 Emission Factors for Natural Gas Liquids Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Waste	Landfill emissions are calculated from first order decay of degradable organic carbon deposited in landfill. Derived emission factor in 2016 = 0.015 kg CH4/tonne solid waste (assuming 70% recovery of landfill methane); 0.050 kg CH4/tonne solid waste not accounting for recovery.	Landfill emissions: *IPCC Guidelines Vol 5*. Ch 3, Equation 3.1

CATEGORY	DESCRIPTION	COMMENT
Wastewater	CH4: 0.48 kg CH4/kg BOD N2O: 3.2 g / (person * year) from advanced treatment 0.005 g /g N from wastewater discharge	CH4 wastewater: *IPCC Guidelines Vol 5*. Ch 6, Tables 6.2 and 6.3; MCF value for anaerobic digester N2O from advanced treatment: *IPCC Guidelines Vol 5*. Ch 6, Box 6.1 N2O from wastewater discharge: *IPCC Guidelines Vol 5*. Ch 6, Section 6.3.1.2

Appendix 2: GPC tables

Table 9. GHG summary

Sector		Total by Scope (tCO2e)				Total	Total by city-induced reporting level (tCO2e)	
		Scope 1	Scope 2	Scope 3	Other Scope 3		BASIC	BASIC+
Stationary Energy	Energy use (all I emissions except I.4.4)	2,638,732	427,541	19,898		3,086,171	3,066,273	3,086,171
	Energy generation supplied to the grid (I.4.4) *							
Transportation (all II emissions)		1,631,491		220,424		1,851,915	1,631,491	1,851,915
Waste	Generated in the city (all III.X.1 and III.X.2)	247,901		0		247,901	247,901	247,901
	Generated outside city (all III.X.3)							
IPPU (all IV emissions)								
AFOLU (all V emissions)								
Total		4,518,124	427,541	240,322	0	5,185,987	4,945,665	5,185,987
		(All territorial emissions)					(All BASIC emissions)	(All BASIC & BASIC+ emissions)

Sources required for BASIC reporting	(green)
Sources required for BASIC+ reporting (green & blue)	(green) (blue)
Sources included in Other Scope 3	(orange)
Sources required for territorial but not for BASIC/BASIC+ reporting	(pink)
Non-applicable emissions	(grey)

Table 10. GPC Summary

GPC ref No.	Scope	GHG Emissions Source	Inclusion	Reason for exclusion (if applicable)	Comments	in tonnes CO2	CH4	N2O	Total CO2e
I		STATIONARY ENERGY SOURCES							
I.1		Residential buildings							
I.1.1	1	Emissions from fuel combustion within the city boundary	Yes			1,053,190	19	20	1,059,913
I.1.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes			187,367	40	4	189,910
I.1.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes			8,720	2	0	8,839
I.2		Commercial and institutional buildings/facilities							
I.2.1	1	Emissions from fuel combustion within the city boundary	Yes			307,182	6	6	309,264
I.2.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes			122,554	26	3	124,217
I.2.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes			5,704	1	0	5,781
I.3		Manufacturing industry and construction							
I.3.1	1	Emissions from fuel combustion within the city boundary	Yes			1,128,579	19	17	1,134,438
I.3.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes			111,889	24	2	113,408
I.3.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes			5,207	1	0	5,278
I.4		Energy industries							
I.4.1	1	Emissions from energy used in power plant auxiliary operations within the city boundary	Yes			5.42			5.49
I.4.2	2	Emissions from grid-supplied energy consumed in power plant auxiliary operations within the city boundary	Yes			0.25			0.26
I.4.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption in power plant auxiliary operations	Yes						
I.4.4	1	Emissions from energy generation supplied to the grid	No	NR					
I.5		Agriculture, forestry and fishing activities							
I.5.1	1	Emissions from fuel combustion within the city boundary	No	NR					
I.5.2	2	Emissions from grid-supplied energy consumed within the city boundary	No	NR					
I.5.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	No	NR					
I.6		Non-specified sources							
I.6.1	1	Emissions from fuel combustion within the city boundary	No	NR					
I.6.2	2	Emissions from grid-supplied energy consumed within the city boundary	No	NR					
I.6.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	No	NR					
I.7		Fugitive emissions from mining, processing, storage, and transportation of coal							

GPC ref No.	Scope	GHG Emissions Source	Inclusion	Reason for exclusion (if applicable)	Comments	in tonnes CO2	CH4	N2O	Total CO2e
I.7.1	1	Emissions from fugitive emissions within the city boundary	No	NR					
I.8		Fugitive emissions from oil and natural gas systems							
I.8.1	1	Emissions from fugitive emissions within the city boundary	Yes			50.61	745.96	0	25413.36
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		Includes personal, commercial & buses	1,516,443	140	331	1,619,956
II.1.2	2	Emissions from grid-supplied energy consumed within the city boundary for on-road transportation	No	NR	No significant EV stock in 2011	2	0	0	2
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		For personal vehicles only	202,575	23	57	220,424
II.2		Railways							
II.2.1	1	Emissions from fuel combustion for railway transportation occurring within the city boundary	Yes			10,264	1	4	11,534
II.2.2	2	Emissions from grid-supplied energy consumed within the city boundary for railways	No	N/A					
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	N/A					
II.3		Water-borne navigation							
II.3.1	1	Emissions from fuel combustion for waterborne navigation occurring within the city boundary	No	N/A					
II.3.2	2	Emissions from grid-supplied energy consumed within the city boundary for waterborne navigation	No	N/A					
II.3.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	No	N/A					
II.4		Aviation							
II.4.1	1	Emissions from fuel combustion for aviation occurring within the city boundary	No	N/A					
II.4.2	2	Emissions from grid-supplied energy consumed within the city boundary for aviation	No	N/A					
II.4.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	No	N/A					
II.5		Off-road							
II.5.1	1	Emissions from fuel combustion for off-road transportation occurring within the city boundary	No	NR					
II.5.2	2	Emissions from grid-supplied energy consumed within the city boundary for off-road transportation	No	NR					
III		WASTE							
III.1		Solid waste disposal							

						in tonnes			
GPC ref No.	Scope	GHG Emissions Source	Inclusion	Reason for exclusion (if applicable)	Comments	CO2	CH4	N2O	Total CO2e
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	3,072	0	104,431
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						
III.1.3	1	Emissions from waste generated outside the city boundary and disposed in landfills or open dumps within the city boundary	No	NR					
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				287	22	16,162
III.2.2	3	Emissions from solid waste generated within the city boundary but treated biologically outside of the city boundary	No	NR					
III.2.3	1	Emissions from waste generated outside the city boundary but treated biologically within the city boundary	No	NR					
III.3		Incineration and open burning							
III.3.1	1	Emissions from solid waste generated and treated within the city boundary	No	NR					
III.3.2	3	Emissions from solid waste generated within the city boundary but treated outside of the city boundary	No	NR					
III.3.3	1	Emissions from waste generated outside the city boundary but treated within the city boundary	No	NR					
III.4		Wastewater treatment and discharge							
III.4.1	1	Emissions from wastewater generated and treated within the city boundary	No	NR			3,728	2	127,308
III.4.2	3	Emissions from wastewater generated within the city boundary but treated outside of the city boundary	Yes						
III.4.3	1	Emissions from wastewater generated outside the city boundary	No	NR					
IV		INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)							
IV.1	1	Emissions from industrial processes occurring within the city boundary	No	ID					
IV.2	1	Emissions from product use occurring within the city boundary	No	ID					
V		AGRICULTURE, FORESTRY AND LAND USE (AFOLU)							
V.1	1	Emissions from livestock within the city boundary	No	NR					
V.2	1	Emissions from land within the city boundary	No	NR					
V.3	1	Emissions from aggregate sources and non-CO2 emission sources on land within the city boundary	No	NR					
VI		OTHER SCOPE 3							
VI.1	3	Other Scope 3	No	N/A					
Reason for exclusion:							TOTAL		5,185,987

GPC ref No.	Scope	GHG Emissions Source	Inclusion	Reason for exclusion (if applicable)	Comments	in tonnes CO2	CH4	N2O	Total CO2e
N/A	Not applicable; Not included in scope								
ID	Insufficient data								
NR	No relevant or limited activities identified								
Other	Reason provided under Comments								

Appendix 3: Establishing a vision

Engagement process

Two stakeholder consultation sessions were held to help develop the vision, goals and objectives – on September 20, 2016 and February 28, 2017. A briefing document was prepared and distributed to stakeholders prior to each meeting. In total 100 stakeholders attended the two sessions.

The primary activity of the stakeholder sessions was to establish the vision and objectives and an iterative process facilitated creation, revision, and consensus around each goal and objective. This framework of vision and objectives guided the selection of actions, which were then modelled.

A subsequent engagement process for the Steering Committee was used to prioritize the scenarios; see the section titled Scenario Prioritization.

Vision, goals and objectives

Following the two stakeholder sessions, the Steering Committee developed a final set of vision statements, goals and objectives, described below.

Vision statement #1: Innovative, smart and diversified energy solutions

GOAL	OBJECTIVE
Develop and promote policies and programs that encourage new community partnerships, acceptance of newer and emerging sustainable eco-technologies and guide the development of diversified energy sources at multiple scales of energy production and consumption.	» Increase Durham Region's energy self-sufficiency and resiliency by increasing local renewable energy sources to 35% by 2030 (vs. 9% in 2015).

Vision statement #2: Transparent, accountable and committed to the vision

GOAL	OBJECTIVES
Measure and communicate the quantitative and qualitative benefits (economic, environmental and social) of implementing the DCEP to increase stakeholder and community support.	» Increase public energy literacy regarding energy sources, impacts and costs via the collaborative development of a communication strategy by 2nd quarter 2018 for implementation following the endorsement of the DCEP by Regional Council. » Increase user understanding of energy costs by advocating for consistent simplification, breakdown and explanation of all costs on all local utility energy bills (including global adjustment charge) by 2019.

Vision statement #3: Reduced carbon footprint

GOAL	OBJECTIVES
Provide user-friendly tools, targets and incentives for consumers and communities to reduce their energy consumption.	» Decrease carbon-based energy consumption by 10% by 2025, 15% by 2035, 45% by 2045 and 50% by 2050 (91% carbon-based in 2015). » Decrease energy use via the development of new local policies and advocate for early implementation of a more stringent Building Code requirement that all new housing be net-zero energy by 2025 and all retrofits by 2040.
Ensure electrical and natural gas grid flexibility for distributed integrated low carbon energy generation.	» Reduce restrictions on energy suppliers through O. Reg. 22/04 (distribution code) to allow for easier adoption of distributed energy reserves. » Increase public awareness surrounding requirements for adopting micro FIT particularly surrounding safety.

Vision statement #4: Economic prosperity, and community and environmental health

GOAL	OBJECTIVES
Incorporate four components of sustainability (economic, environmental, social and cultural) when making community planning decisions.	» Increase energy production from Durham community energy projects to a minimum of 50% of consumption by 2050 (vs. 19% in 2015). » Increase the number of local energy businesses by 50% by 2030.
Provide light rail transit (LRT) in lakeshore municipalities connecting to Toronto by 2050.	» Increase mixed-use development along Highway 2 corridor for increased light rail transit (LRT) user base. » Increase collaboration with developers and planners to prioritize transit localization (hub development) (e.g. maximum 500-metre walking distance to transit).
Create healthy, accessible communities with an excellent and well-integrated active transportation network, employment close to home and telecommute/virtual work options.	» Increase all forms of mobility by 2022 through the creation of a walkable community master plan that aligns with the DCEP, includes an inventory of existing assets (sidewalks), connects existing active transportation networks throughout Durham Region and enhances safety and accessibility (lighting and landscape design). » Decrease car use and parking through disincentives.

Vision statement #5: Reliable, resilient, integrated, sustainable and financially viable energy sources

GOAL	OBJECTIVES
Maximize community energy self-sufficiency and resiliency, and maintain flexibility and sustainability.	» Increase grid capacity to accommodate electrical vehicle charging. » Increase number of EV owners charging/discharging during off-peak hours through education. » Increase price differential between on- and off-peak hours. » Increase resiliency measures when designing and constructing new infrastructure or retrofitting existing infrastructure. » Increase cost synergies during infrastructure work (roads, sewers, gas, etc.).

Vision statement #6: Affordability for all!

GOAL	OBJECTIVES
Provide affordable energy services to all consumers.	» Reduce demand by increasing energy efficiency. » Increase micro-generation and energy storage being used by all customers by 2050. » Increase advocacy for Province to continue to tax unsustainable fossil fuel practices (carbon tax; cap and trade tax) and fund/incent sustainable practices. » Increase/develop an incentive program to install micro/renewable energy to help decentralize the grid. » Increase options for consumers (microgrid, solar islanded mode, multiple/competitive market supply) that supports a smarter grid supply.

Vision statement #7: Community collaboration for innovative solutions

GOAL	OBJECTIVES
Engage community stakeholders through collaboration to develop effective and innovative solutions.	» Maintain an up-to-date DCEP communication plan. » Increase commitment and involvement of the community in the DCEP and its implementation to 90% by year end 2018. » Decrease administrative barriers (streamline the process) to distributed energy resource generation (re. Germany). » Regularly report successes and setbacks regarding the implementation of the DCEP and gather feedback.

The vision, goals and objectives informed the development of scenarios for the technical modelling process.

Following the two stakeholder sessions, the Steering Committee developed a final set of vision statements, goals and objectives, described below.

Vision statement #1: Innovative, smart and diversified energy solutions

GOAL	OBJECTIVE
Develop and promote policies and programs that encourage new community partnerships, acceptance of newer and emerging sustainable eco-technologies and guide the development of diversified energy sources at multiple scales of energy production and consumption.	» Increase Durham Region's energy self-sufficiency and resiliency by increasing local renewable energy sources to 35% by 2030 (vs. 9% in 2015).

Vision statement #2: Transparent, accountable and committed to the vision

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Maximize community energy self-sufficiency and resiliency, and maintain flexibility and sustainability.	» Increase grid capacity to accommodate electrical vehicle charging. » Increase number of EV owners charging/ discharging during off-peak hours through education. » Increase price differential between on and off-peak hours. » Increase resiliency measures when designing and constructing new infrastructure or retrofitting existing infrastructure. » Increase cost synergies during infrastructure work (roads, sewers, gas, etc.).

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GOAL	OBJECTIVES
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