
3

Edmonton’s Energy Transition Plan

Portfolio Forecast: Costs of ETP

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Introduction

If Edmonton's Energy Transition Plan (ETP) is to be successful, a robust enabling framework is needed to encourage aggressive investment by private individuals and businesses in alternative energy, energy efficiency, and conservation. A key element of an effective enabling framework is stable, long-term public funding at sufficient levels to leverage the private sector investment required to meet the goals of the ETP.

Stable, long-term public support facilitates longer planning horizons and reduces investment uncertainty for individuals and businesses. Alternative energy projects and some energy efficiency projects may take several years to develop. Most businesses will need assurance that public financial support is going to be available during all phases of multi-year clean energy or energy efficiency project opportunities before proceeding. Stable, long–term financial support is also important to help ensure that short–lived energy efficiency opportunities, such as new construction and equipment replacement decisions, do not become lost opportunities. Furthermore, achieving the targets in the ETP will require significant transformation of energy markets. Market transformation initiatives take time to permanently change behavior in a target marketplace. These initiatives thus require stable, long-term financial support and longer planning horizons. Such support helps ensure market transformation initiatives maintain momentum, so clean energy and efficiency measures can reach tipping points in markets, after which they become the market standard and energy savings or clean energy supply become persistent without further public intervention.

Numerous reports by government, non-profits, and private businesses have surveyed approaches for funding alternative energy and efficiency programs and projects, including C3's *Energy Efficiency Funding and Administration Options for Alberta*. In assignment 1.7(a) of this study we reviewed a number of innovative municipal financing models that simultaneously address many recognized market barriers, including the first-time cost barrier, and that encourage the adoption of cutting-edge technologies and deep improvements in energy efficiency. These financing models provide scalable solutions, and are designed to use limited public funds to mobilize, leverage, and support significant private sector investment.

The objective of this assignment, 1.7(b), is to provide **high-level estimates** of, firstly, the private sector investment required to implement a number of "energy transition options" and, secondly, the public (program) funding required to facilitate and incent these investments. Estimates are provided for the following energy transition options: ❶ increasing the energy efficiency of new and existing residential, commercial, institutional and industrial buildings; ❷ increasing renewable energy generation in these buildings; ❸ increasing the energy efficiency of industrial processes; and ❹ increasing the up-take of electric personal vehicles.

Cost estimates are provided for a shift from the Reference Case to the Reduced Carbon Case, and for a shift from the Reference Case to the Low Carbon Case. The magnitude of the required investment will inform the choice of funding model. Note that this is not a cost-benefit study and therefore does not assess whether the estimated levels of investment are justified in terms of improving the welfare of Edmontonians.

Buildings: Residential

Assumptions

The assumptions listed below, which underpin the analysis, have been adopted from the ETP Discussion Paper. These assumptions reflect our interpretation of the information provided in the Paper. Where we have made additional assumptions, they are denoted with "*".

- GHG intensity of natural gas : 0.0509 t CO_2e per GJ. This is assumed constant over the forecast period 2009-2044.
- GHG intensity of electricity under the Reference Case: 880 t CO_2e per GWh (2009), 628 t CO_2e per GWh (2024), and 538 t CO_2e per GWh (2044). The GHG intensity is assumed to follow a linear path between 2009 and 2024 and between 2024 and 2044.
- GHG intensity of electricity under the Reduced Carbon Case: 880 t CO_2e per GWh (2009), 580 t CO_2e per GWh (2024), and 429 t CO_2e per GWh (2044). The GHG intensity is assumed to follow a linear path between 2009 and 2024 and between 2024 and 2044.
- GHG intensity of electricity under the Low Carbon Case : 880 t CO_2e per GWh (2009), 442 t CO_2e per GWh (2024), and 100 t CO_2e per GWh (2044). The GHG intensity is assumed to follow a linear path between 2009 and 2024 and between 2024 and 2044.
- Total number of residential dwellings (all housing types): 360,000 units under all cases (2009), 560,000 units under the Reference Case (2044), 562,000 units under the Reduced Carbon Case (2044), and 578,000 units under the Low Carbon Case (2044). The total number of dwellings is assumed to follow a linear path between 2009 and 2044.
- Single family homes (multi-family homes) account for 65% (35%) of total dwellings in 2009 (based on NRCAN data).*
- The survival rate of existing homes is 99.6% (C3 analysis of NRCAN data).*
- The average size of a single family home (multi-family home) in 2009 is 151 m^2 (110 m^2) (C3 analysis of NRCAN data). The average size of a residential home in 2009 is 137 m^2 (C3 analysis of NRCAN data).*

Buildings: Residential

- The average size of a new single family home in 2044 is: 180 m^2 under the Reference Case, 170 m^2 under the Reduced Carbon Case, and 160 m^2 under the Low Carbon Case. The average size of a new single family home is assumed to follow a linear path between 2009 and 2044. The average size of a multi-family home (110 m^2) is assumed to remain constant over the forecast period.

- According to C3 analysis of NRCAN data: the space heating energy intensity of single family homes (multi-family homes) in 2009 is 0.80 GJ per m^2 (0.45 GJ per m^2); the water heating energy intensity of single family homes (multi-family homes) in 2009 is 0.21 GJ per m^2 (0.24 GJ per m^2); the appliance energy intensity of single family homes (multi-family homes) in 2009 is 0.11 GJ per m^2 (0.12 GJ per m^2); and the lighting heating energy intensity of single family homes (multi-family homes) in 2009 is 0.04 GJ per m^2 (0.02 GJ per m^2). The total energy intensity of single family homes (multi-family homes) in 2009 is 1.16 GJ per m^2 (0.84 GJ per m^2).*

- According to the ETP Discussion Paper, the implied space heating energy intensity of single family homes (multi-family homes) in 2009 as estimated by C3 is 0.50 GJ per m^2 (0.29 GJ per m^2); the implied water heating energy intensity of single family homes (multi-family homes) in 2009 is 0.13 GJ per m^2 (0.15 GJ per m^2); the implied appliance energy intensity of single family homes (multi-family homes) in 2009 is 0.07 GJ per m^2 (0.08 GJ per m^2); and the implied lighting heating energy intensity of single family homes (multi-family homes) in 2009 is 0.03 GJ per m^2 (0.01 GJ per m^2). The implied total energy intensity of single family homes (multi-family homes) in 2009 is 0.73 GJ per m^2 (0.3 GJ per m^2).

- As a result of new energy requirements in the building code -- relative to homes built in 2009 -- the energy intensity of all newly constructed homes will improve by: 25% (over the entire period 2014-2029) and 50% (over the entire period 2030-2044) under the Reference Case; 27.5% (2014-2029) and 52.5% (2030-2044) under the Reduced Carbon Case; and 50% (2014-2029) and 85% (2030-2044) under the Low Carbon Case. The improvements are assumed to apply to space heating and water heating. Note that the improvements in energy efficiency are assumed to be realized immediately in full when the code changes (i.e., in 2014 and again in 2030).

- The penetration of renewable energy technologies in all newly constructed homes is: 1% of new construction (by 2024) and 1% of new construction (by 2044) under the Reference Case; 1.5% of new construction (by 2024) and 2% of new construction (by 2044) under the Reduced Carbon Case; and 90% of new construction (by 2024) and 90% of new construction (by 2044) under the Low Carbon Case. The penetration rate is assumed to follow a linear path between 2009 (assumed to be 0%) and 2024 and between 2024 and 2044.

Buildings: Residential

- Energy from renewable technologies is assumed to displace: 20% of both space heating and water heating energy use in single family new construction; and 10% of both space heating and water heating energy use in multi-family new construction.
- Under the Reference Case 2.5% of all existing homes annually install measures to improve their energy intensity over the period 2009-2044.
- By 2024 under the Reduced Carbon Case and Low Carbon Case, respectively, 3% and 8% of all existing homes install measures to improve their energy intensity. The penetration rate follows a linear path from 2009 (starting at 2.5%) to 2024.
- Between 2024 and 2044 under the Reduced Carbon Case and Low Carbon Case, respectively, 3% and 8% of all existing homes annually install measures to improve their energy intensity.
- The upgrades in both single family and multi-family existing homes improve the energy intensity of both space heating and water heating by 10% under all cases.
- The penetration of renewable energy technologies in all existing homes is: 0.25% by 2044 under the Reference Case; 0.5% by 2044 under the Reduced Carbon Case; and 5% by 2034 (and constant thereafter till 2044) under the Low Carbon Case. The penetration rate is assumed to follow a linear path between 2009 (where it is assumed to be 0%) and these future dates.
- Energy from renewable technologies installed in existing homes is assumed to displace 100% of water heating energy use in both single family and multi-family homes.
- As a result of behavioral change for energy conservation, the energy intensity of all newly constructed homes and all existing homes in 2009 will improve by: 0% by 2044 under the Reference Case; 3% by 2044 under the Reduced Carbon Case; and 10% by 2044 under the Low Carbon Case. The improvements are assumed to apply to appliances and lighting.
- The installed (pre-incentive) cost of energy efficiency improvements in homes is, on average, $8,085 (±25%) per TJ saved. Program delivery costs comprise: incentive payments equal to $3,865 (±25%) per TJ; and technical assistance, administration, and other overhead equal to $1,285 (±25%) per TJ. Total program deliver costs equal incentive payments plus technical assistance, administration, and other overhead costs. Total participation costs to home owners comprise installed costs less incentive payments (all figures based on C3 analysis of industrial programs in North America).*

Buildings: Residential

- Based on the City of Edmonton Renewable Energy Plan the installed (pre-incentive) cost of renewable energy technologies in existing homes (single family and multi-family) is, on average, $30,550 per TJ supplied. Only solar hot water technology is assumed to be installed on existing homes. Program delivery cost comprises: incentive payments equal to 25% of installed costs plus education equal to 1% of installed cost; and administration and other overhead equal to 30% of total delivery costs. Total deliver costs equal incentive payments plus administration and other overhead costs. Total participation costs to home owners comprise installed costs less incentive payments.*

- Based on the City of Edmonton Renewable Energy Plan the installed (gross) cost of renewable energy technologies in newly constructed homes (single family and multi-family) is, on average, $64,220 per TJ supplied. A weighted average of solar PV, solar air heating, passive solar, and solar hot water technology is assumed to be installed on existing homes. The weights are based on the achievable potential identified in the Renewable Energy Plan. Program delivery cost comprises: regulatory costs equal to 5% of installed costs plus education equal to 1% of installed cost; and administration and other overhead equal to 30% of total delivery costs. Total deliver costs equal regulatory cost plus administration and other overhead costs.*

- In theory, **the unit costs of energy efficiency upgrades and renewable energy technologies should reduce over time as cumulative installations increase**—due to, for example, labor efficiencies, standardization, network effects, better use of equipment, economies of scale. However, the impact of these “experience effects” on unit costs is not modelled—it could be incorporated at a later date through the use of assumed learning rates or progress ratios.

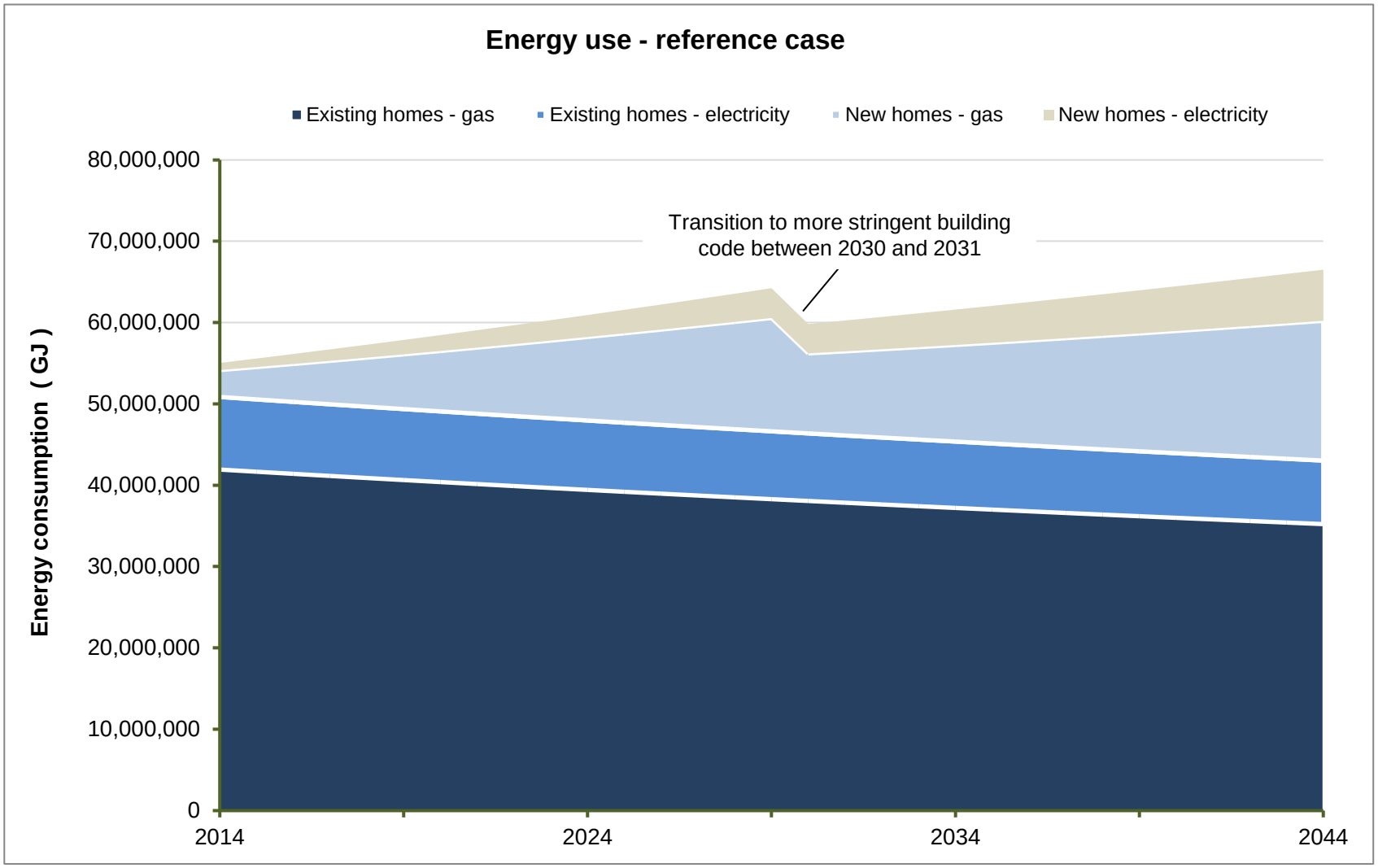
Results

Two sets of results are presented below. A detailed set of results is presented using the energy intensities derived from the NRCAN data as the starting point for the Reference Case in 2009. For contrast, summary results are presented using the energy intensities implied by the ETP Discussion Paper as the starting point for the Reference Case in 2009.

Note: the impact of both (a) reductions in the GHG intensity of the Alberta electricity grid and (b) decreases in the average size of new single-family homes are embedded in the results reported. However, the policies that induce both these outcomes are not specified or included in the cost estimates.

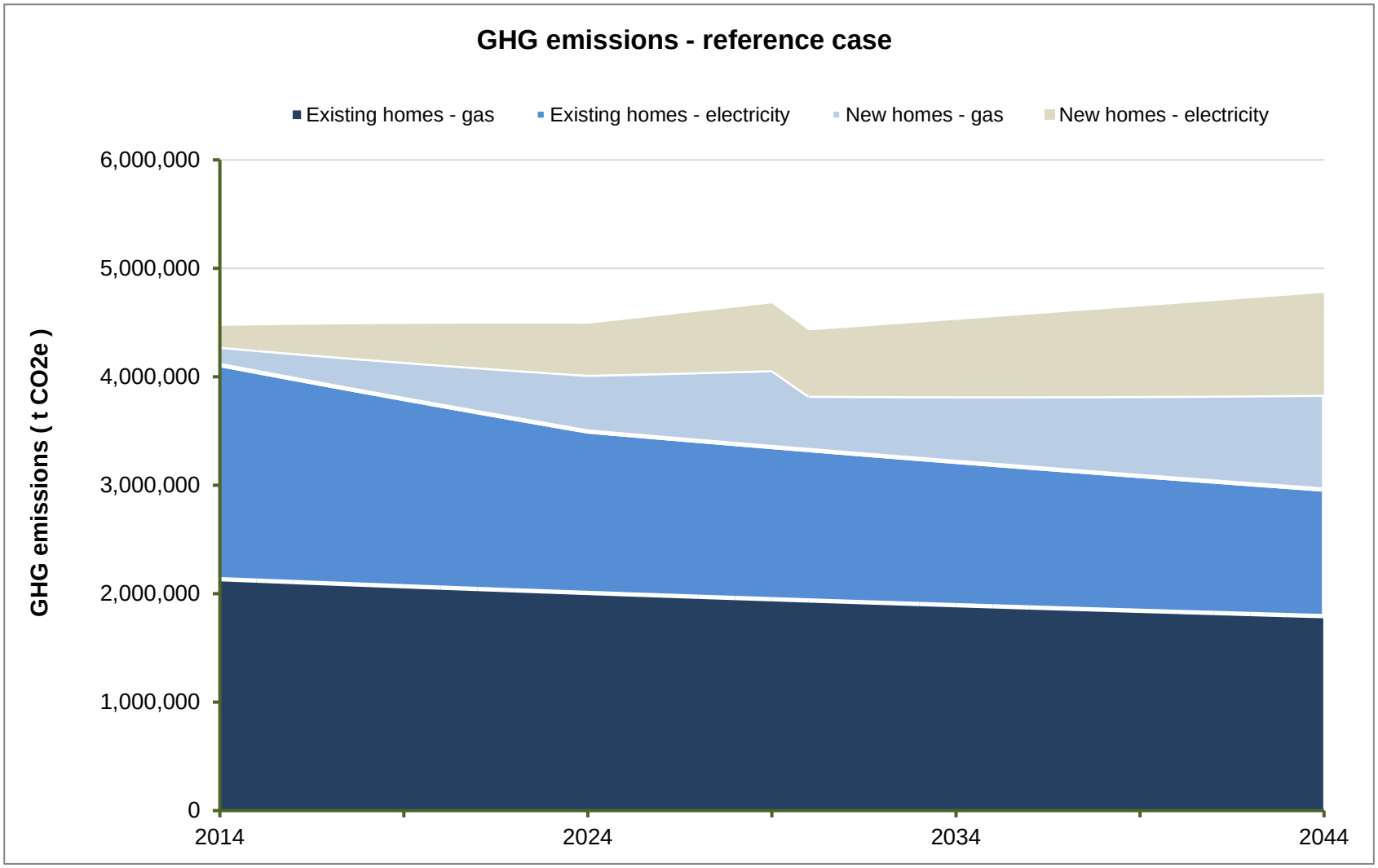
Buildings: Residential

Figure 1. Projected energy use under the Reference Case. Total energy consumption by residential buildings in 2014 is 55 PJ; rising to 67 PJ in 2044.



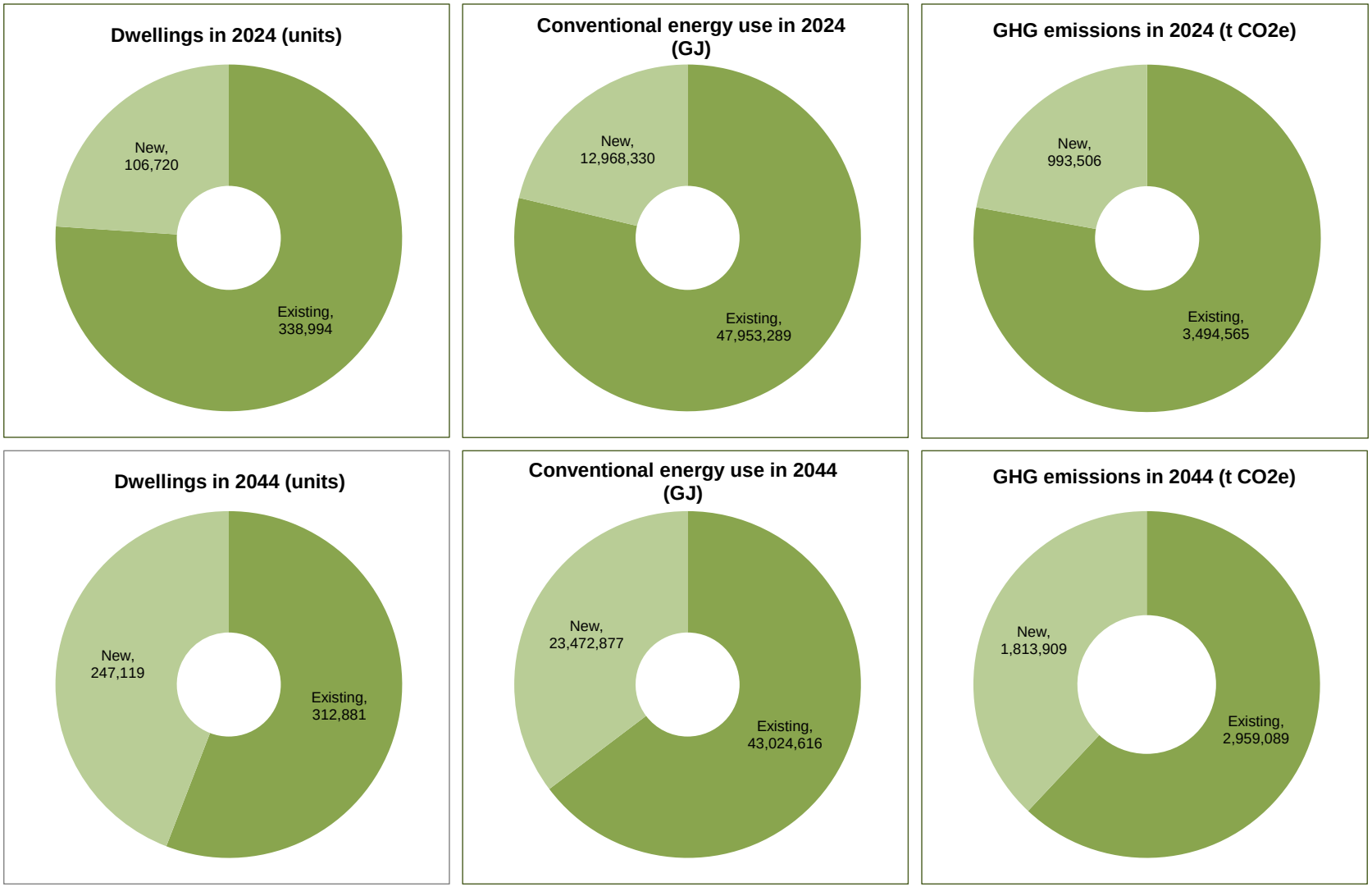
Buildings: Residential

Figure 2. Projected GHG emissions under the Reference Case. Total GHG emissions by residential buildings in 2014 are 4.4 Mt CO_2e; rising to 4.7 Mt CO_2e in 2044.



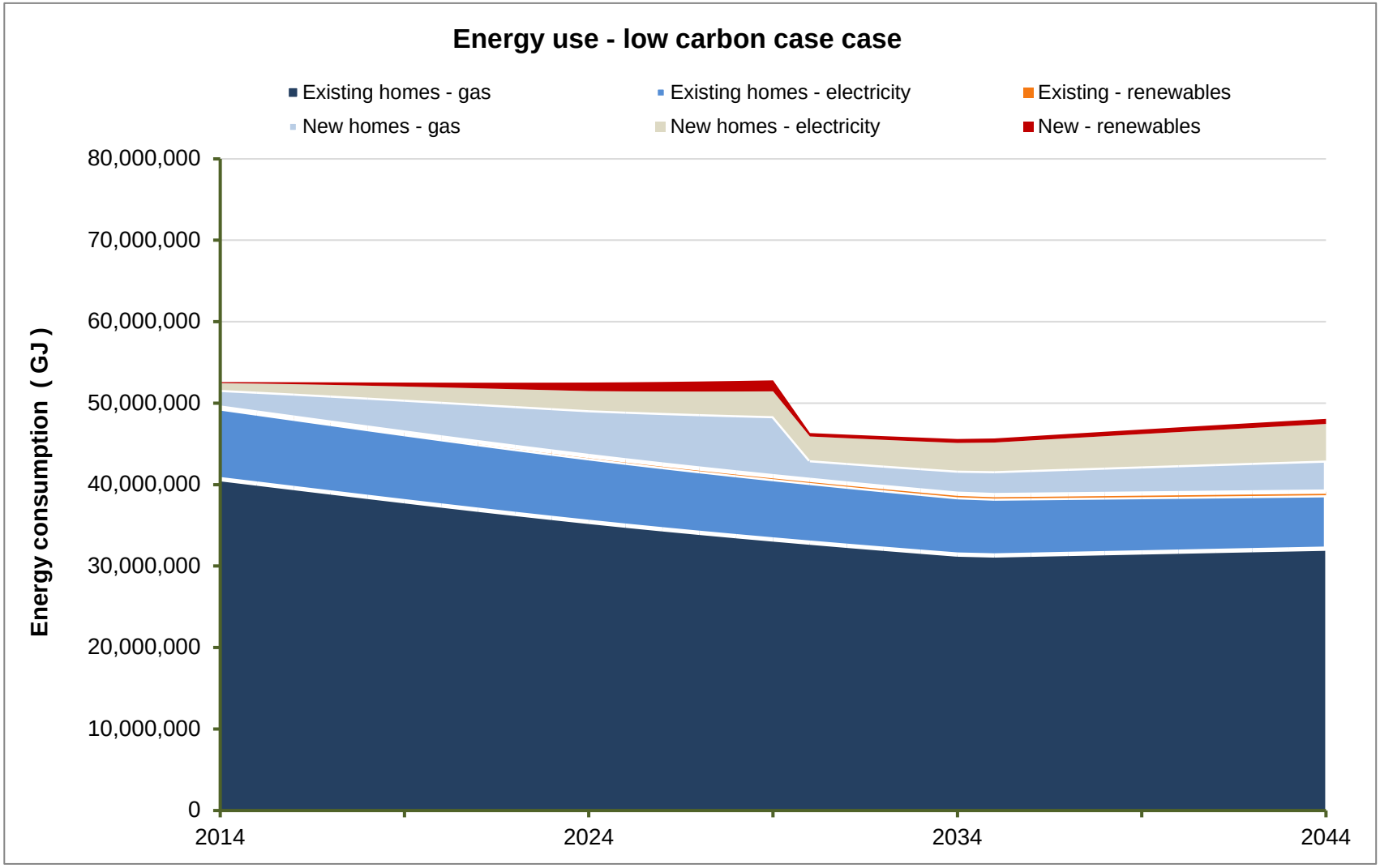
Buildings: Residential

Figure 3. Projected energy use and GHG emissions by existing and new homes under the Reference Case.



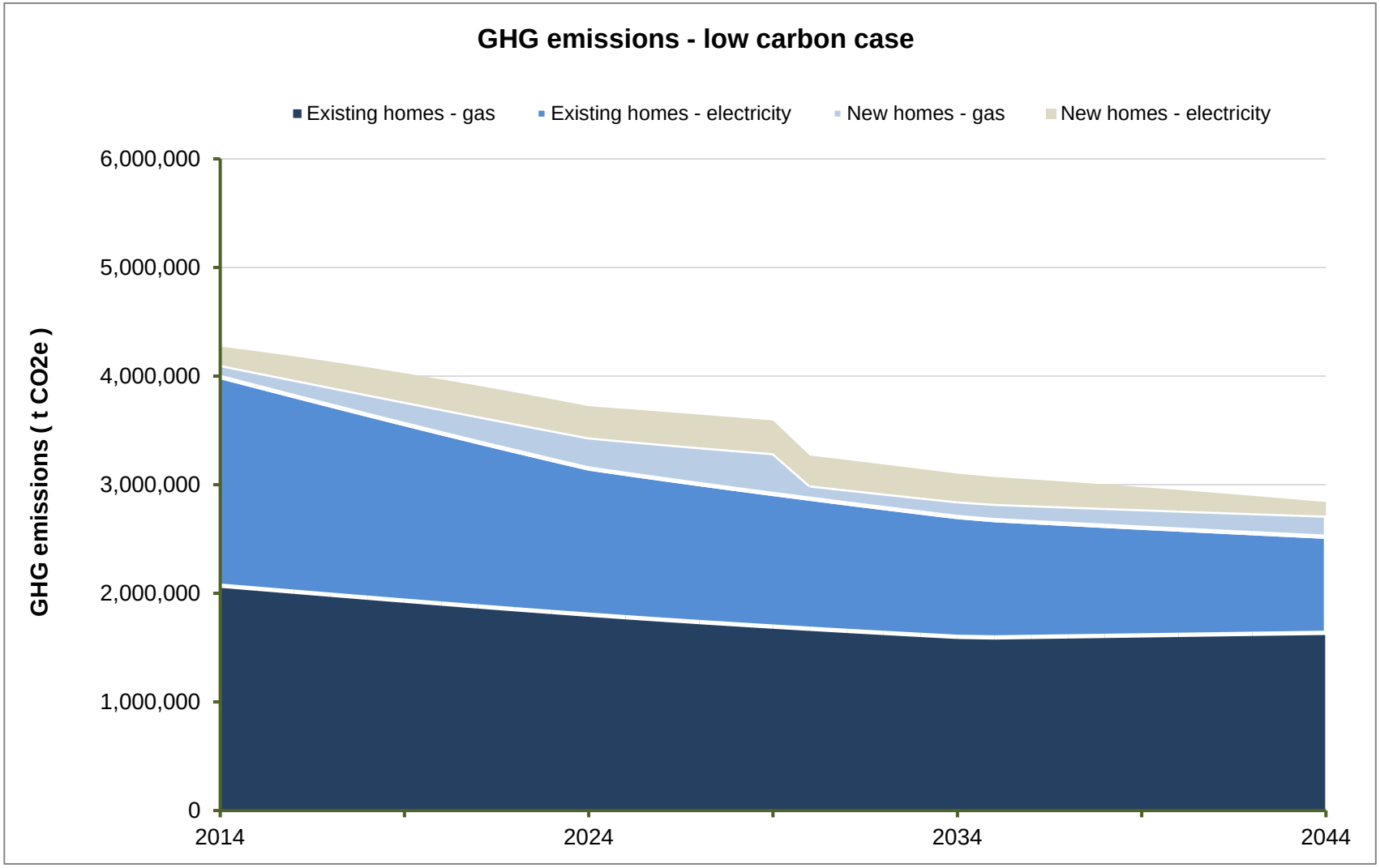
Buildings: Residential

Figure 4. Projected energy use under the Low Carbon Case. Total energy consumption by residential buildings in 2014 is 53 PJ; falling to 48 PJ in 2044. Energy use in 2044 is about 28% less than under the Reference Case.



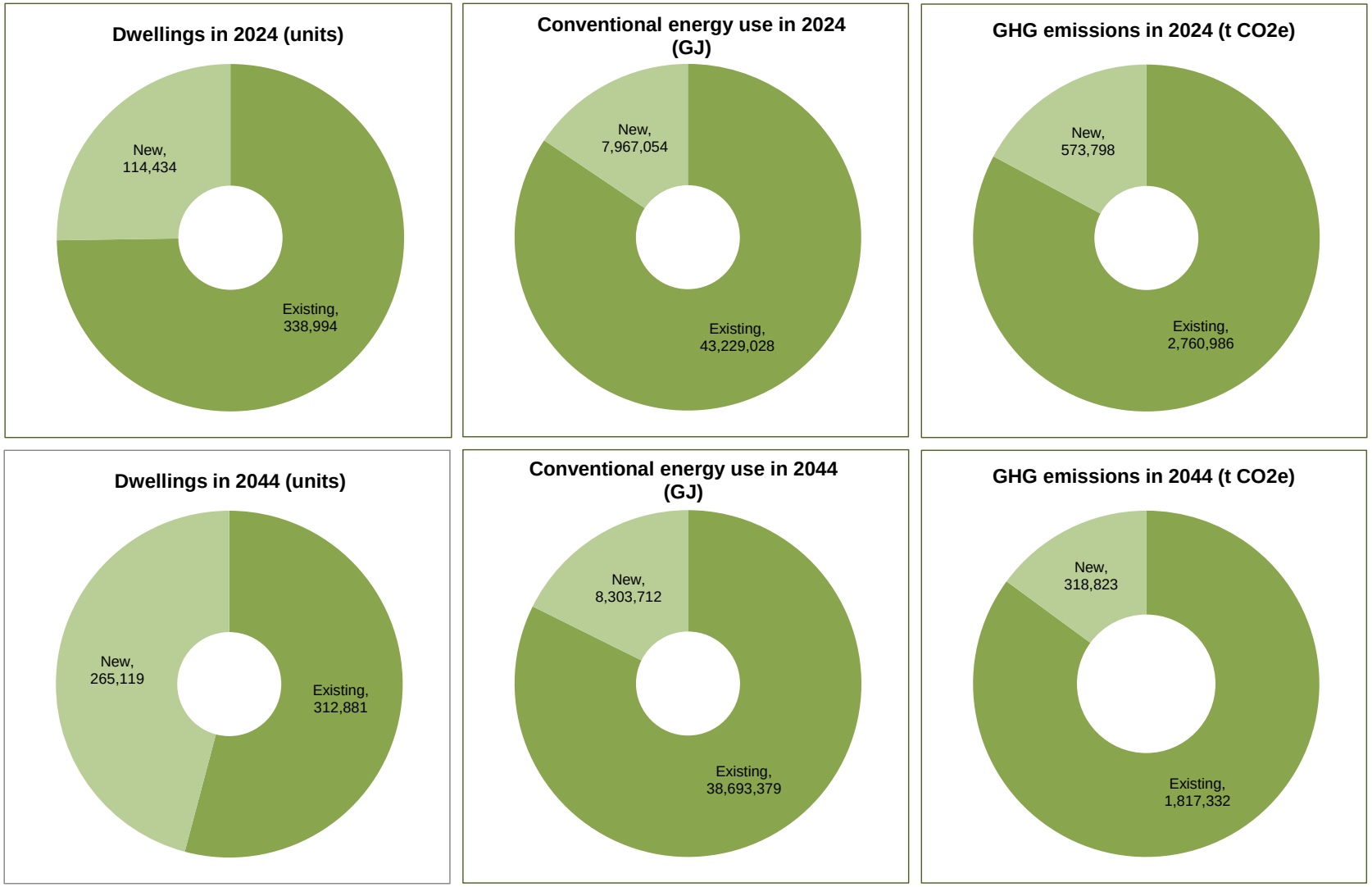
Buildings: Residential

Figure 5. Projected GHG emissions under the Low Carbon Case. Total GHG emissions by residential buildings in 2014 are 4.4 Mt CO_2e; falling to 2.1 Mt CO_2e in 2044. GHG emissions in 2044 are about 55% lower than under the Reference Case.



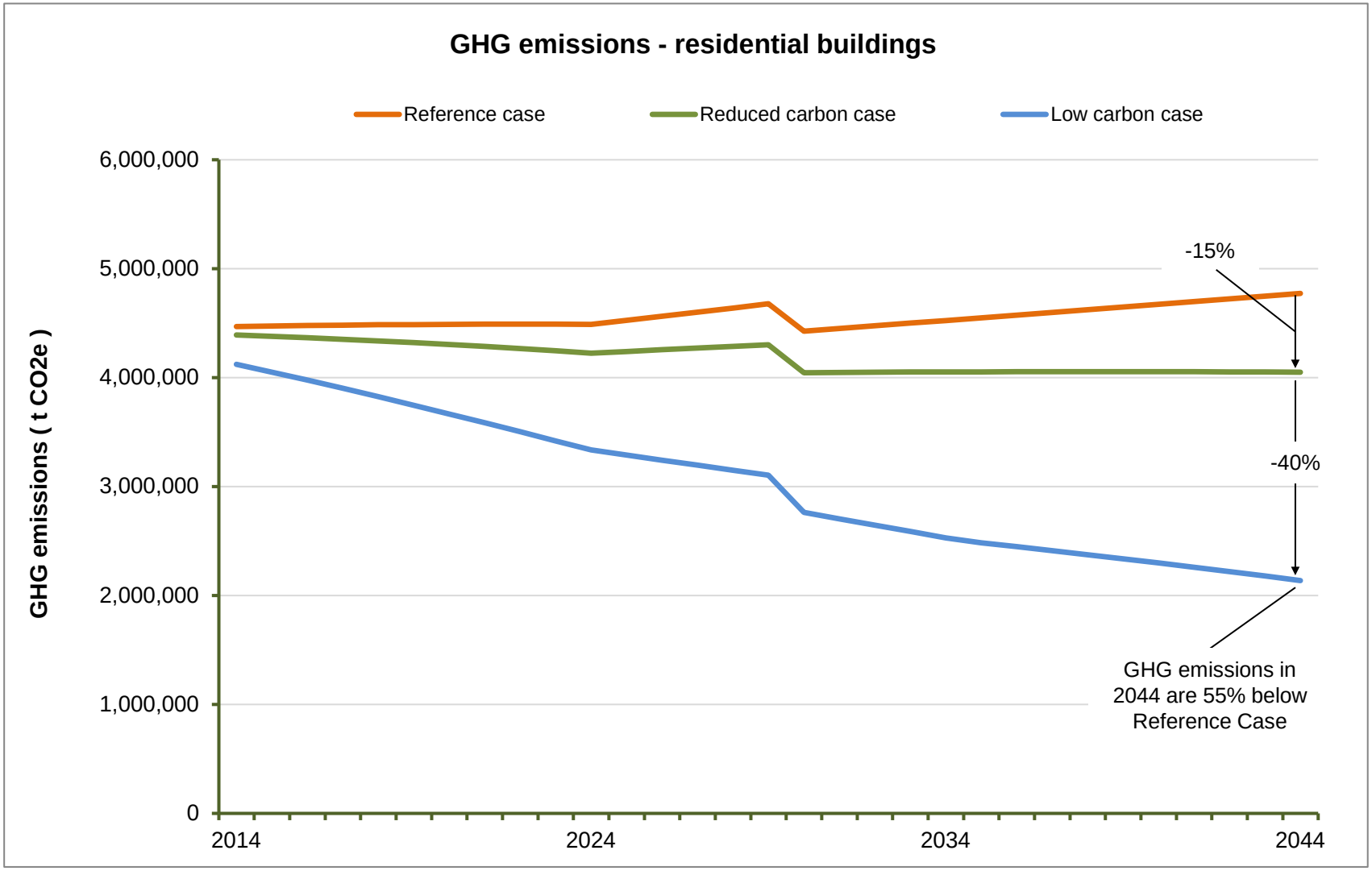
Buildings: Residential

Figure 6. Projected energy use and GHG emissions by existing and new homes under the Low Carbon Case.



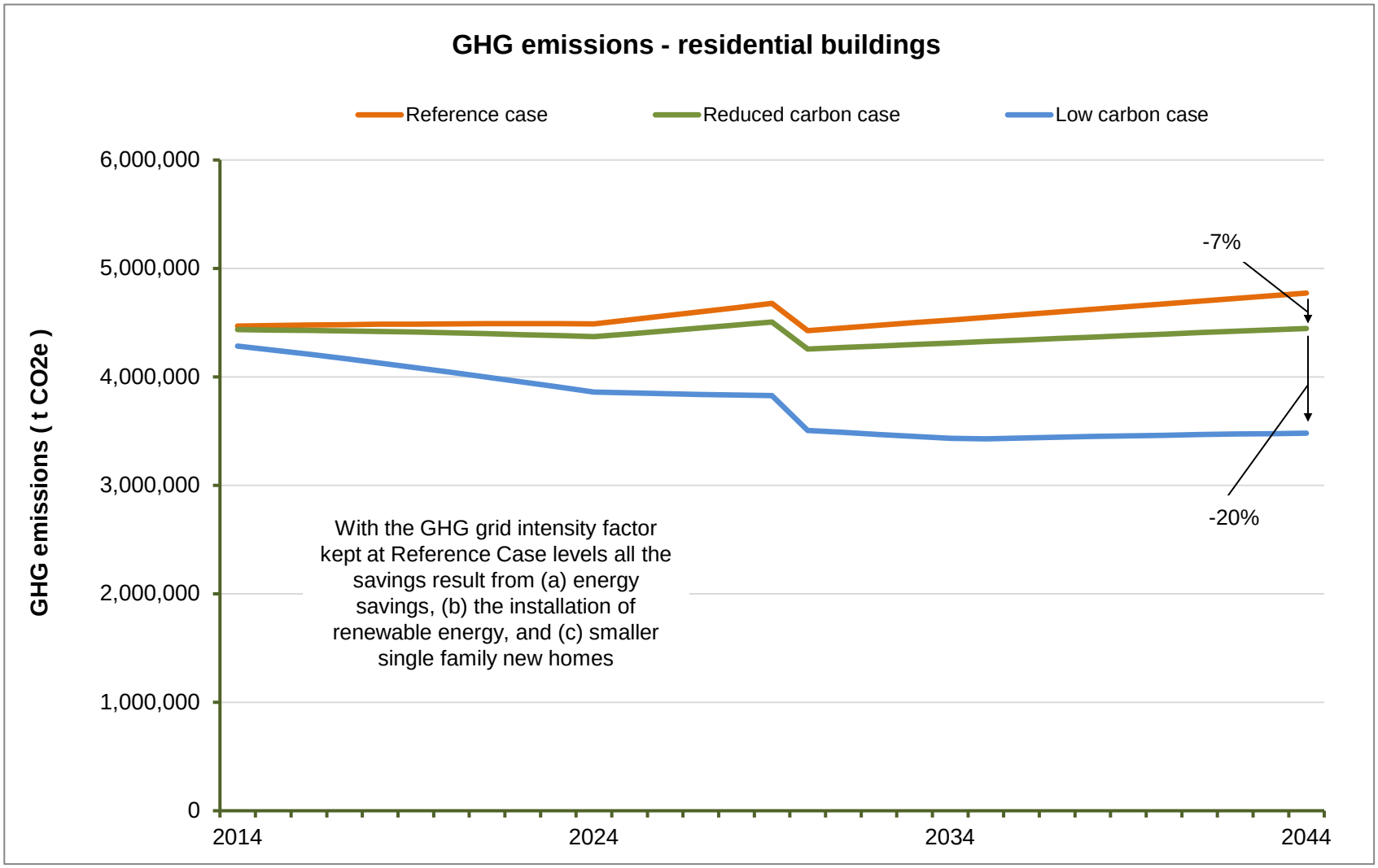
Buildings: Residential

Figure 7. Projected GHG emissions under the Reference Case, the Reduced Carbon Case, and the Low Carbon Case.



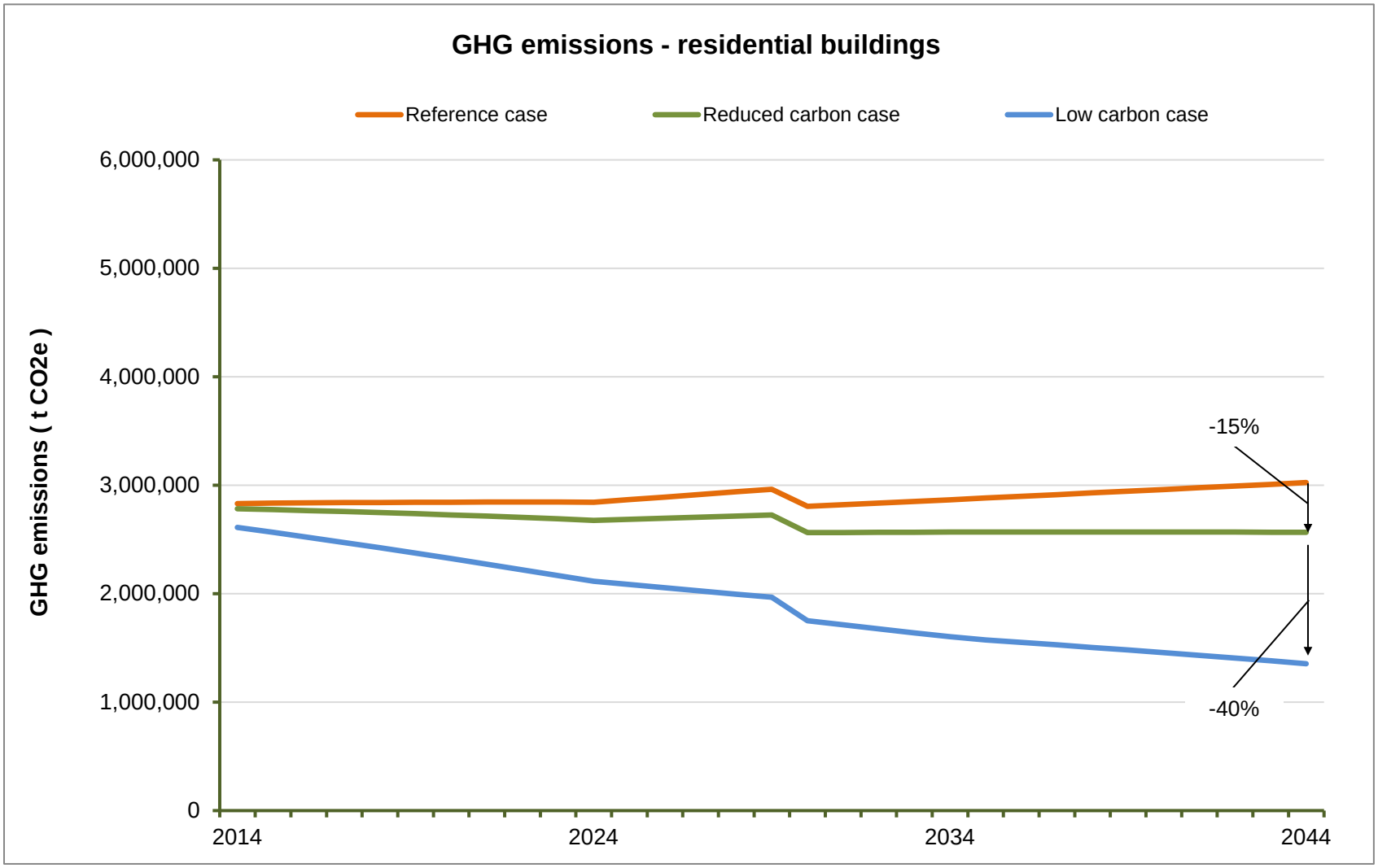
Buildings: Residential

Figure 8. Projected GHG emissions under the Reference Case, the Reduced Carbon Case, and the Low Carbon Case (assuming the GHG intensity of the Alberta electricity grid does not change from Reference Case values).



Buildings: Residential

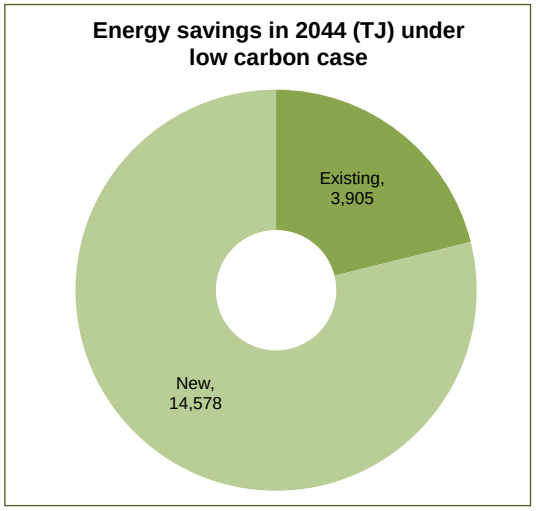
Figure 9. Projected GHG emissions under the Reference Case, the Reduced Carbon Case, and the Low Carbon Case (based on ETP Discussion Paper values as starting point in 2009).

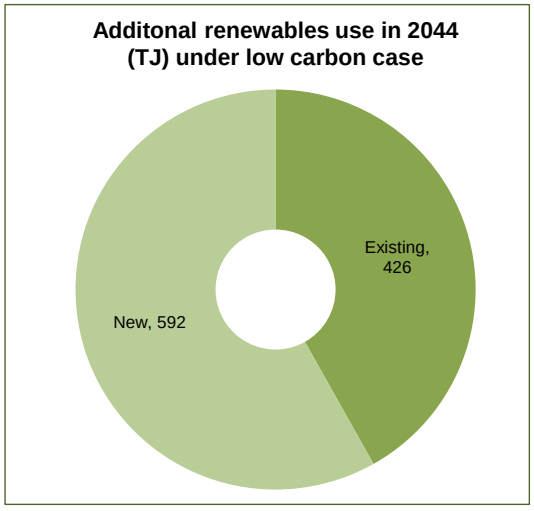


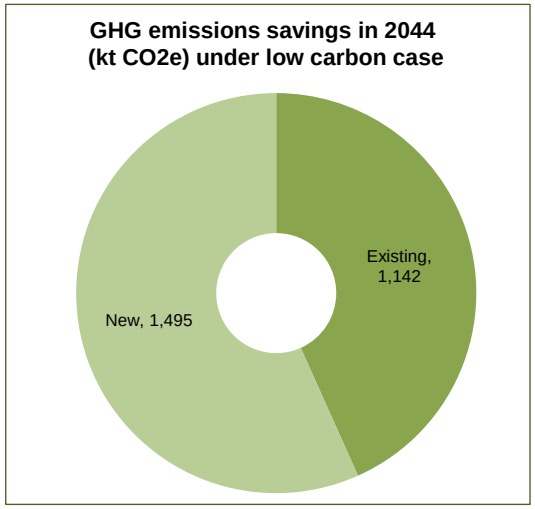
Buildings: Residential

Table 1. Estimated energy savings and GHG emissions avoided under the Reduced Carbon Case and the Low Carbon Case.

		2014	2024	2034	2044	Cumulative
Savings from energy efficiency and conservation						
Reduced carbon case vs. reference case	TJ	422	1,611	2,870	4,499	71,387
Low carbon case vs. reference case	TJ	2,447	8,423	16,031	18,483	358,321
Additional installed renewable energy						
Reduced carbon case vs. reference case	TJ	5	18	28	44	729
Low carbon case vs. reference case	TJ	223	1,302	880	1,017	29,052
GHG emissions avoided						
Reduced carbon case vs. reference case	kt CO2e	77	264	472	724	11,706
Low carbon case vs. reference case	kt CO2e	348	1,153	1,996	2,637	47,834



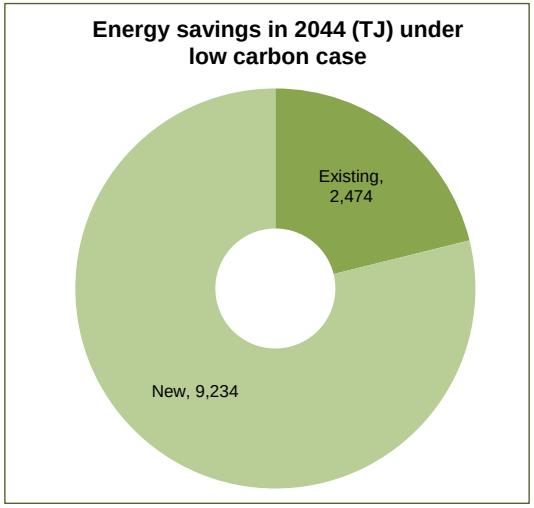


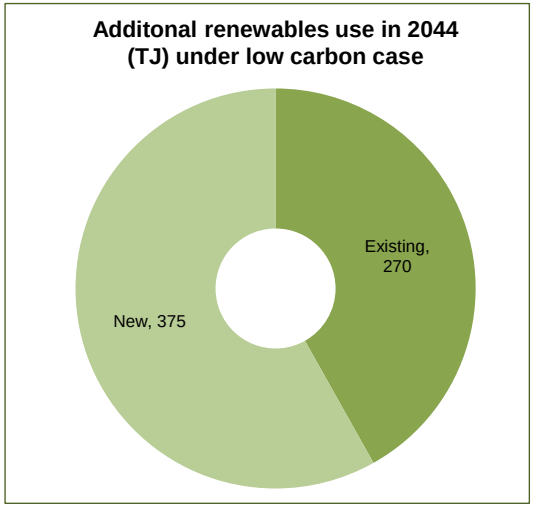


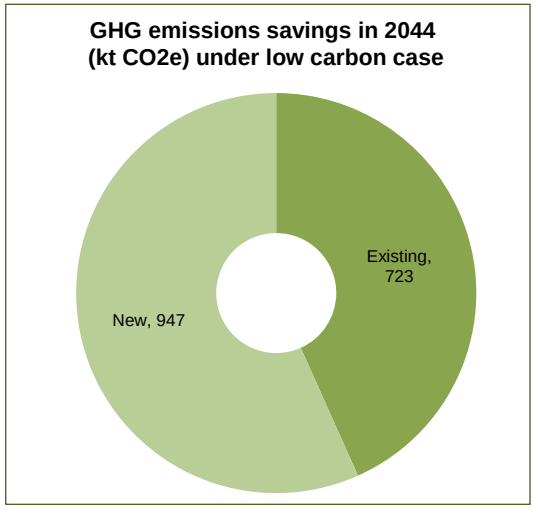
Buildings: Residential

Table 2. Estimated energy savings and GHG emissions avoided under the Reduced Carbon Case and the Low Carbon Case (based on ETP Discussion Paper values as starting point in 2009).

		2014	2024	2034	2044	Cumulative
Savings from energy efficiency and conservation						
Reduced carbon case vs. reference case	TJ	267	1,020	1,818	2,850	45,219
Low carbon case vs. reference case	TJ	1,550	5,336	10,155	11,708	226,975
Additional installed renewable energy						
Reduced carbon case vs. reference case	TJ	3	11	18	28	462
Low carbon case vs. reference case	TJ	141	825	557	644	18,403
GHG emissions avoided						
Reduced carbon case vs. reference case	kt CO2e	49	167	299	459	7,415
Low carbon case vs. reference case	kt CO2e	221	731	1,264	1,670	30,300







Buildings: Residential

Table 3. Estimated incremental costs under the Reduced Carbon Case and the Low Carbon Case.

		2014	2024	2034	2044	Cumulative
Costs of energy efficiency and conservation						
Reduced carbon case vs. reference case	$ million	4	15	27	43	682
Low carbon case vs. reference case	$ million	23	79	150	173	3,359
Costs of installed renewable energy						
Reduced carbon case vs. reference case	$ million	0	1	1	2	37
Low carbon case vs. reference case	$ million	13	86	49	59	1,770
Total costs						
Reduced carbon case vs. reference case	$ million	4	16	29	45	719
Low carbon case vs. reference case	$ million	36	165	199	232	5,129

Table 4. Estimated incremental costs under the Reduced Carbon Case and the Low Carbon Case (based on ETP Discussion Paper values as starting point in 2009).

		2014	2024	2034	2044	Cumulative
Costs of energy efficiency and conservation						
Reduced carbon case vs. reference case	$ million	3	10	17	27	432
Low carbon case vs. reference case	$ million	15	50	95	110	2,127
Costs of installed renewable energy						
Reduced carbon case vs. reference case	$ million	0	1	1	2	24
Low carbon case vs. reference case	$ million	8	54	31	37	1,121
Total costs						
Reduced carbon case vs. reference case	$ million	3	10	18	29	455
Low carbon case vs. reference case	$ million	23	104	126	147	3,249

Buildings: Residential

Table 5. Estimated incremental costs under the Reduced Carbon Case and the Low Carbon Case: Sensitivity test: all costs +25%

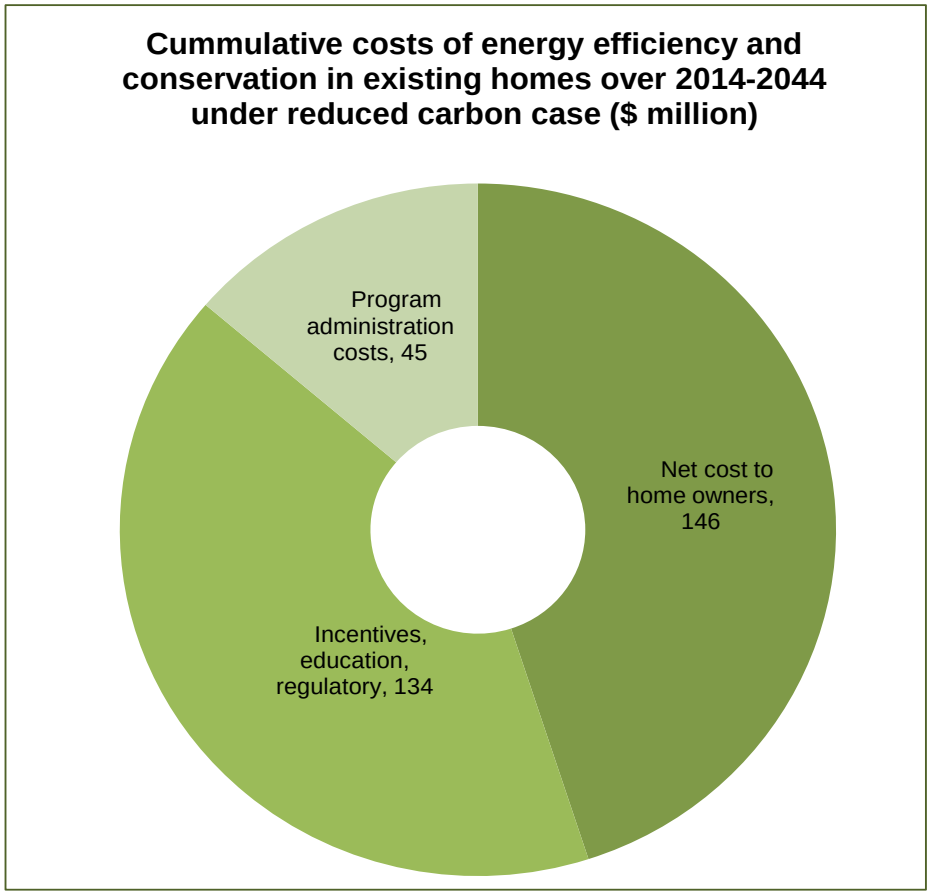
		2014	2024	2034	2044	Cumulative
Costs of energy efficiency and conservation						
Reduced carbon case vs. reference case	$ million	5	19	34	54	852
Low carbon case vs. reference case	$ million	29	99	188	217	4,198
Costs of installed renewable energy						
Reduced carbon case vs. reference case	$ million	0	1	1	2	37
Low carbon case vs. reference case	$ million	13	86	49	59	1,770
Total costs						
Reduced carbon case vs. reference case	$ million	5	20	36	56	889
Low carbon case vs. reference case	$ million	41	184	237	275	5,968

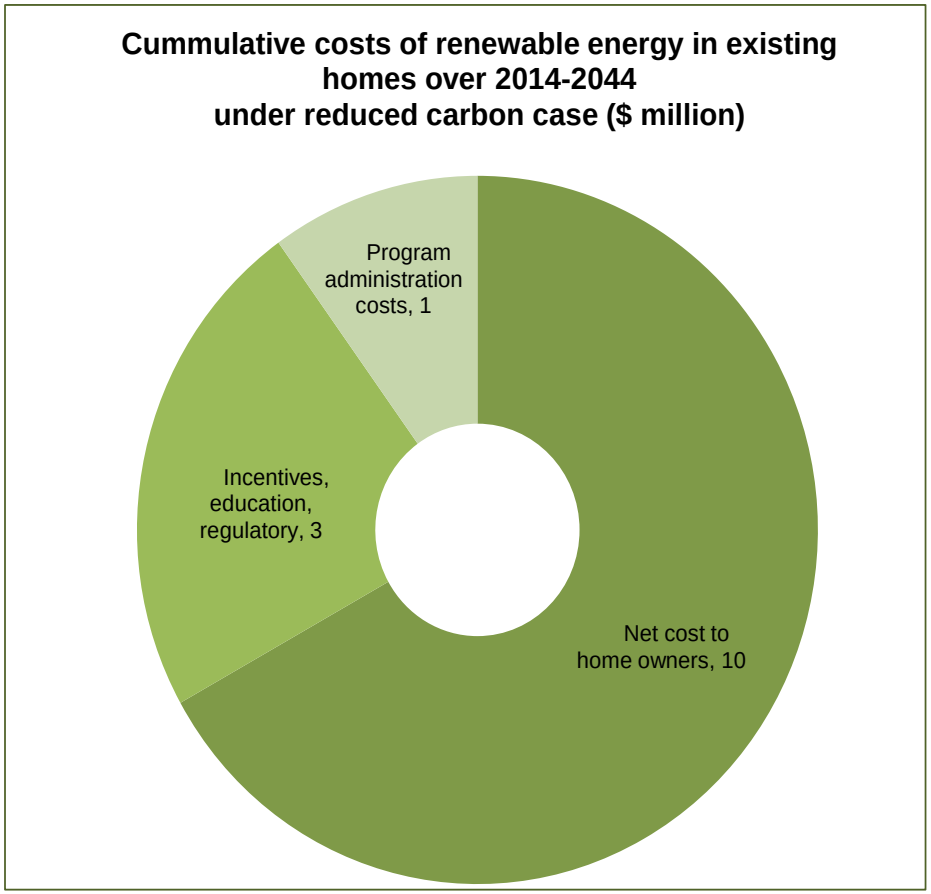
Table 6. Estimated incremental costs under the Reduced Carbon Case and the Low Carbon Case: Sensitivity test: all costs -25%

		2014	2024	2034	2044	Cumulative
Costs of energy efficiency and conservation						
Reduced carbon case vs. reference case	$ million	3	12	21	32	511
Low carbon case vs. reference case	$ million	17	59	113	130	2,519
Costs of installed renewable energy						
Reduced carbon case vs. reference case	$ million	0	1	1	2	37
Low carbon case vs. reference case	$ million	13	86	49	59	1,770
Total costs						
Reduced carbon case vs. reference case	$ million	3	13	22	35	549
Low carbon case vs. reference case	$ million	30	145	162	189	4,289

Buildings: Residential

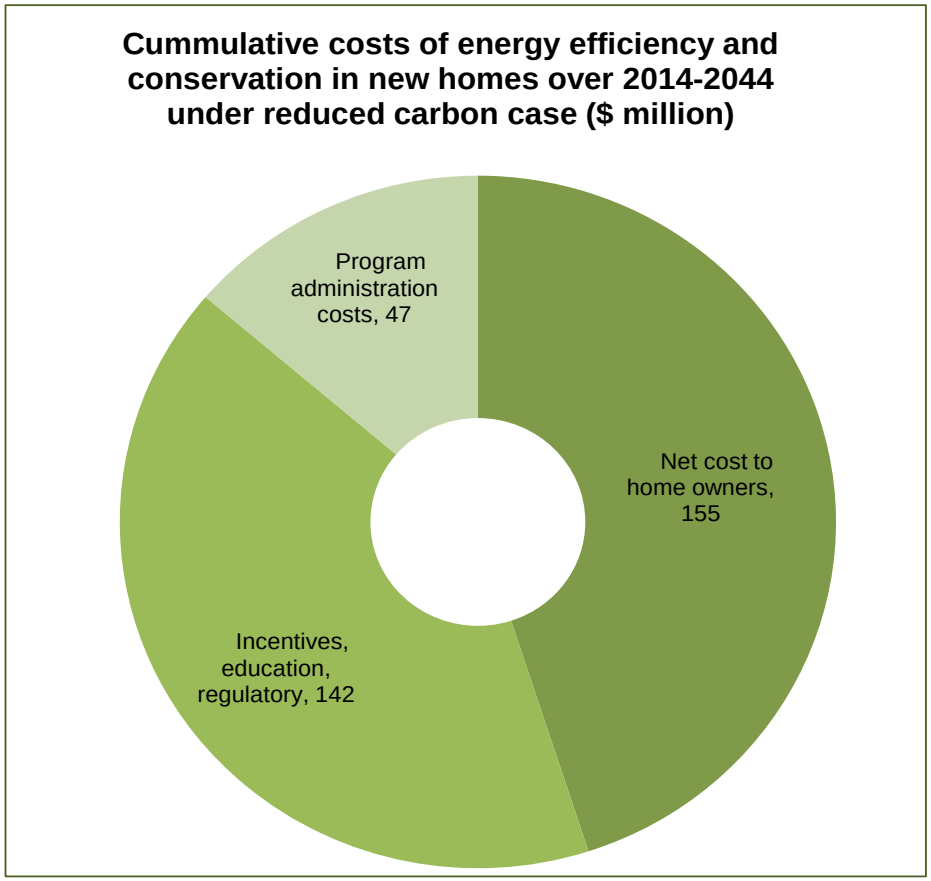
Figure 10. Breakdown of incremental cumulative costs for existing homes under the Reduced Carbon Case.

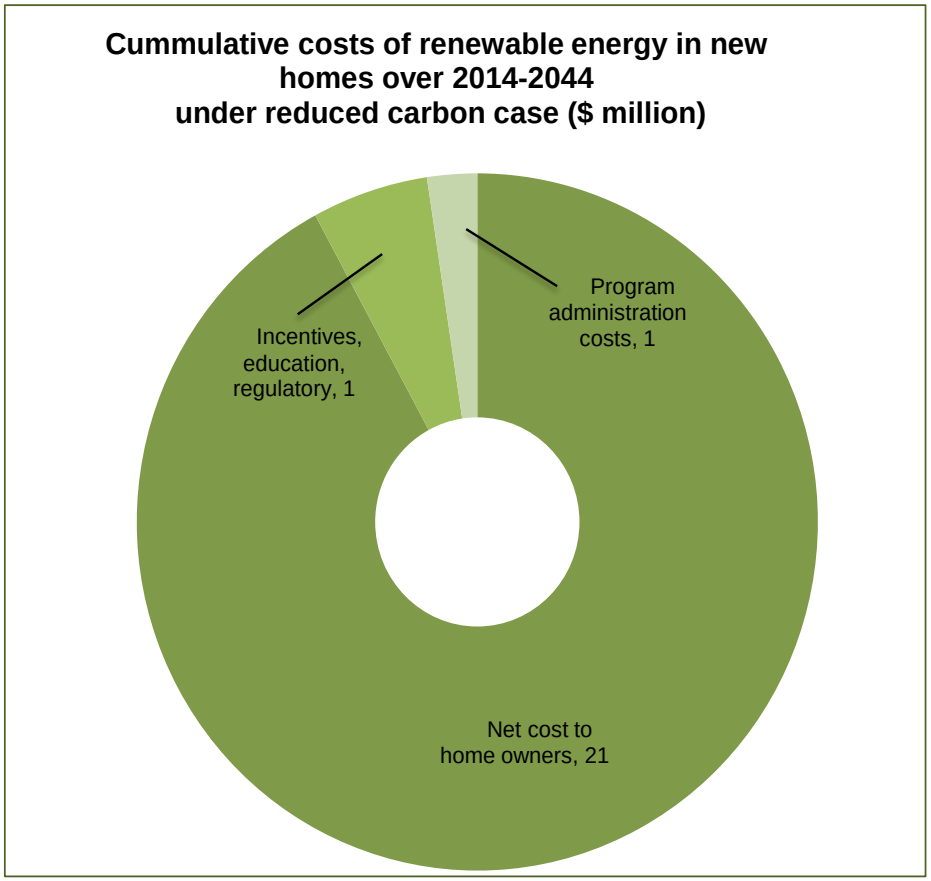




Buildings: Residential

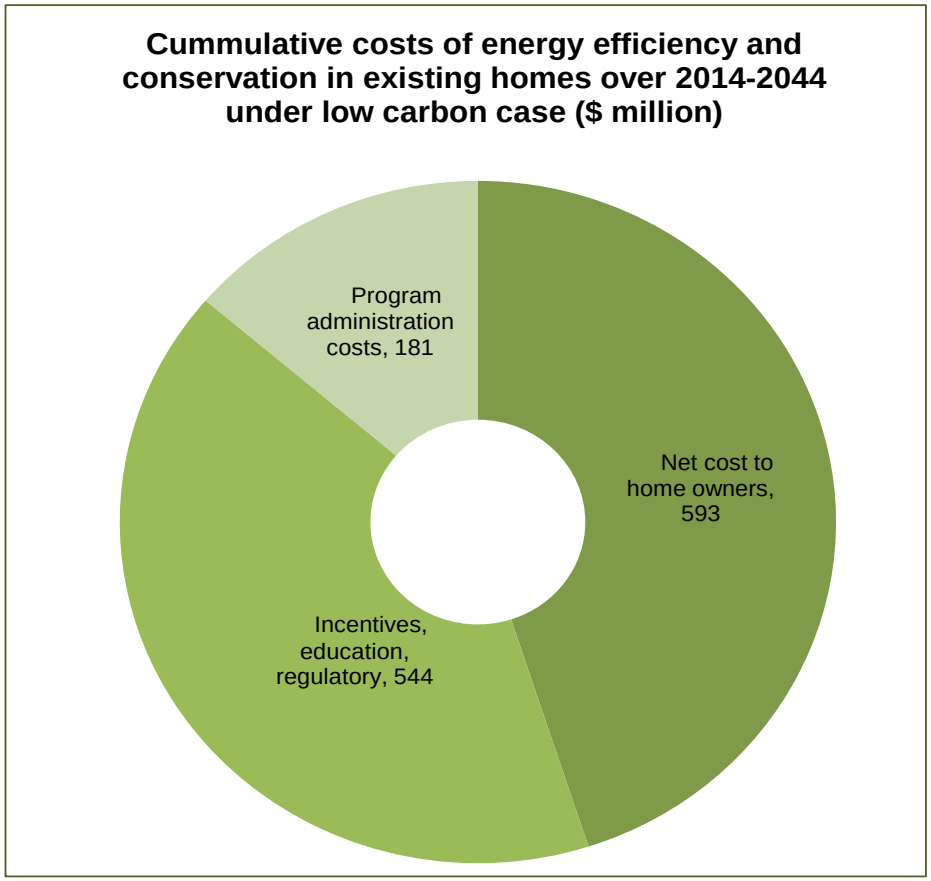
Figure 11. Breakdown of incremental cumulative costs for new homes under the Reduced Carbon Case.

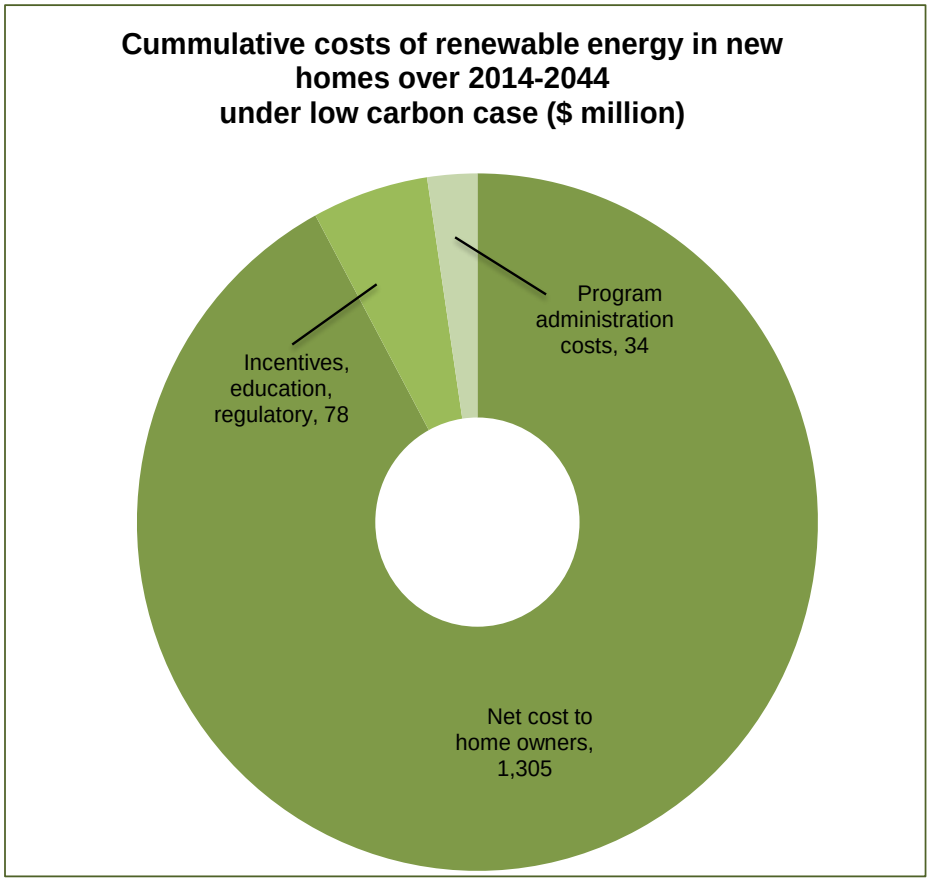




Buildings: Residential

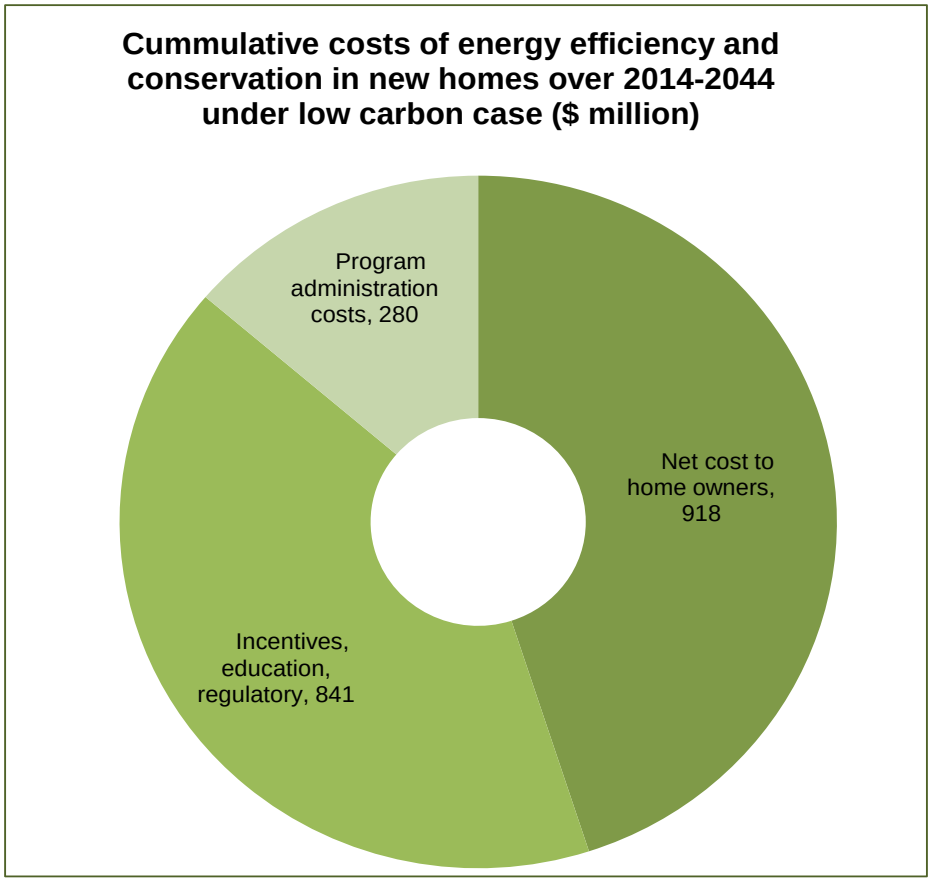
Figure 12. Breakdown of incremental cumulative costs for existing homes under the Low Carbon Case.

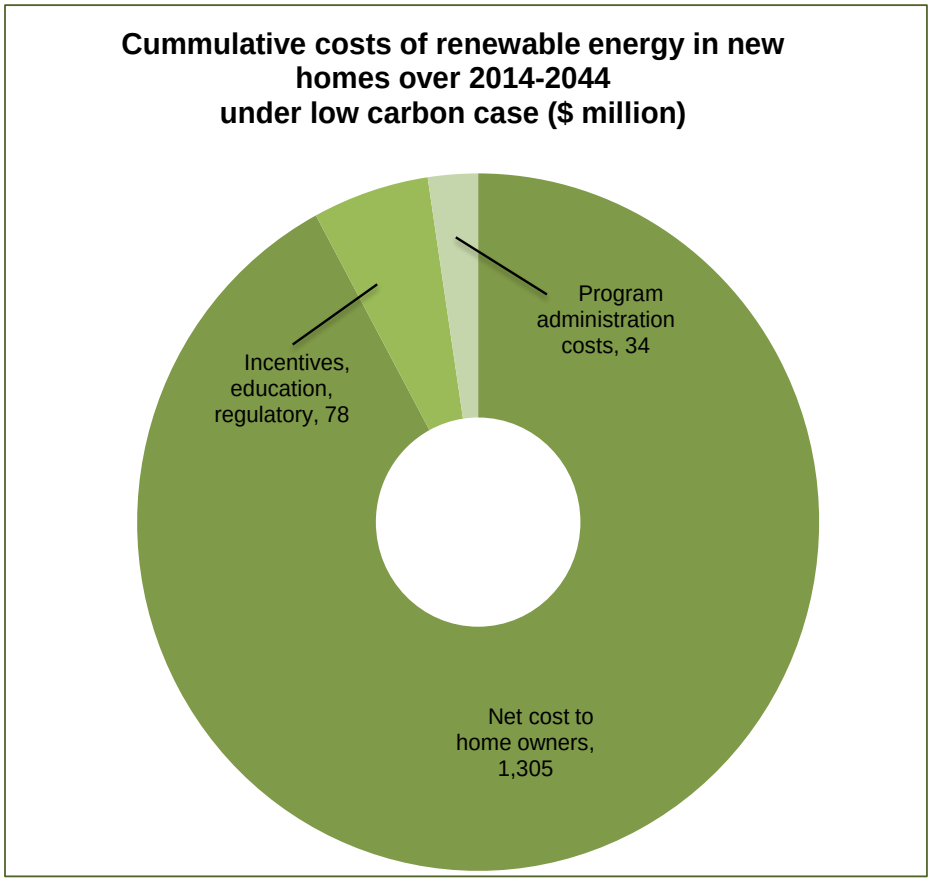




Buildings: Residential

Figure 13. Breakdown of incremental cumulative costs for new homes under the Low Carbon Case.





Buildings: Institutional, Commercial, and Industrial

Assumptions

Assumptions that underpin the analysis are listed below; only those assumptions that differ from those outlined above for residential homes are listed. They are based on our interpretation of the ETP Discussion Paper. Where we have made assumptions additional to those in the Paper, they are denoted with "*".

- Total floor space of institutional, commercial, and industrial (ICI) buildings (all activity types): 260 million ft^2 under all cases (2009), 350 million ft^2 under the Reference Case (2044), 350 million ft^2 under the Reduced Carbon Case (2044), and 360 million ft^2 under the Low Carbon Case (2044). The total floor space is assumed to follow a linear path between 2009 and 2044.
- The survival rate of existing ICI floor space is the same as existing homes at 99.6%.*
- According to the ETP Discussion Paper, the implied natural gas and electricity energy intensity of ICI buildings in 2009 is, respectively, 1.77 GJ per m^2 and 0.76 GJ per m^2. The total energy intensity of ICI buildings in 2009 is thus 2.53 GJ per m^2.
- The implied space heating and cooling energy intensity of ICI buildings in 2009 (as estimated by C3 using NRCAN data) is 1.49 GJ per m^2; the implied water heating energy intensity of ICI buildings in 2009 is 0.23 GJ per m^2; the implied lighting energy intensity of ICI buildings in 2009 is 0.28 GJ per m^2; and the implied auxiliary equipment and motors energy intensity of ICI buildings in 2009 is 0.54 GJ per m^2.*
- As a result of new energy requirements in the building code -- relative to buildings built in 2009 -- the energy intensity of all newly constructed buildings will improve by: 25% (over the entire period 2014-2029) and 50% (over the entire period 2030-2044) under the Reference Case; 27.5% (2014-2029) and 52.5% (2030-2044) under the Reduced Carbon Case; and 50% (2014-2029) and 85% (2030-2044) under the Low Carbon Case. The improvements are assumed to apply to space heating and cooling and water heating. Note that the improvements in energy efficiency are assumed to be realized immediately in full when the code changes (i.e., in 2014 and again in 2030).
- The penetration of renewable energy technologies in all newly constructed buildings is: 1% of new construction (by 2024) and 1% of new construction (by 2044) under the Reference Case; 1.5% of new construction (by 2024) and 2% of new construction (by 2044) under the Reduced Carbon Case; and 90% of new construction (by 2024) and 90% of new construction (by 2044) under the Low Carbon Case. The penetration rate is assumed to follow a linear path between 2009 (assumed to be 0%) and 2024 and between 2024 and 2044.

Buildings: Institutional, Commercial, and Industrial

- Energy from renewable technologies is assumed to displace 10% of both space heating and cooling and water heating energy use in new buildings.
- Under the Reference Case 2.5% of all existing buildings annually install measures to improve their energy intensity over the period 2009-2044.
- By 2024 under the Reduced Carbon Case and Low Carbon Case, respectively, 3% and 8% of all existing buildings install measures to improve their energy intensity. The penetration rate follows a linear path from 2009 (starting at 2.5%) to these levels in 2024.
- Between 2024 and 2044 under the Reduced Carbon Case and Low Carbon Case, respectively, 3% and 8% of all existing homes annually install measures to improve their energy intensity. In other words, between 2024 and 2044 ,3% and 8% of all existing buildings annually install measures to improve their energy intensity under the Reduced Carbon Case and Low Carbon Case, respectively.
- The upgrades in existing buildings improve the energy intensity of end-uses by 10% under all cases.
- The penetration of renewable energy technologies in all existing buildings is: 0.25% by 2044 under the Reference Case; 0.5% by 2044 under the Reduced Carbon Case; and 5% by 2034 (and constant thereafter till 2044) under the Low Carbon Case. The penetration rate is assumed to follow a linear path between 2009 (where it is assumed to be 0%) and these future dates.
- Energy from renewable technologies installed in existing buildings is assumed to displace 100% of water heating energy use.
- No DSM programs are implemented to induce behavioral change for energy conservation.
- The installed (pre-incentive) cost of energy efficiency improvements in ICI buildings is, on average, $6,915 (±25%) per TJ saved. Program delivery costs comprise: incentive payments equal to $3,310 (±25%) per TJ; and technical assistance, administration, and other overhead equal to $1,105 (±25%) per TJ. Total program deliver costs equal incentive payments plus technical assistance, administration, and other overhead costs. Total participation costs to building owners comprise installed costs less incentive payments (all figures based on C3 analysis of industrial programs in North America).*

Buildings: Institutional, Commercial, and Industrial

- Based on the City of Edmonton Renewable Energy Plan the installed (gross) cost of renewable energy technologies in existing buildings is, on average, $30,550 per TJ supplied. Only solar hot water technology is assumed to be installed on existing buildings. Program delivery cost comprises: incentive payments equal to 25% of installed costs plus education equal to 1% of installed cost; and administration and other overhead equal to 30% of total delivery costs. Total deliver costs equal incentive payments plus administration and other overhead costs. Total participation costs to building owners comprise installed costs less incentive payments.*
- Based on the City of Edmonton Renewable Energy Plan the installed (gross) cost of renewable energy technologies in newly constructed buildings is, on average, $64,220 per TJ supplied. A weighted average of solar PV, solar air heating, passive solar, and solar hot water technology is assumed to be installed on existing buildings. The weights are based on the achievable potential identified in the Renewable Energy Plan. Program delivery cost comprises: regulatory costs equal to 5% of installed costs plus education equal to 1% of installed cost; and administration and other overhead equal to 30% of total delivery costs. Total deliver costs equal regulatory cost plus administration and other overhead costs.*
- The impact of “experience effects” on unit costs is not modelled.

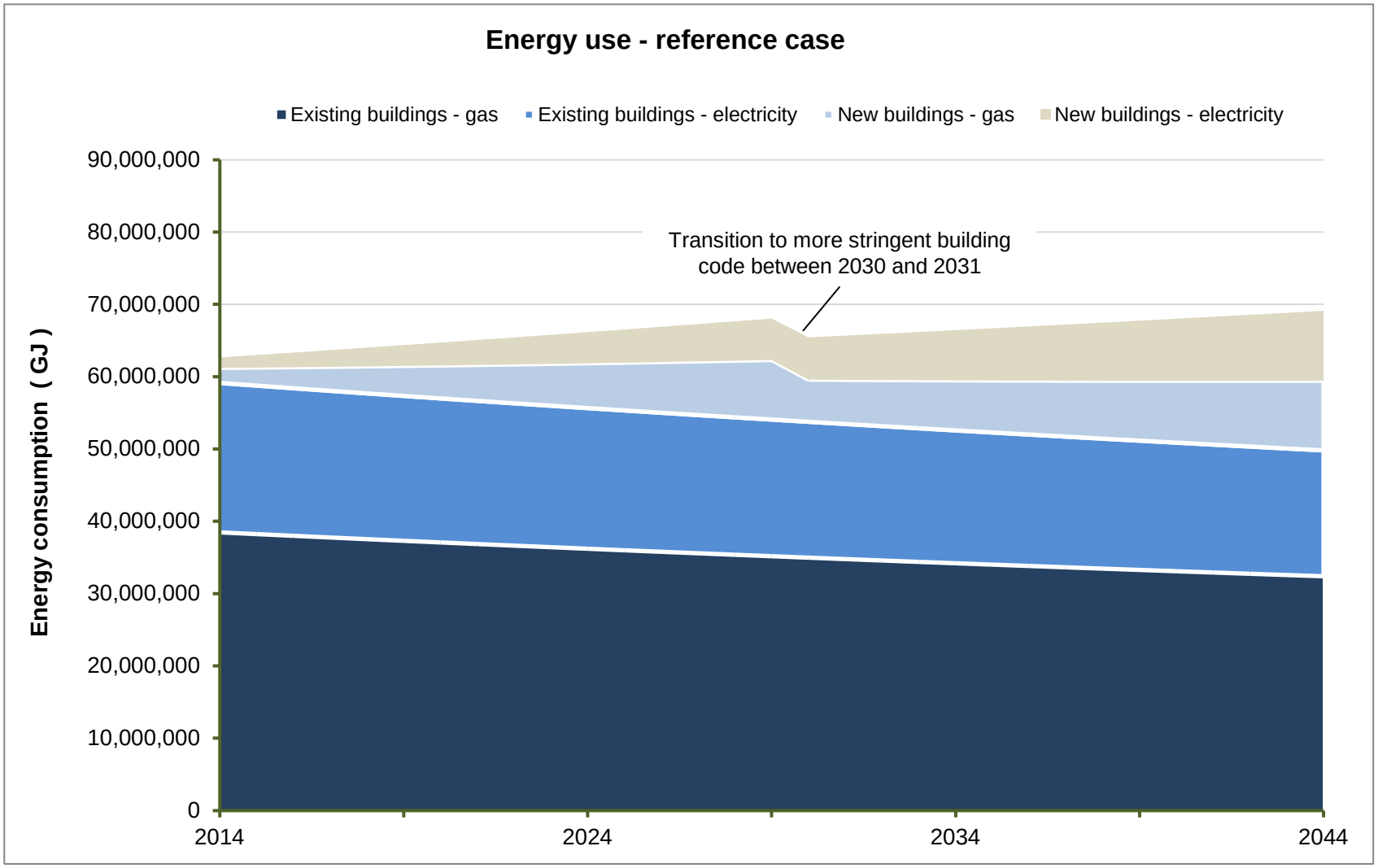
Results

The results for ICI buildings are presented below.

Note: the impact of reductions in the GHG intensity of the Alberta electricity grid are embedded in the results reported; the policies that induce these reductions are not specified or included in the cost estimates.

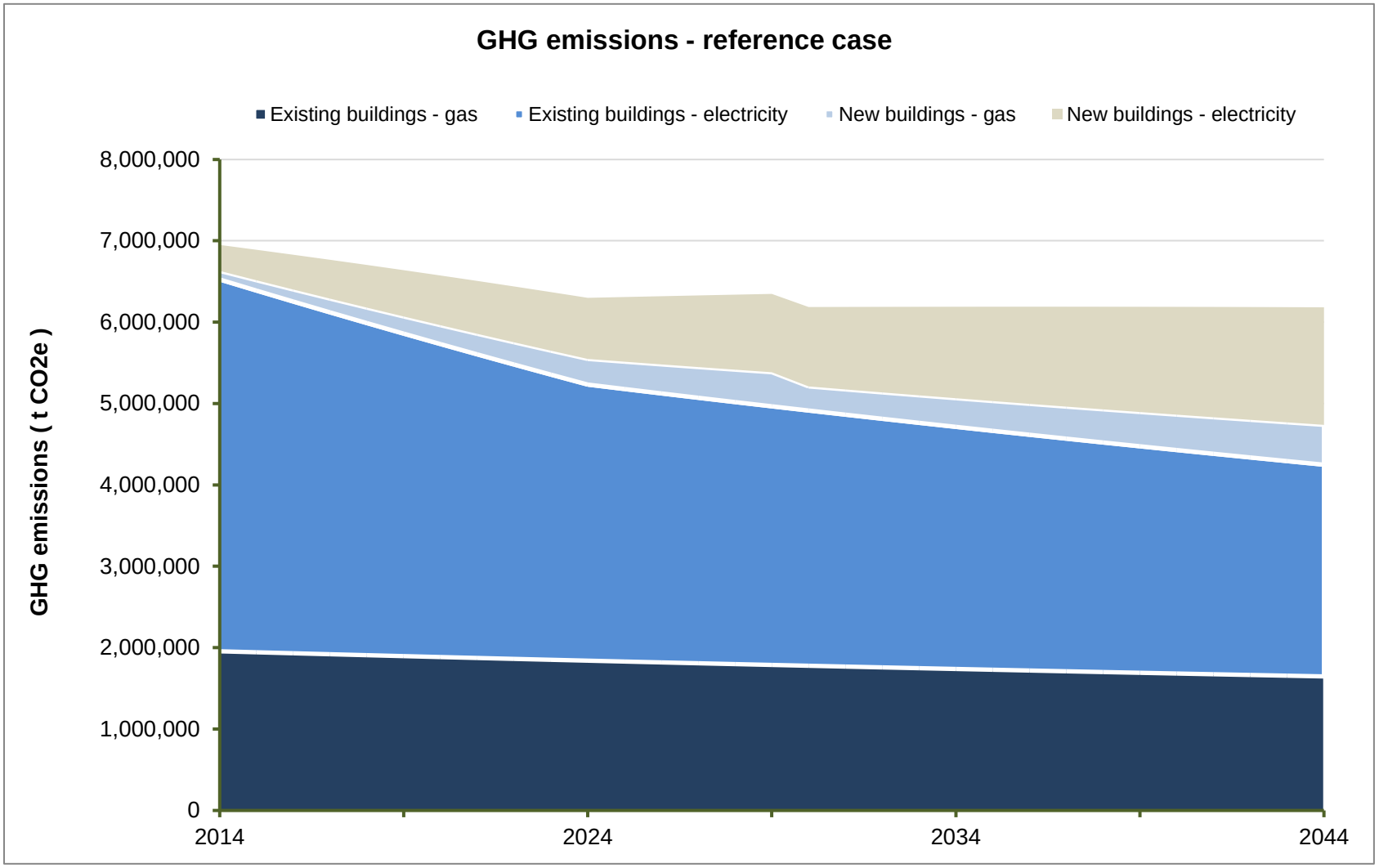
Buildings: Institutional, Commercial, and Industrial

Figure 14. Projected energy use under the Reference Case. Total energy consumption by ICI buildings in 2014 is 63 PJ; rising to 69 PJ in 2044.



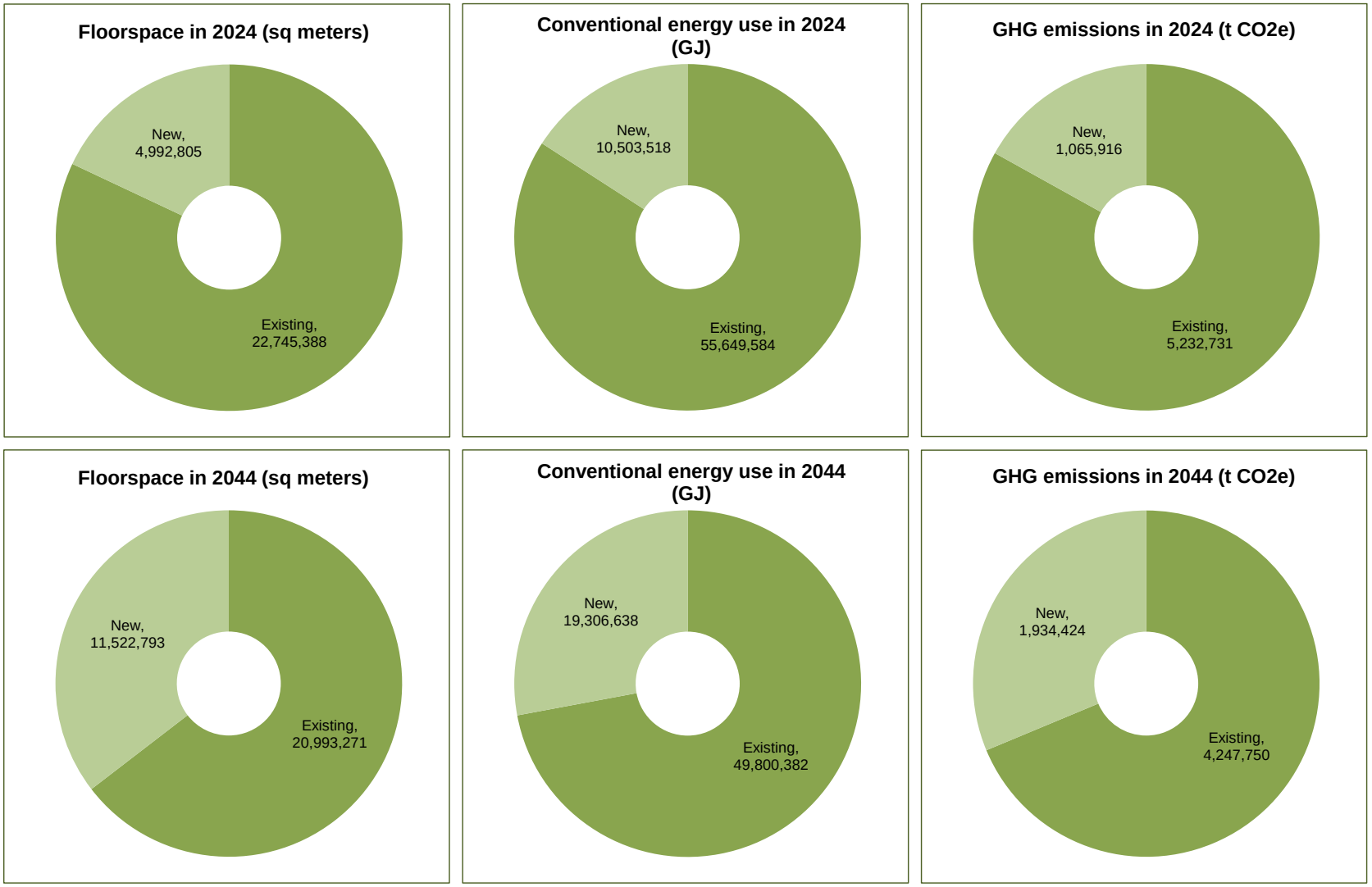
Buildings: Institutional, Commercial, and Industrial

Figure 15. Projected GHG emissions under the Reference Case. Total GHG emissions by ICI buildings in 2014 are 6.9 Mt CO_2e; falling to 6.2 Mt CO_2e in 2044.



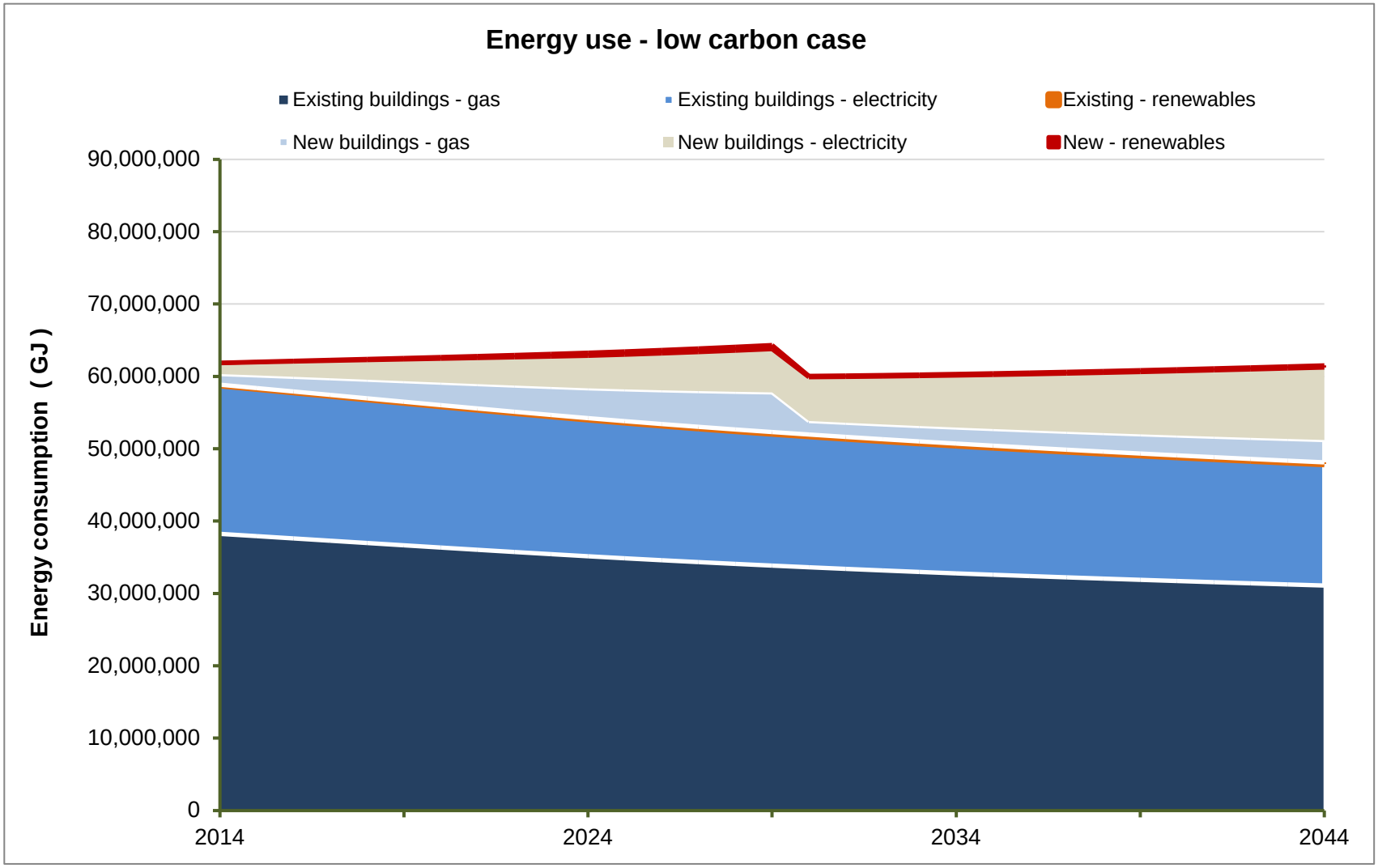
Buildings: Institutional, Commercial, and Industrial

Figure 16. Projected energy use and GHG emissions by existing and new ICI buildings under the Reference Case.



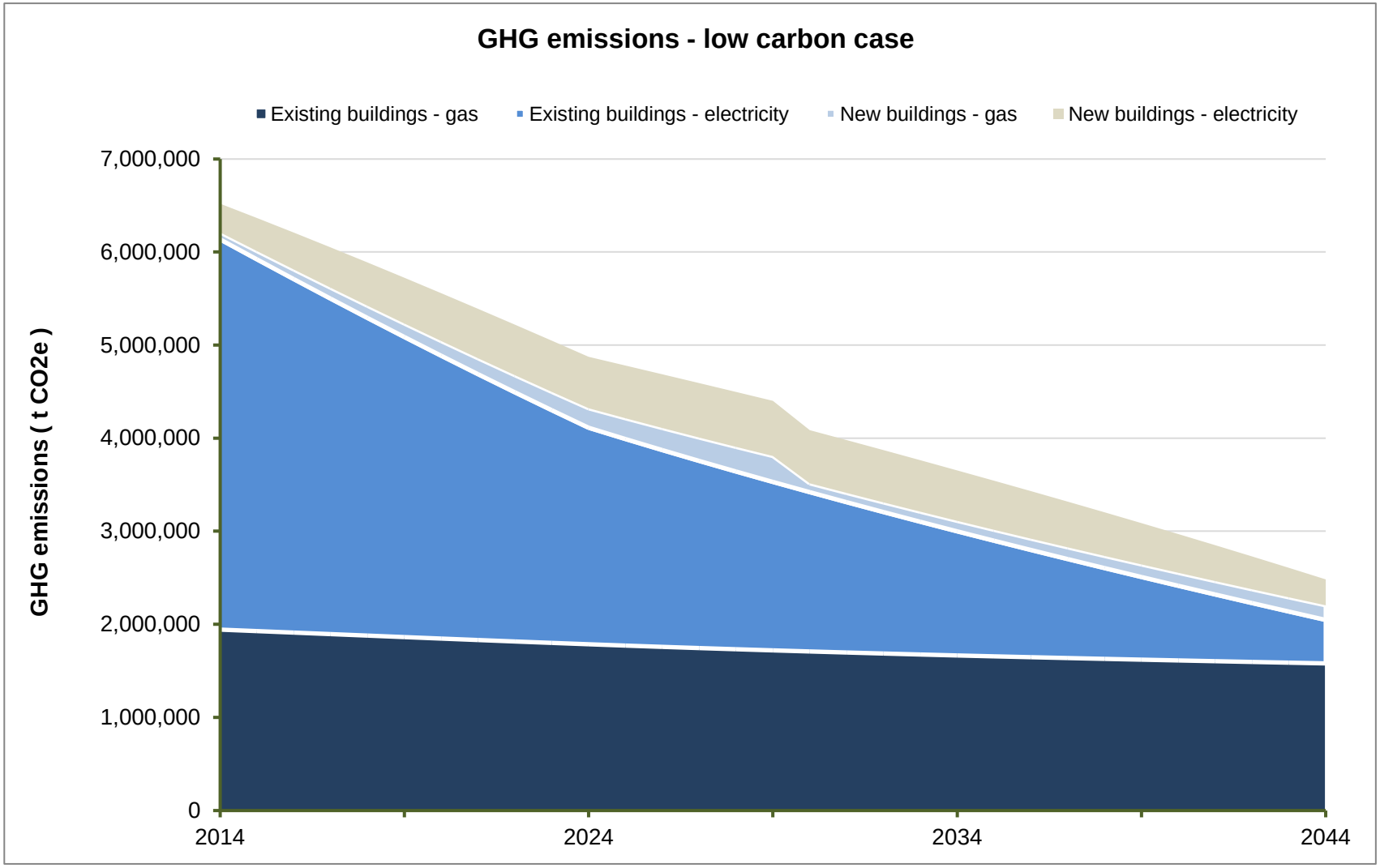
Buildings: Institutional, Commercial, and Industrial

Figure 17. Projected energy use under the Low Carbon Case. Total energy consumption by ICI buildings in 2014 is 62 PJ; falling to 61 PJ in 2044. Energy use in 2044 is about 11% less than under the Reference Case.



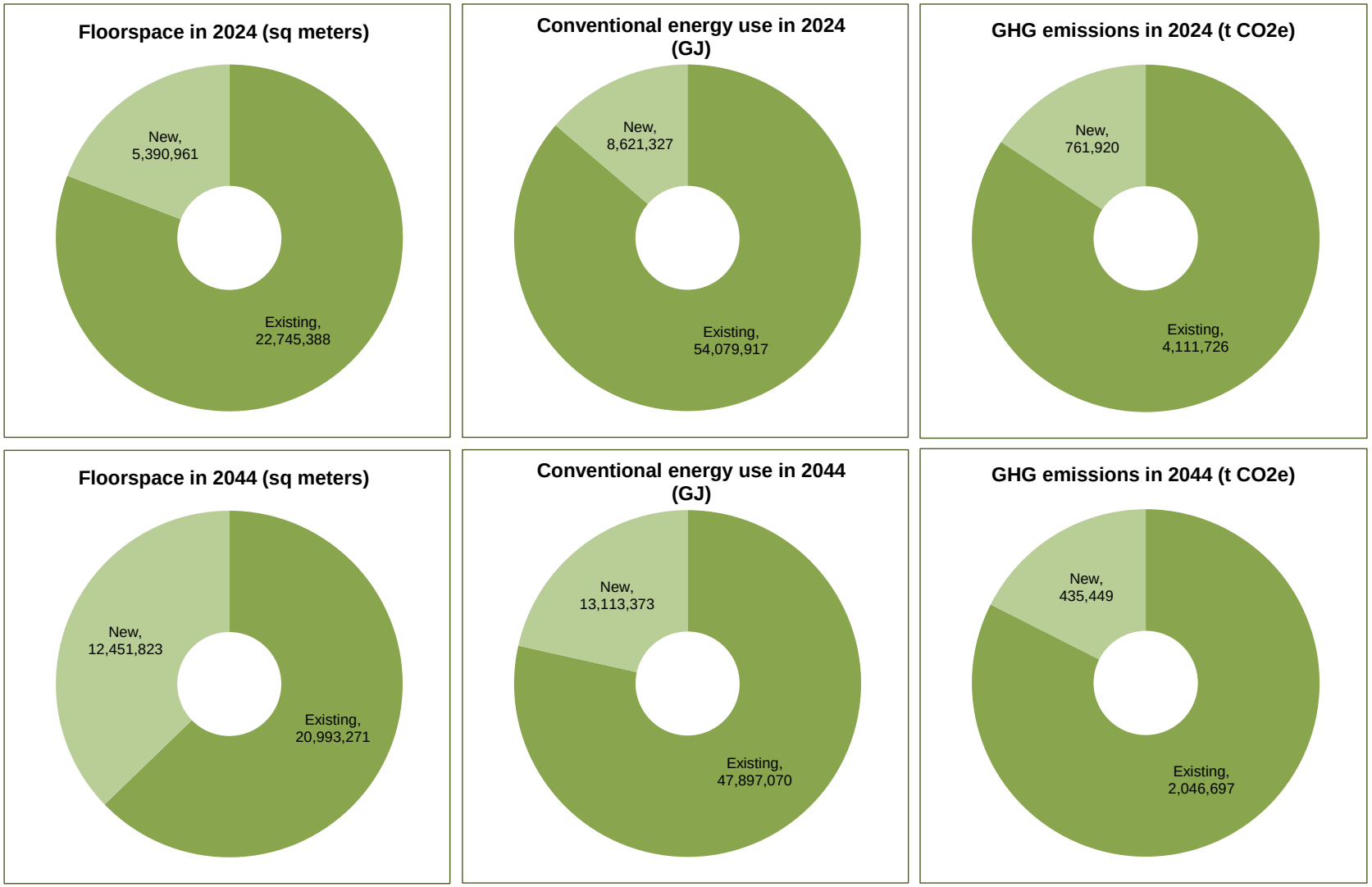
Buildings: Institutional, Commercial, and Industrial

Figure 18. Projected GHG emissions under the Low Carbon Case. Total GHG emissions by ICI buildings in 2014 are 6.5 Mt CO_2e; falling to 2.5 Mt CO_2e in 2044. GHG emissions in 2044 are about 60% lower than under the Reference Case.



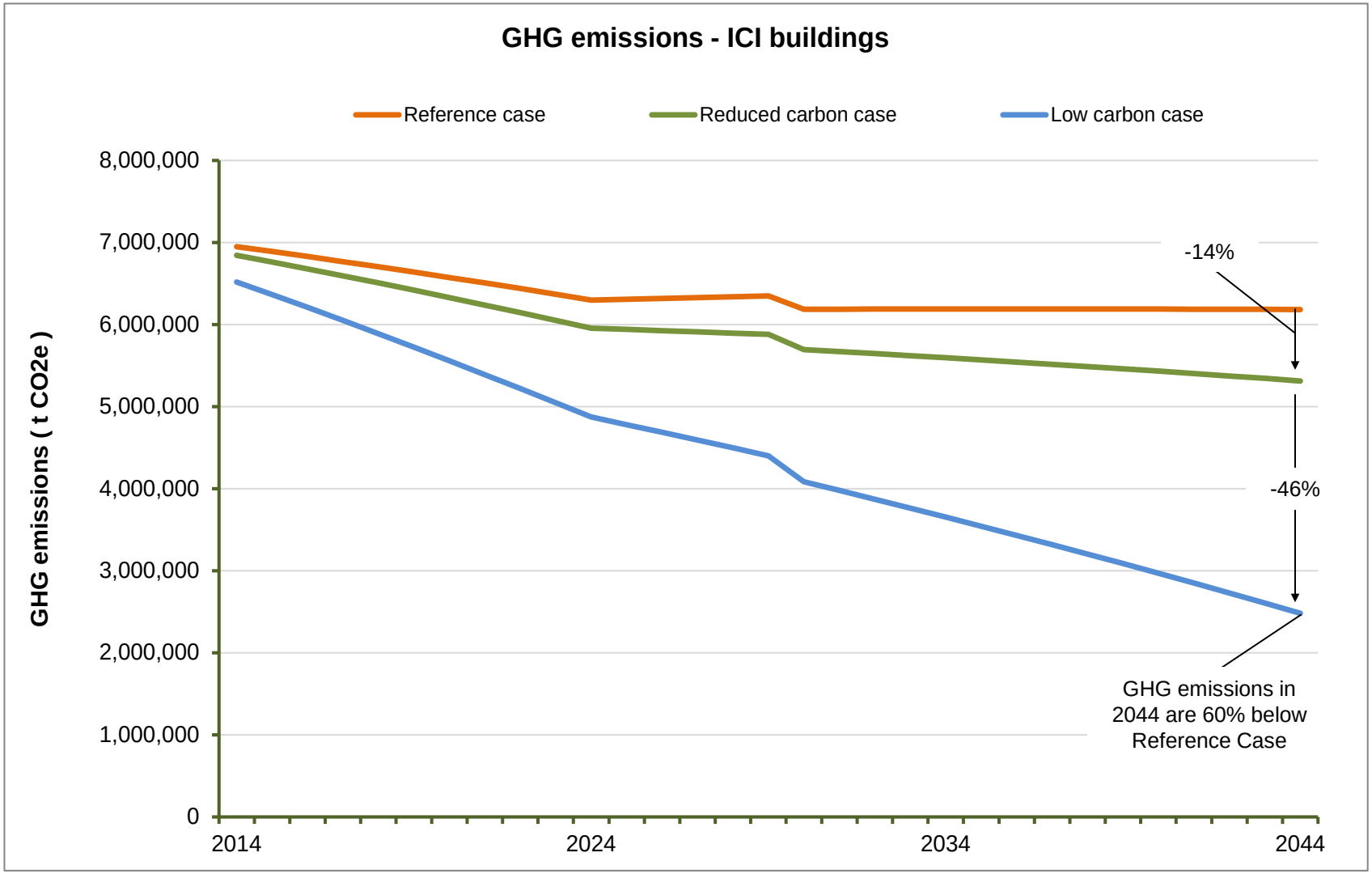
Buildings: Institutional, Commercial, and Industrial

Figure 19. Projected energy use and GHG emissions by existing and new ICI buildings under the Low Carbon Case.



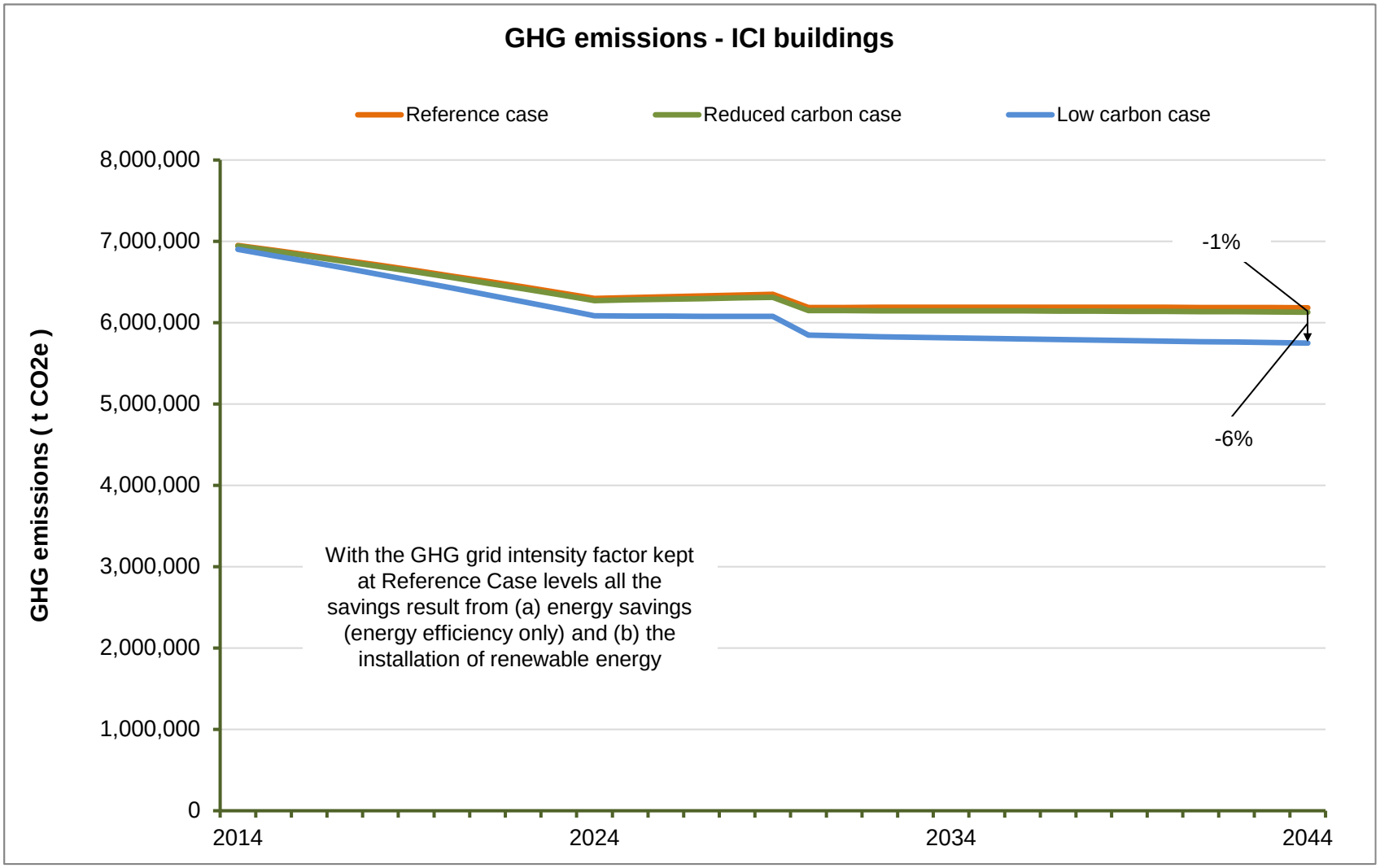
Buildings: Institutional, Commercial, and Industrial

Figure 20. Projected GHG emissions under the Reference Case, the Reduced Carbon Case, and the Low Carbon Case.



Buildings: Institutional, Commercial, and Industrial

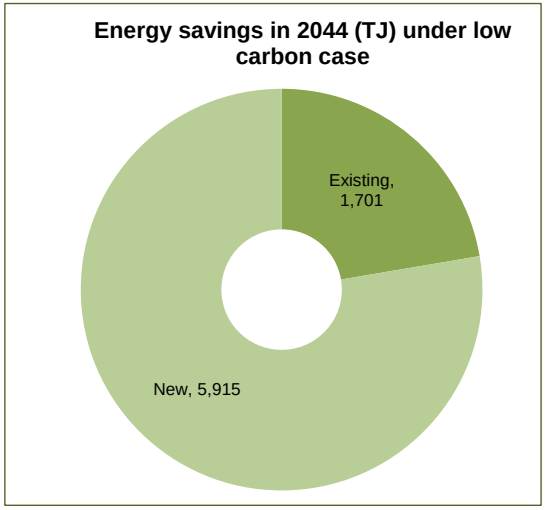
Figure 21. Projected GHG emissions under the Reference Case, the Reduced Carbon Case, and the Low Carbon Case (assuming the GHG intensity of the Alberta electricity grid does not change from Reference Case values).

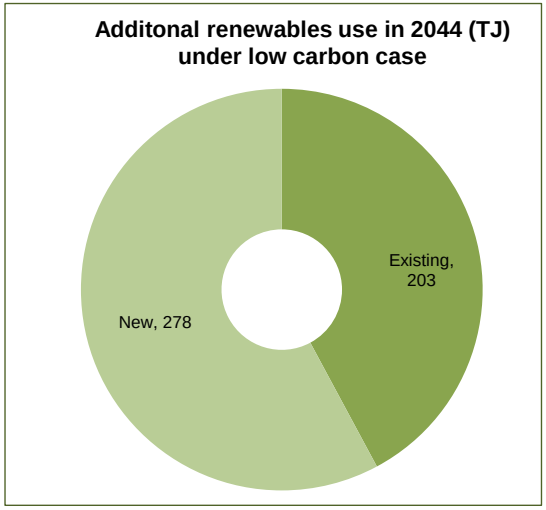


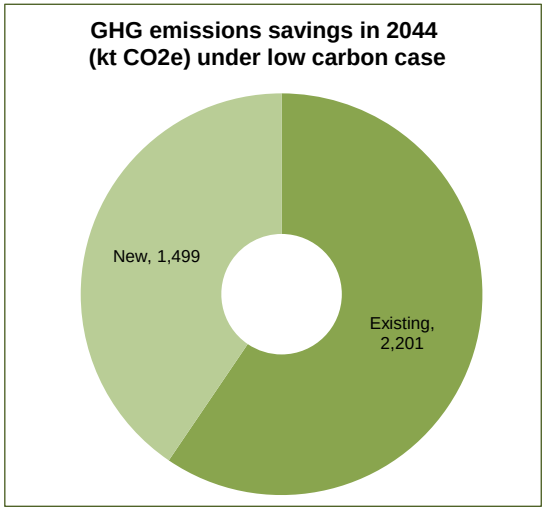
Buildings: Institutional, Commercial, and Industrial

Table 7. Estimated energy savings and GHG emissions avoided under the Reduced Carbon Case and the Low Carbon Case.

		2014	2024	2034	2044	Cumulative
Savings from energy efficiency and conservation						
Reduced carbon case vs. reference case	TJ	98	370	612	785	14,751
Low carbon case vs. reference case	TJ	781	2,903	6,118	7,615	135,791
Additional installed renewable energy						
Reduced carbon case vs. reference case	TJ	2	8	13	20	332
Low carbon case vs. reference case	TJ	96	549	417	481	12,983
GHG emissions avoided						
Reduced carbon case vs. reference case	kt CO2e	106	343	594	870	14,672
Low carbon case vs. reference case	kt CO2e	430	1,425	2,536	3,700	62,049







Buildings: Institutional, Commercial, and Industrial

Table 8. Estimated incremental costs under the Reduced Carbon Case and the Low Carbon Case.

		2014	2024	2034	2044	Cumulative
Costs of energy efficiency and conservation						
Reduced carbon case vs. reference case	$ million	0.8	3.0	4.9	6.3	118.3
Low carbon case vs. reference case	$ million	6.3	23.3	49.1	61.1	1,089.1
Costs of installed renewable energy						
Reduced carbon case vs. reference case	$ million	0.1	0.4	0.6	1.0	16.2
Low carbon case vs. reference case	$ million	5.2	35.1	22.5	27.8	768.5
Total costs						
Reduced carbon case vs. reference case	$ million	0.9	3.4	5.5	7.3	134.5
Low carbon case vs. reference case	$ million	11.5	58.4	71.6	88.9	1,857.6

Table 9. Estimated incremental costs under the Reduced Carbon Case and the Low Carbon Case: Sensitivity test: all costs +25%

		2014	2024	2034	2044	Cumulative
Costs of energy efficiency and conservation						
Reduced carbon case vs. reference case	$ million	1.0	3.7	6.1	7.9	147.9
Low carbon case vs. reference case	$ million	7.8	29.1	61.3	76.3	1,361.3
Costs of installed renewable energy						
Reduced carbon case vs. reference case	$ million	0.1	0.4	0.6	1.0	16.2
Low carbon case vs. reference case	$ million	5.2	35.1	22.5	27.8	768.5
Total costs						
Reduced carbon case vs. reference case	$ million	1.1	4.1	6.7	8.9	164.1
Low carbon case vs. reference case	$ million	13.0	64.2	83.8	104.1	2,129.8

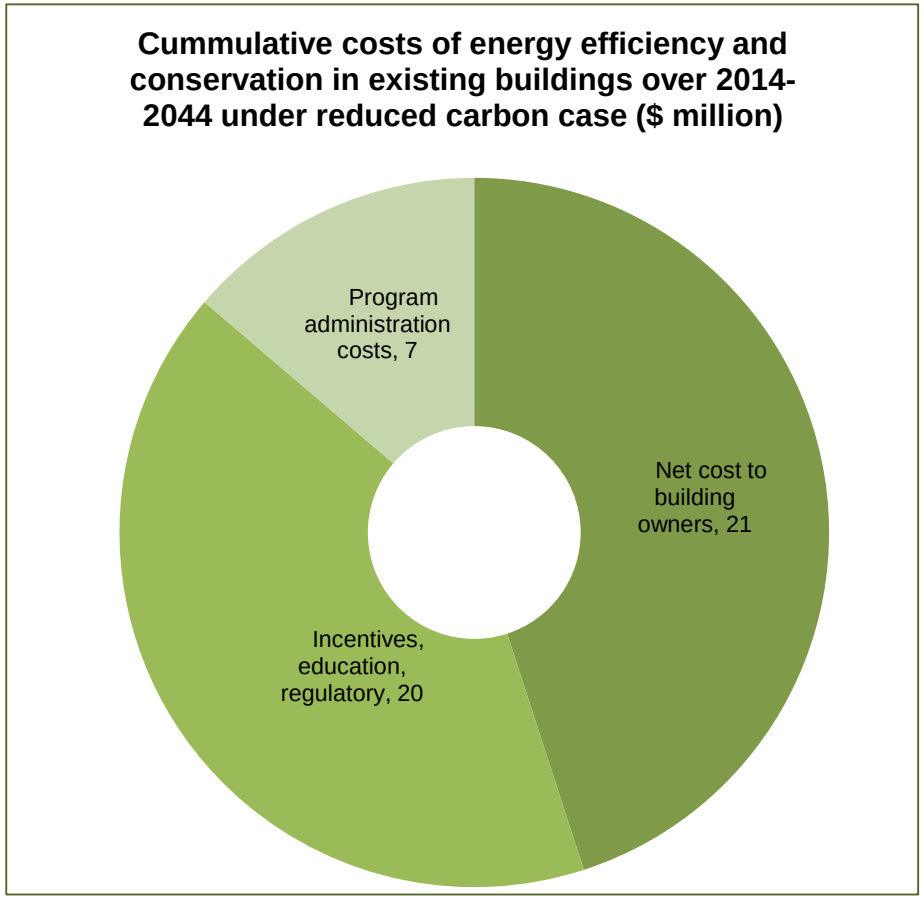
Buildings: Institutional, Commercial, and Industrial

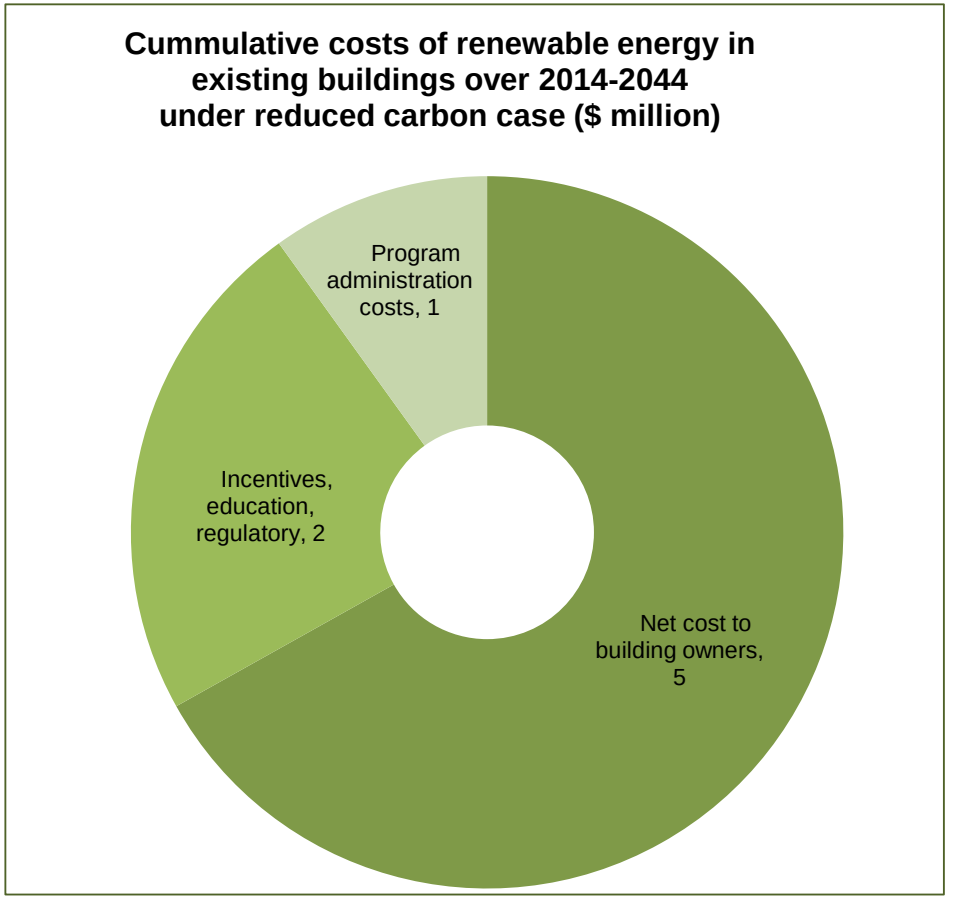
Table 10. Estimated incremental costs under the Reduced Carbon Case and the Low Carbon Case: Sensitivity test: all costs -25%

		2014	2024	2034	2044	Cumulative
Costs of energy efficiency and conservation						
Reduced carbon case vs. reference case	$ million	0.6	2.2	3.7	4.7	88.7
Low carbon case vs. reference case	$ million	4.7	17.5	36.8	45.8	816.8
Costs of installed renewable energy						
Reduced carbon case vs. reference case	$ million	0.1	0.4	0.6	1.0	16.2
Low carbon case vs. reference case	$ million	5.2	35.1	22.5	27.8	768.5
Total costs						
Reduced carbon case vs. reference case	$ million	0.7	2.6	4.3	5.7	104.9
Low carbon case vs. reference case	$ million	9.9	52.6	59.3	73.6	1,585.3

Buildings: Institutional, Commercial, and Industrial

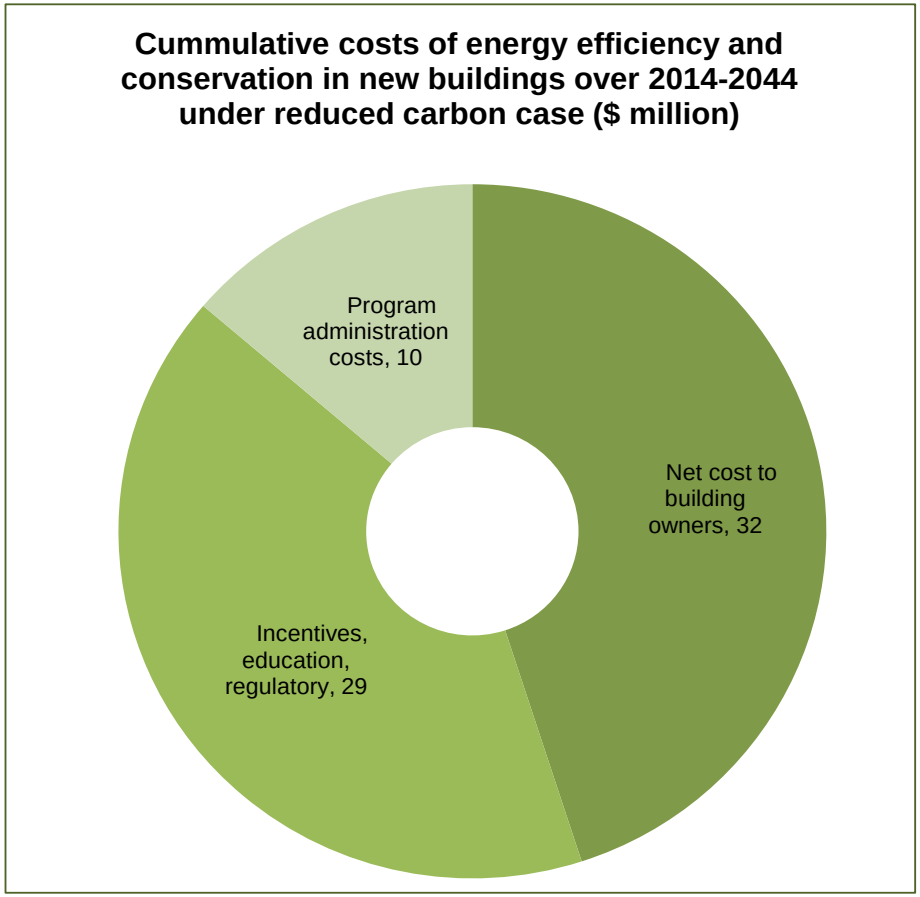
Figure 22. Breakdown of incremental cumulative costs for existing ICI buildings under the Reduced Carbon Case.

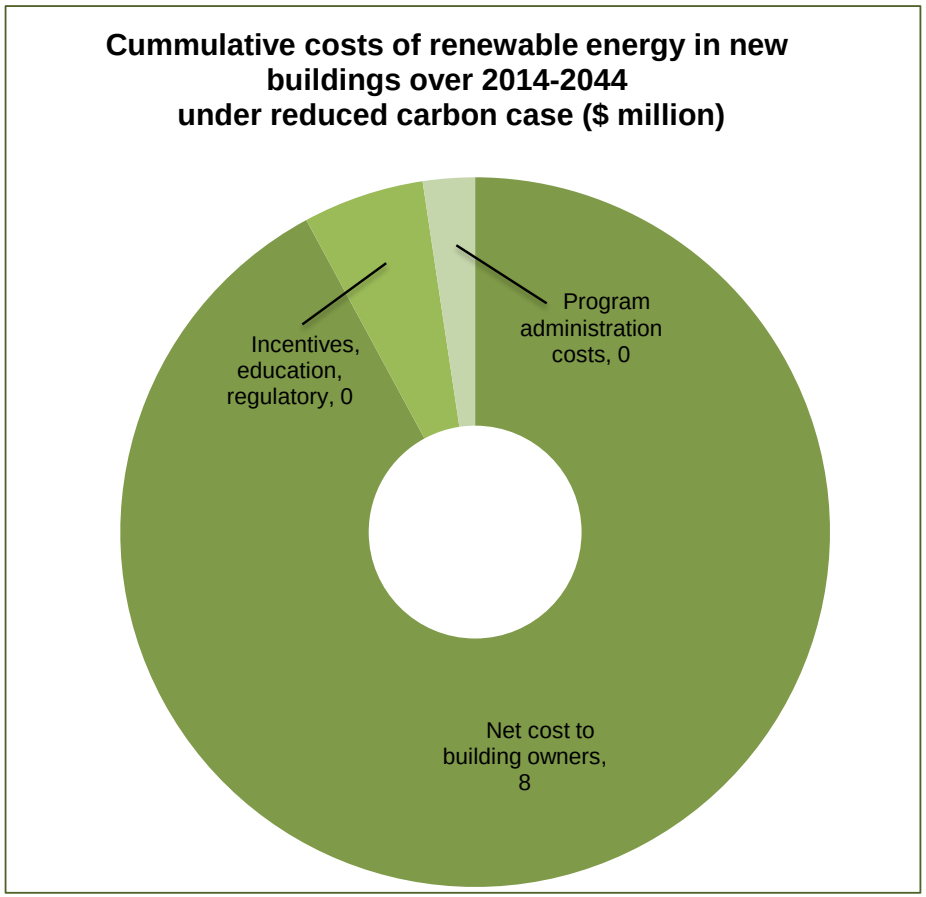




Buildings: Institutional, Commercial, and Industrial

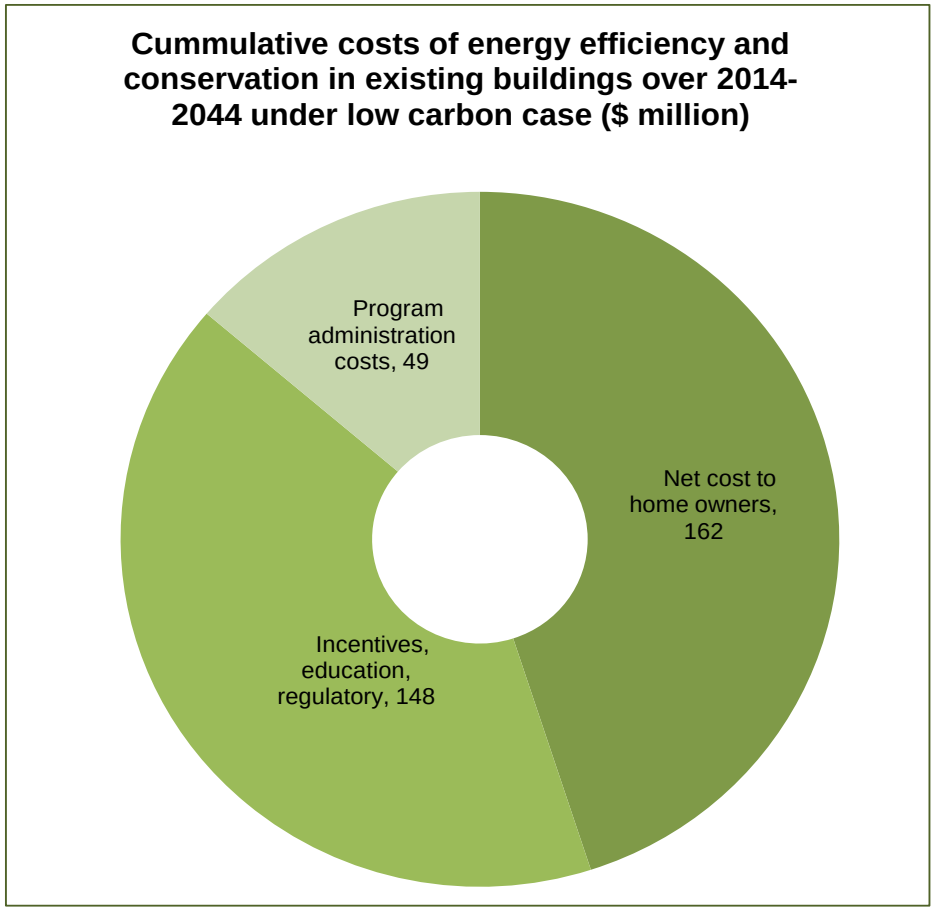
Figure 23. Breakdown of incremental cumulative costs for new ICI buildings under the Reduced Carbon Case.

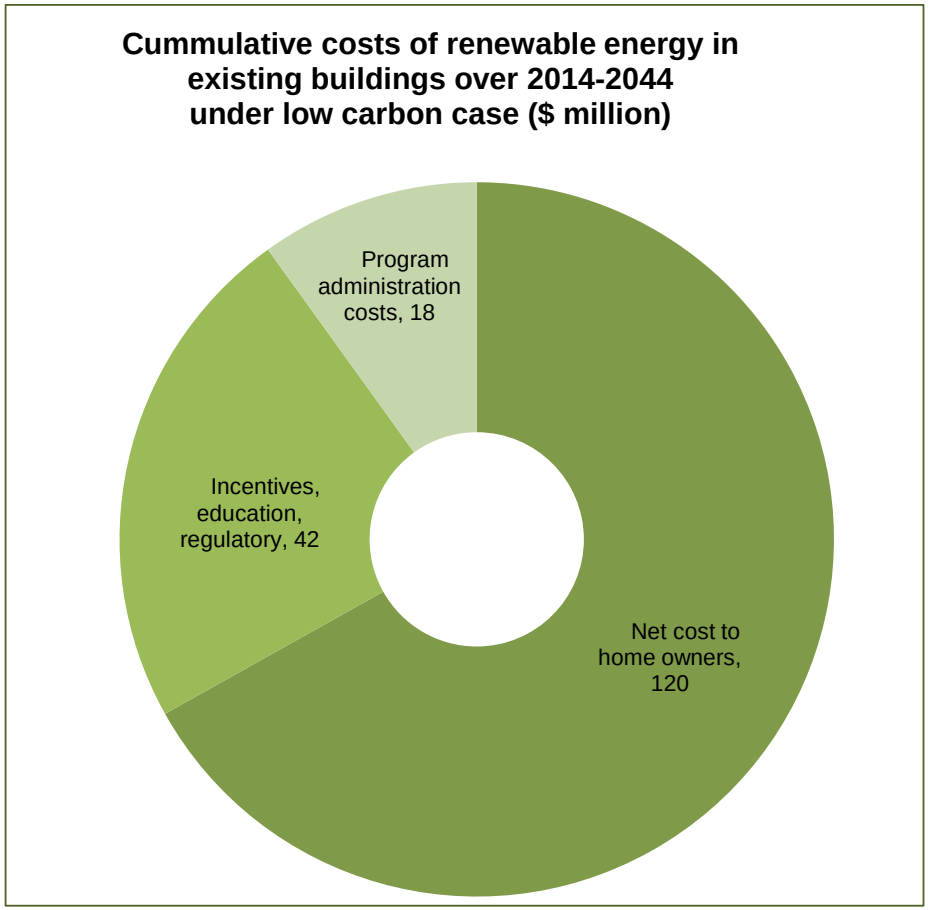




Buildings: Institutional, Commercial, and Industrial

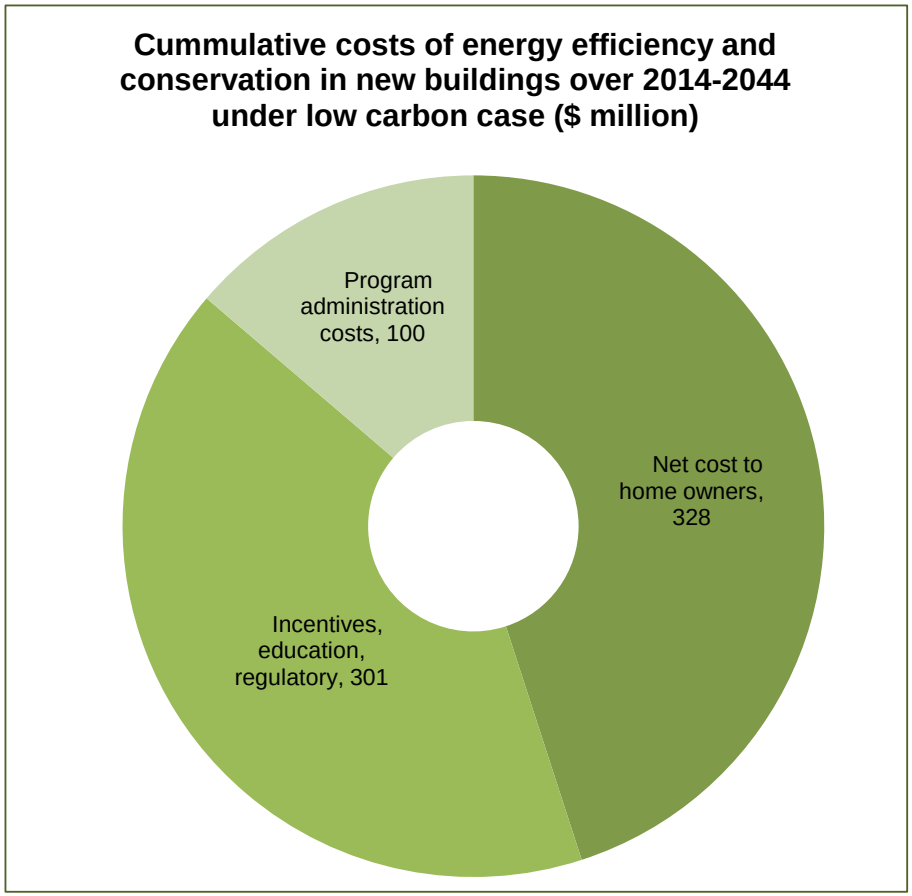
Figure 24. Breakdown of incremental cumulative costs for existing ICI buildings under the Low Carbon Case.

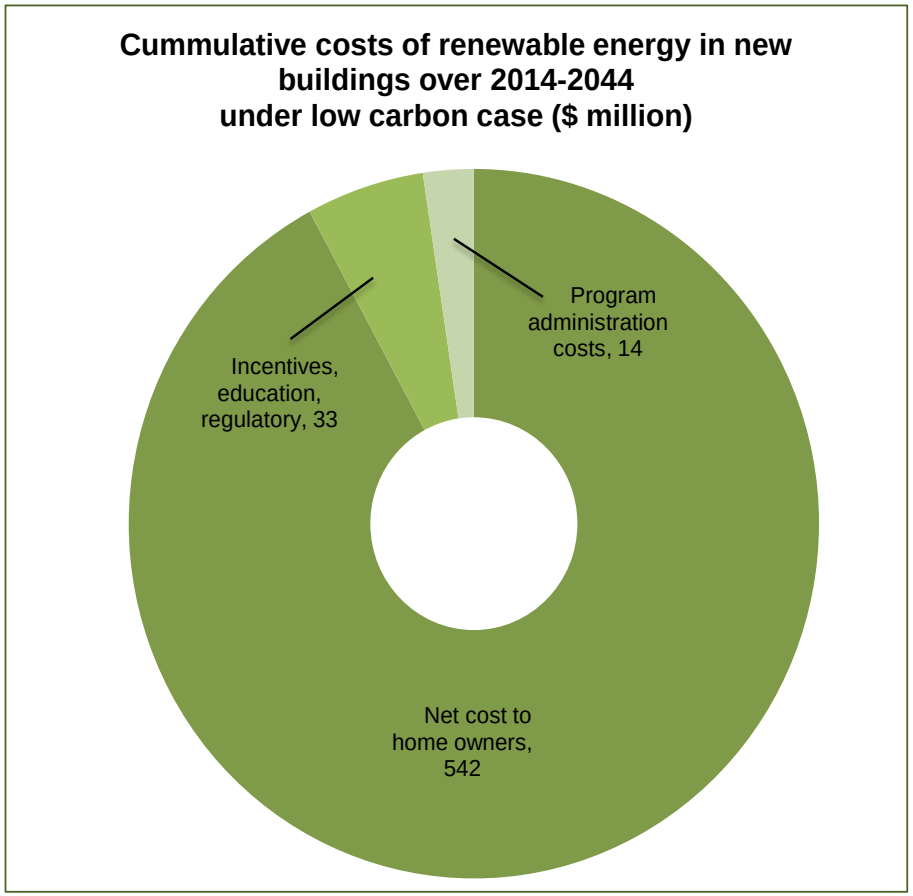




Buildings: Institutional, Commercial, and Industrial

Figure 25. Breakdown of incremental cumulative costs for new ICI buildings under the Low Carbon Case.





Large Industrial Facilities

Assumptions

Assumptions that underpin the analysis are listed below; only those assumptions that differ from those outlined above for residential buildings are listed. They are based on our interpretation of the ETP Discussion Paper. Where we have made assumptions additional to those in the Paper, they are denoted with "*".

- GHG emissions from large industry are 1,947,000 t CO_2e in 2009.
- According to NRCAN data ,total industrial energy use in 2009 in Alberta is 1,025.7 PJ. Of this amount, 66.1 PJ relates to electricity use, with the remaining 959.6 PJ relating to the use of other fuels (e.g., natural gas, coal, fuel oil, LPG, etc.) The ETP assumes the GHG intensity of electricity in 2009 is 880 t CO_2e per GWh. Hence, GHG emissions from industrial use of electricity in Alberta in 2009 are 16.2 Mt CO_2e. GHG emissions from industrial use of other fuels in Alberta in 2009—as reported by NRCAN—are 53.4 Mt CO_2e. The implied GHG intensity of other fuels is 0.056 t CO_2e per GJ. The relative fuel shares of total industrial GHG emissions in 2009 are: 23% electricity and 77% other fuels. Assuming the industrial fuel mix in Edmonton is very similar to that in Alberta as a whole, industrial GHG emissions from each fuel in Edmonton in 2009 are approximated as: electricity = 1,947,000 t CO_2e x 0.23 = 447,810 t CO_2e and other fuels = 1,947,000 t CO_2e x 0.77 = 1,499,190 t CO_2e.Using the GHG intensity of each fuel to work backwards, the implied use of electricity and other fuels by industry in Edmonton in 2009 is, respectively, 1,848,771 GJ and 26,862,367 GJ.*
- Industrial energy use is assumed to grow at the following rates (based on projected job growth in Edmonton): 0.89% per annum (over the entire period 2009-2044) under the Reference Case; 0.45% per annum (over the entire period 2009-2044) under the Low Carbon Case; and 0% per annum (over the entire period 2009-2044) under the Low Carbon Case.
- Improvements in the efficiency of boilers, pumps, motors, fans, cooling towers, processes, and plant operations are assumed to improve industrial energy efficiency as follows: 1% improvement in efficiency under the Base Case (in 2009); 1% improvement in efficiency under the Reference Case (by 2044, therefore no change relative to Base Case); 10% improvement in efficiency under the Reduced Carbon Case (by 2044); and 25% improvement in efficiency under the Low Carbon Case (by 2044).

Large Industrial Facilities

- The installed (pre-incentive) cost of energy efficiency improvements in large industrial facilities is, on average, $2,740 (±25%) per TJ saved. Program delivery costs comprise: incentive payments equal to $1,310 (±25%) per TJ; and technical assistance, administration, and other overhead equal to $435 (±25%) per TJ. Total program deliver costs equal incentive payments plus technical assistance, administration, and other overhead costs. Total participation costs to facility owners comprise installed costs less incentive payments (all figures based on C3 analysis of industrial programs in North America).*
- The impact of “experience effects” on unit costs is not modelled.

Results

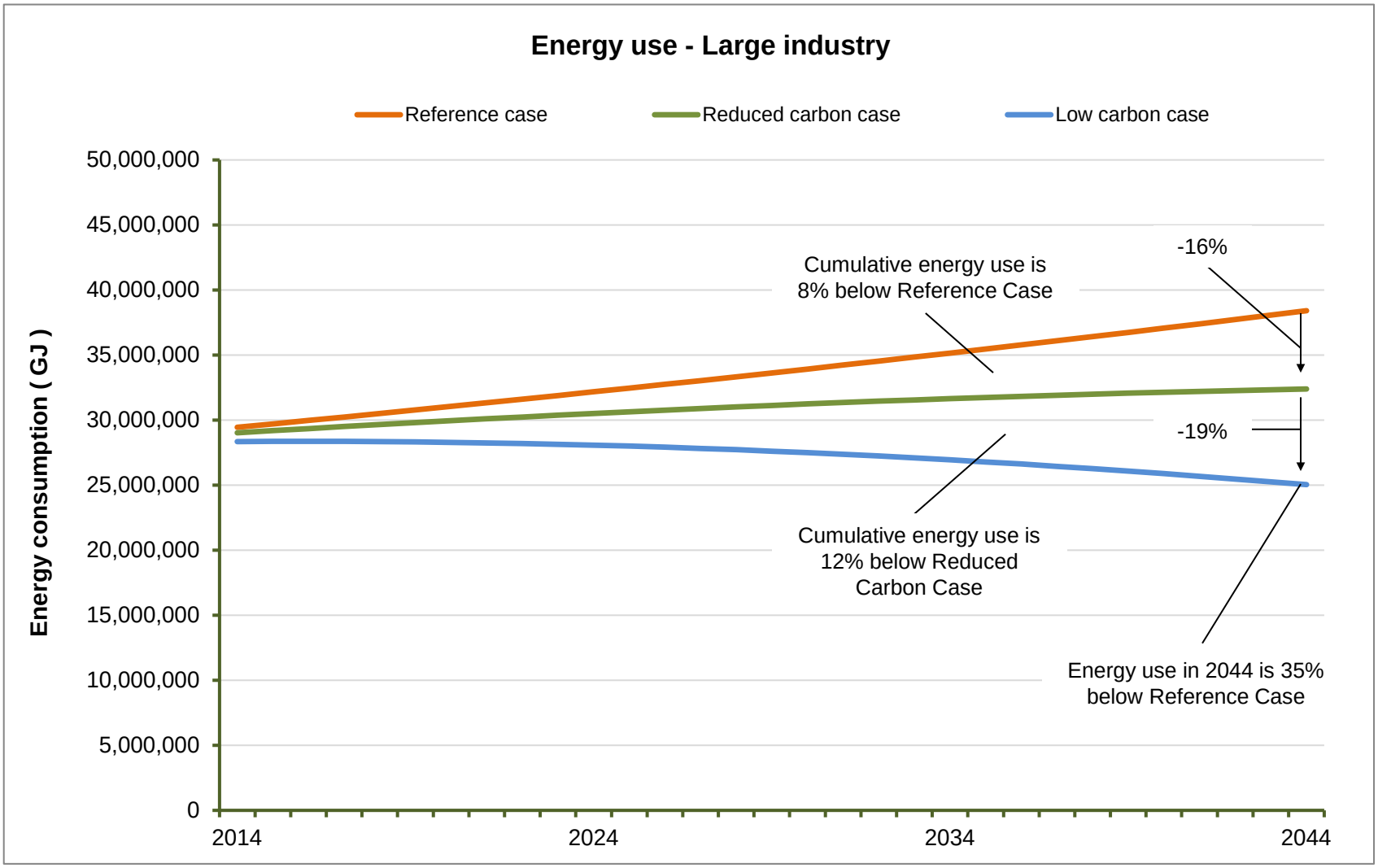
The results for large industrial facilities are presented below.

Note: the impact of both (a) reductions in the GHG intensity of the Alberta electricity grid and (b) reductions in the growth of large industry in Edmonton (it is assumed that growth is diverted to the less GHG-intensive ICI sector) are embedded in the results reported. However, the policies that induce both these outcomes are not specified or included in the cost estimates

Furthermore, the ETP reports reductions in industrial GHG emissions by 2044 of 3% and 8% relative to the Reference Case under the Reduced Carbon Case and the Low Carbon Case, respectively. Yet, the underlying modelling assumes efficiency improvements of 10% and 25% by 2044 under each scenario. These assumptions suggest much higher GHG emission reductions—as indicated by the results below. Indeed, even with keeping the GHG intensity of the electricity grid unchanged from Reference Case values, cumulative (over 2009-2044) GHG reductions from efficiency improvements and slowed growth in the sector are 7% and 17%, respectively, under the Reduced Carbon Case and Low Carbon Case.

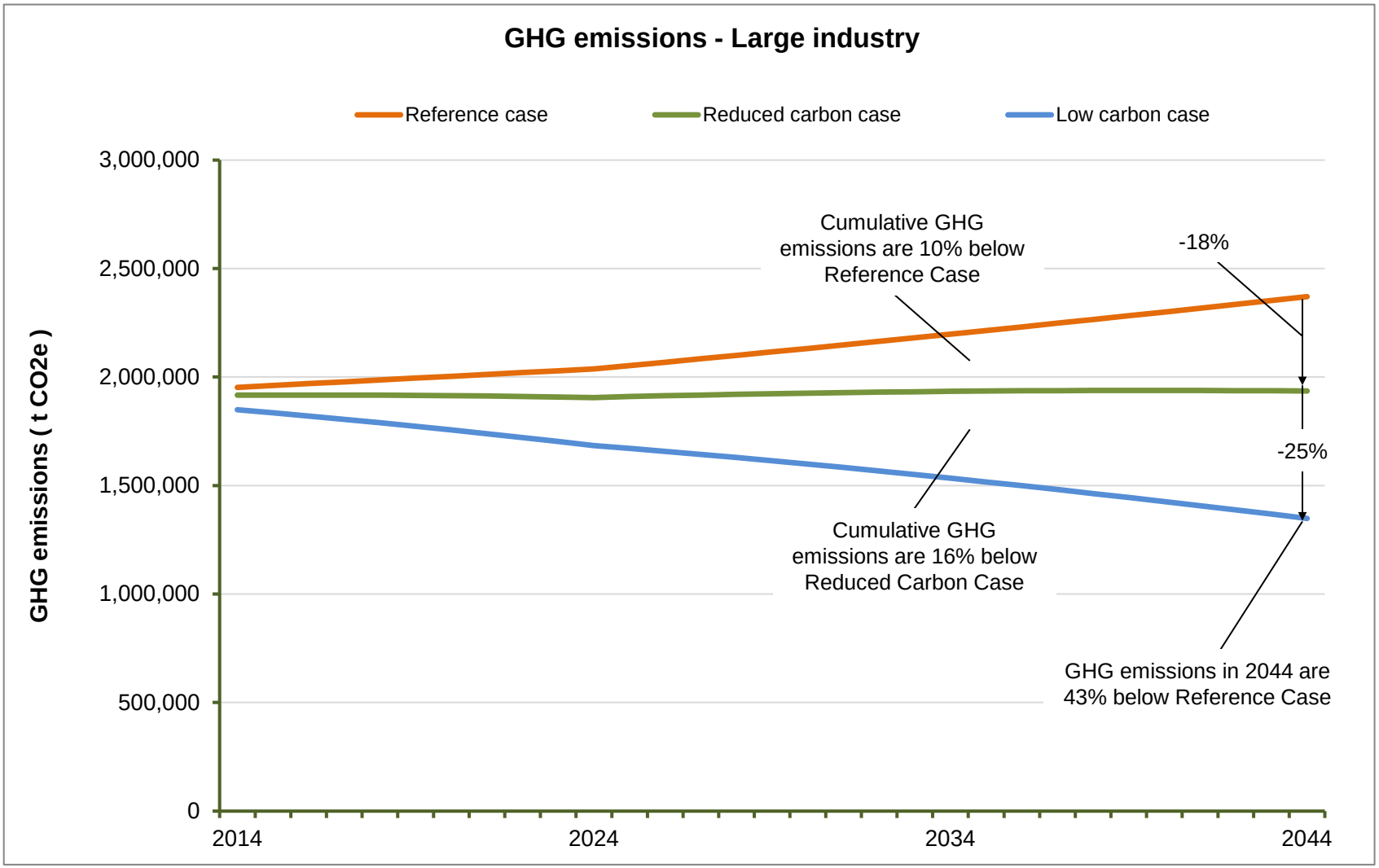
Large Industrial Facilities

Figure 26. Projected energy use under the Reference Case, the Reduced Carbon Case, and the Low Carbon Case. Total energy use in 2044 under each scenario, respectively, is about 38.4 PJ, 32.4 PJ, and 25.0 PJ.



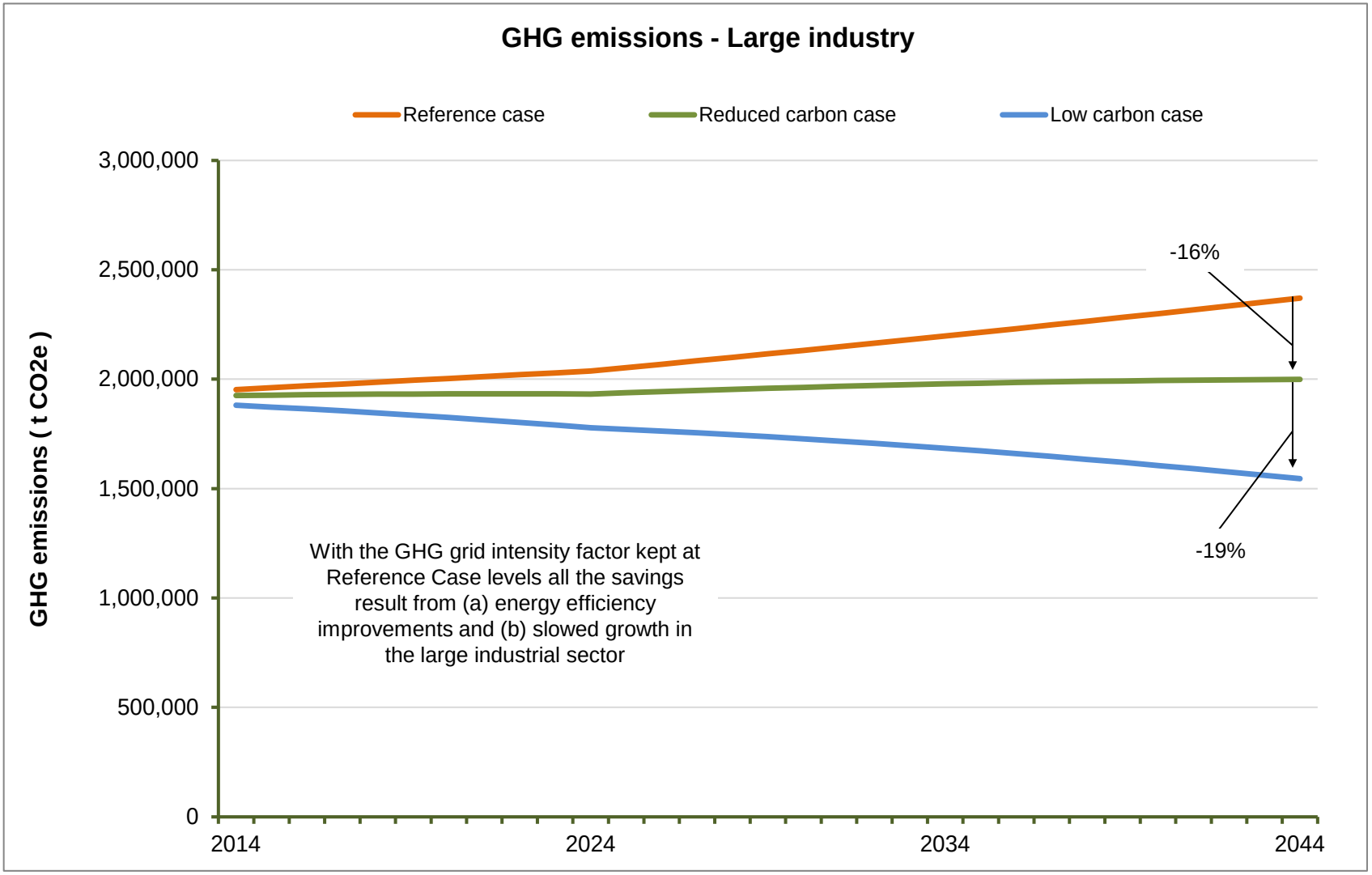
Large Industrial Facilities

Figure 27. Projected GHG emissions under the Reference Case, the Reduced Carbon Case, and the Low Carbon Case. Total GHG emissions in 2044 under each scenario, respectively, are about 2.37 Mt CO_2e, 1.94 Mt CO_2e, and 1.35 Mt CO_2e.



Large Industrial Facilities

Figure 28. Projected GHG emissions under the Reference Case, the Reduced Carbon Case, and the Low Carbon Case. (assuming the GHG intensity of the Alberta electricity grid does not change from Reference Case values).



Large Industrial Facilities

Table 11. Estimated energy savings and GHG emissions avoided under the Reduced Carbon Case and the Low Carbon Case.

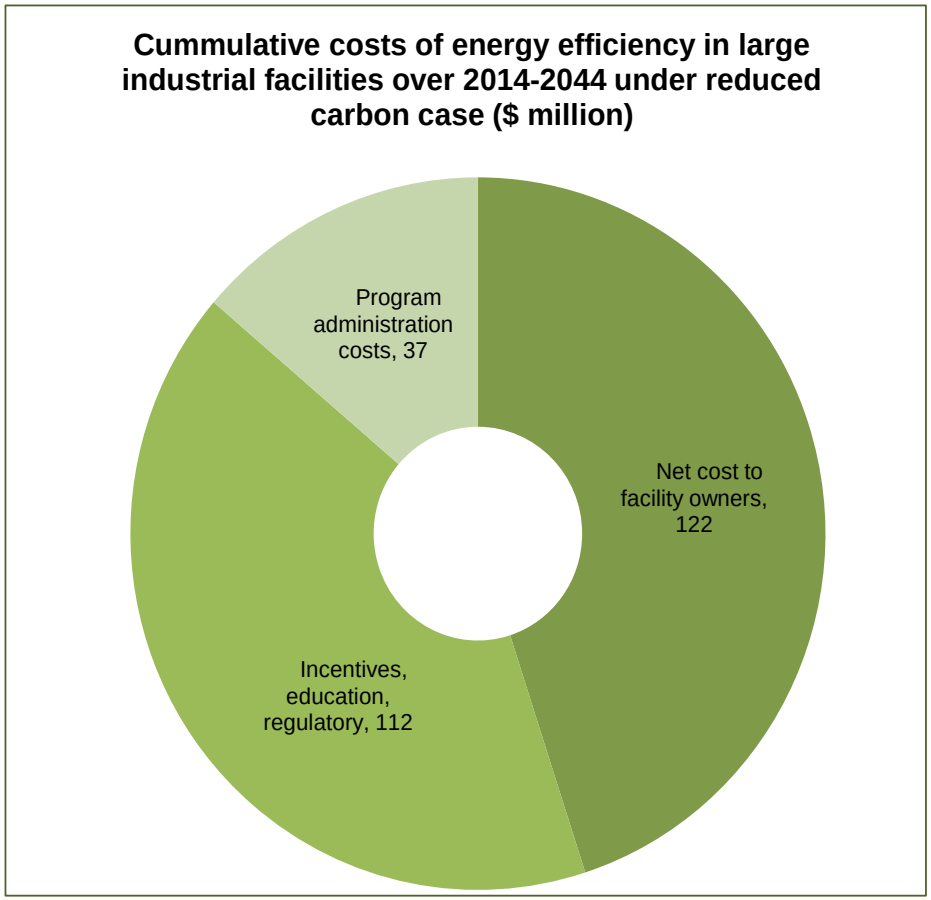
		2014	2024	2034	2044	Cumulative
Savings from energy efficiency						
Reduced carbon case vs. reference case	TJ	419	1,660	3,503	6,017	86,240
Low carbon case vs. reference case	TJ	1,091	4,096	8,207	13,372	202,000
GHG emissions avoided						
Reduced carbon case vs. reference case	kt CO2e	28	105	219	371	5,402
Low carbon case vs. reference case	kt CO2e	72	259	513	825	12,660

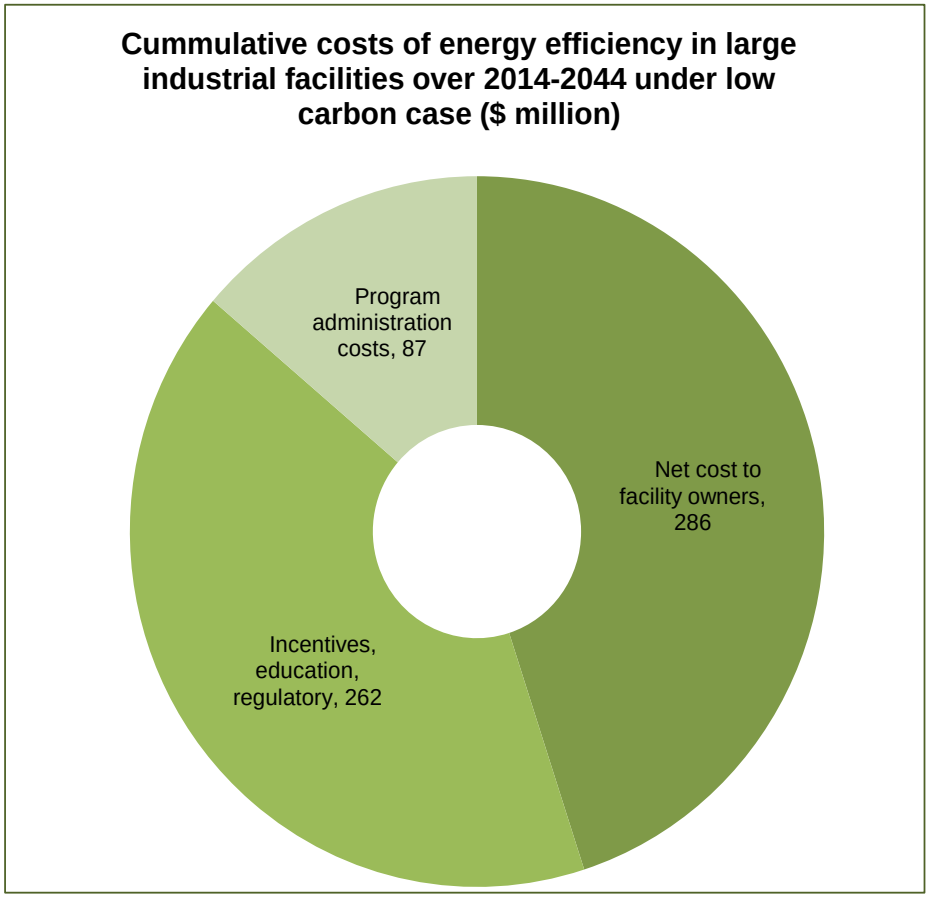
Table 12. Estimated incremental costs under the Reduced Carbon Case and the Low Carbon Case.

		2014	2024	2034	2044	Cumulative
Total costs of energy efficiency improvements						
Reduced carbon case vs. reference case	$ million	1	5	11	19	272
Low carbon case vs. reference case	$ million	4	13	26	43	636

Large Industrial Facilities

Figure 29. Breakdown of incremental cumulative costs for large industrial facilities under the Reduced Carbon Case and the Low Carbon Case.





Large Industrial Facilities

Table 13. Estimated incremental costs under the Reduced Carbon Case and the Low Carbon Case: Sensitivity test: all costs +25%

		2014	2024	2034	2044	Cumulative
Total costs of energy efficiency improvements						
Reduced carbon case vs. reference case	$ million	2	7	14	24	340
Low carbon case vs. reference case	$ million	4	16	33	53	794

Table 14. Estimated incremental costs under the Reduced Carbon Case and the Low Carbon Case: Sensitivity test: all costs -25%

		2014	2024	2034	2044	Cumulative
Total costs of energy efficiency improvements						
Reduced carbon case vs. reference case	$ million	1	4	8	14	204
Low carbon case vs. reference case	$ million	3	10	20	32	477

Personal Transportation: Electric Vehicles

Assumptions

Assumptions that underpin the analysis are listed below. They are based on our interpretation of the ETP Discussion Paper. Where we have made assumptions additional to those in the Paper, they are denoted with "*".

- Total energy consumption for personal transportation in 2009 is 25,273,000 GJ.
- The energy content of gasoline and diesel is, respectively, 32.18 MJ per liter and 35.86 MJ per liter. In 2009 gasoline accounted for 92.5% of total fuel use for personal transport (passenger car and passenger truck) in Alberta; diesel accounted for virtually all of the remaining 7.5%. The weighted average energy content of passenger fuels is thus assumed to be 32.46 MJ per liter.*
- Total implied fuel consumption in 2009 is 778.7 million liters.*
- The average fuel economy of a personal transport vehicle (weighted average of NRCAN passenger car and passenger truck data) in Alberta in 2009 is 10.54 liters per 100 km. The average fuel economy of an electric vehicle is 20.5 kWh per 100 km The average annual distance traveled by a personal transport vehicle in Alberta in 2009 is 14,390 km (again, based on NRCAN data). Note the ETP suggests a value of 11.40 liters per 100 km for 2009.*
- The average distance travelled is assumed constant over the forecast period (2009-2044) and applies to both electric and non-electric vehicles.*
- The average fuel economy of a personal transport vehicles under the different scenarios is (liters per 100 km): 8.0 in 2024 and 6.6 in 2044 under the Reference Case; 8.0 in 2024 and 6.6 in 2044 under the Reduced Carbon Case; and 7.8 in 2024 and 6.1 in 2044 under the Low Carbon Case.
- Total implied km driven by personal transport vehicles in 2009 are 7,386.5 million.*
- The implied total number of personal transport vehicles operating (registered) in Edmonton in 2009 is 513,250.*
- The number of personal transport vehicles operating (registered) in Edmonton is assumed to grow at 1.5% per year (based on NRCAN data over the period 1990-2010).*
- The assumed survival rate for personal transport vehicles is 0.95 (based on analysis of NRCAN sales and stock data). *

Personal Transportation: Electric Vehicles

Assumptions

- Electric vehicles are assumed to account for the following shares of total **new** vehicle purchases under each scenario: 0.01% in 2009, 3% in 2024 and 20% in 2044 under the Reference Case; 5% in 2024 and 31% in 2044 under the Reduced Carbon Case; and 9% in 2024, and 67% in 2044 under the Low Carbon Case.*
- The GHG intensity of gasoline and diesel is, respectively, 2,437 g per liter and 2,729 g per liter (according to National GHG Inventory emission factors). The weighted average GHG intensity of personal transport vehicles is thus 2,459 g per liter.*
- The implied GHG intensity of personal transport is 259 per km (based on National Inventory and NRCAN data); the ETP suggests a value of 284 g per km.
- Total GHG emissions from personal transportation are estimated at 1,914,620 t CO_2e in 2009 (corresponding to total energy consumption of 25,273,000 GJ). The ETP suggests a value of 1,716,000 t CO_2e in 2009. We were unable to calibrate our calculations to both energy consumption and GHG emissions for 2009 as reported in the ETP—based on the assumptions provided it appears that the two values are inconsistent with one another. The results below are calibrated to start from a value of 25,273,000 GJ for total energy consumption in 2009.*
- GHG intensity of electricity under the Reference Case: 880 t CO_2e per GWh (2009), 628 t CO_2e per GWh (2024), and 538 t CO_2e per GWh (2044). The GHG intensity is assumed to follow a linear path between 2009 and 2024 and between 2024 and 2044.
- GHG intensity of electricity under the Reduced Carbon Case: 880 t CO_2e per GWh (2009), 580 t CO_2e per GWh (2024), and 429 t CO_2e per GWh (2044). The GHG intensity is assumed to follow a linear path between 2009 and 2024 and between 2024 and 2044.
- GHG intensity of electricity under the Low Carbon Case : 880 t CO_2e per GWh (2009), 442 t CO_2e per GWh (2024), and 100 t CO_2e per GWh (2044). The GHG intensity is assumed to follow a linear path between 2009 and 2024 and between 2024 and 2044.

Personal Transportation: Electric Vehicles

- The average price of a new electric vehicle is $37,500 (based on average of 12 vehicles). The average price of all new cars sold in Alberta is $29,670 (based on DesRosiers market survey). The incremental (pre-incentive) cost of an electric vehicle is thus $7,830.*
- It is assumed that a Level 1 charger is sold with the vehicle. The average price of a Level 2 charger is $845, with installation costs of $600. The results presented below are based on incremental vehicle costs.*
- Program delivery costs comprise: incentive payments for the purchase of an electric (BEV or PHEV) vehicle equal to $5,250 (mid-point of low and high incentives currently offered in Canada, $2,500 in BC to $8,000 in Quebec and Ontario) and for the purchase of a Level 2 charger equal to $1,000 (maximum incentive offered in Quebec and Ontario); and administration and other overhead equal to 25% of total delivery costs. It is assumed that only 50% of people purchasing a new electric vehicle also purchase a Level 2 charger. Total program deliver costs equal incentive payments plus administration and other overhead costs. Total participation costs to vehicle owners comprise installed costs less incentive payments.*
- The impact of “experience effects” on vehicle and charger unit costs is not modelled.

Results

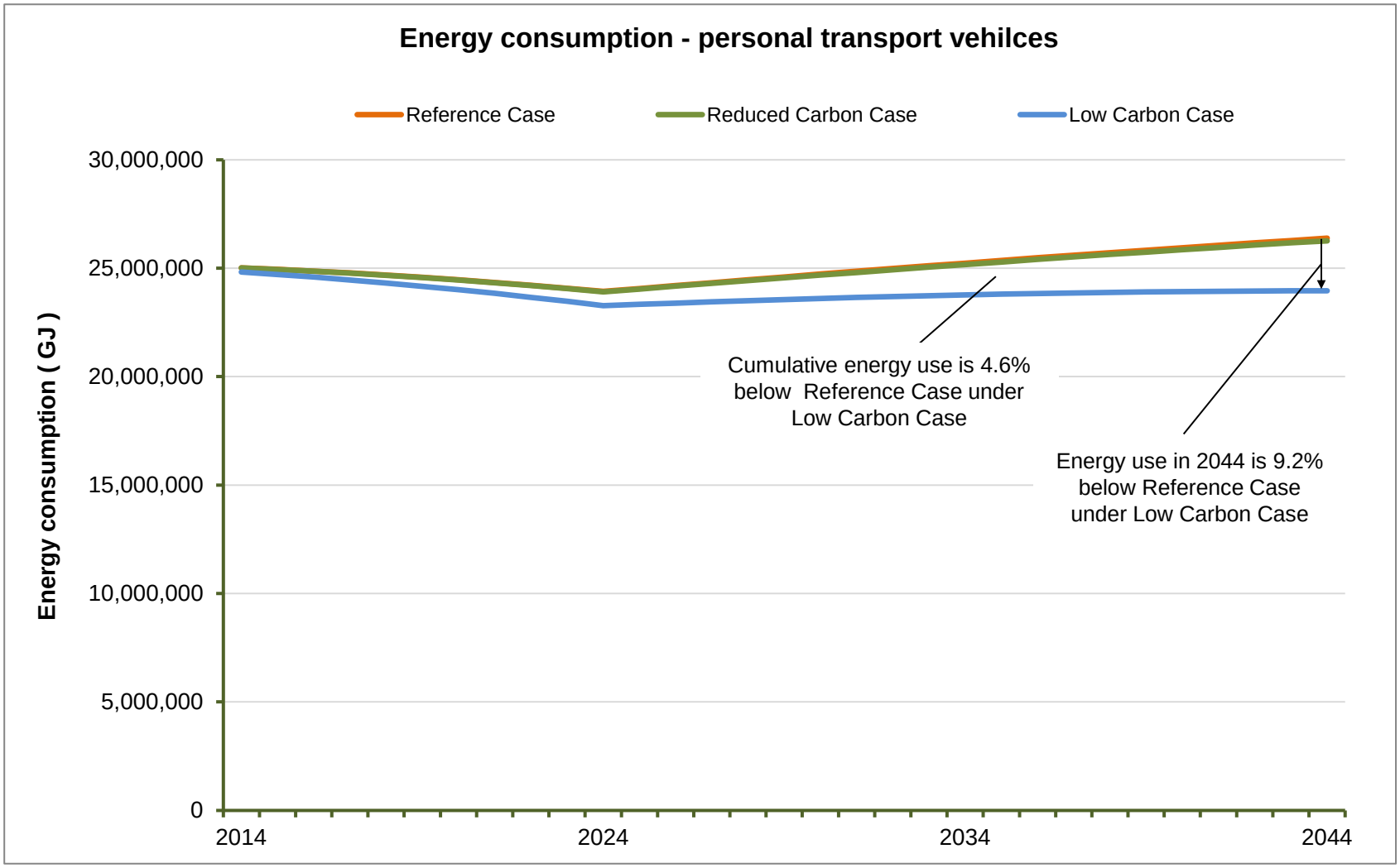
The results for personal transportation are presented below.

Note: the impact of both (a) reductions in the GHG intensity of the Alberta electricity grid and (b) improvements in the fuel economy of non-electric personal transport vehicles are embedded in the results reported. However, the policies that induce both these outcomes are not specified or included in the cost estimates.

As noted above, our calculations are calibrated to energy consumption in 2009 and not to GHG emissions in 2009, as reported in the ETP. Consequently, estimated values for the GHG intensity of personal transport do not match those suggested in the ETP.

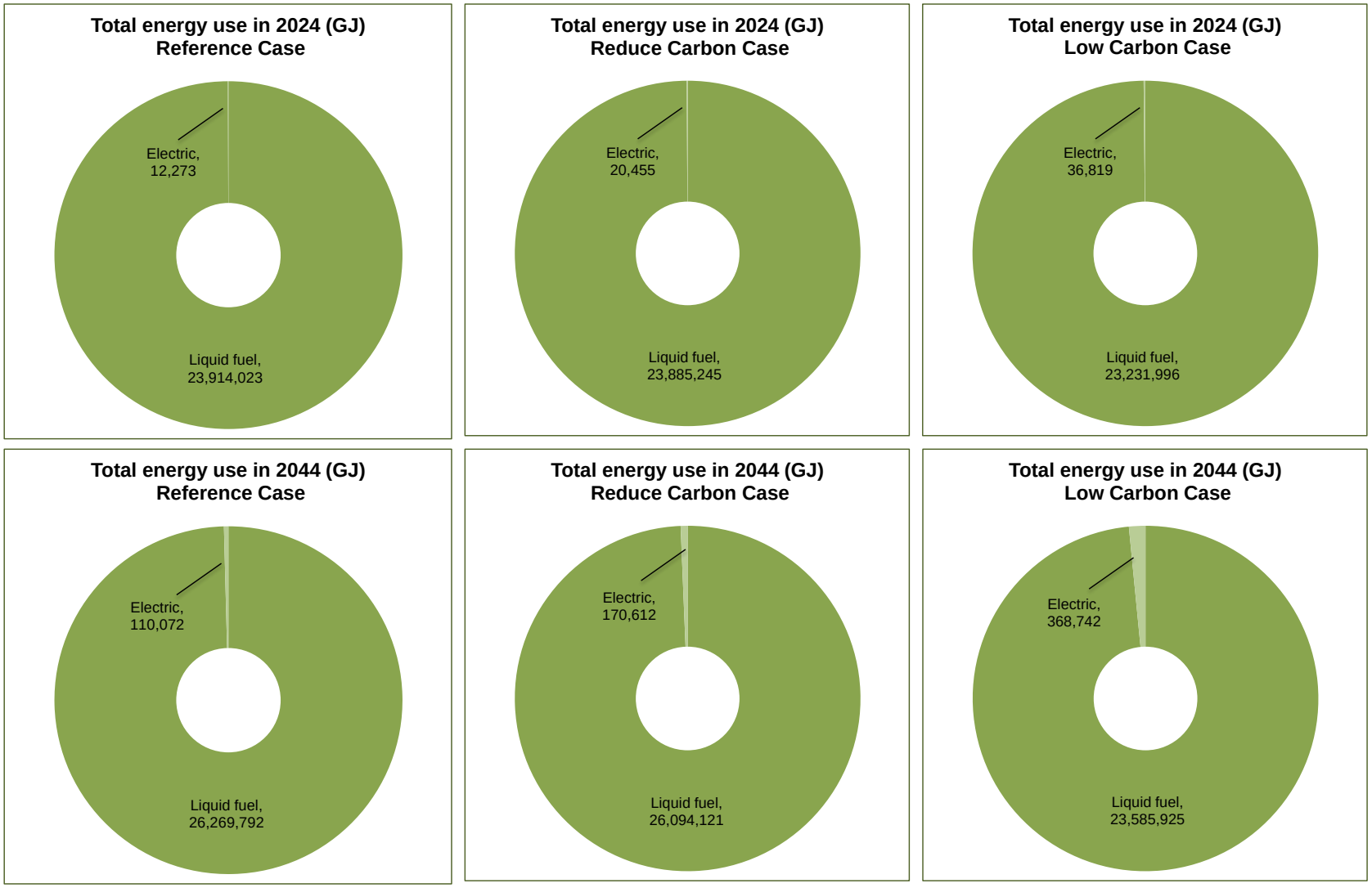
Personal Transportation: Electric Vehicles

Figure 30. Projected energy use under the Reference Case, the Reduced Carbon Case, and the Low Carbon Case. Total energy use in 2044 under each scenario, respectively, is about 26.4 PJ, 26.2 PJ, and 23.9 PJ.



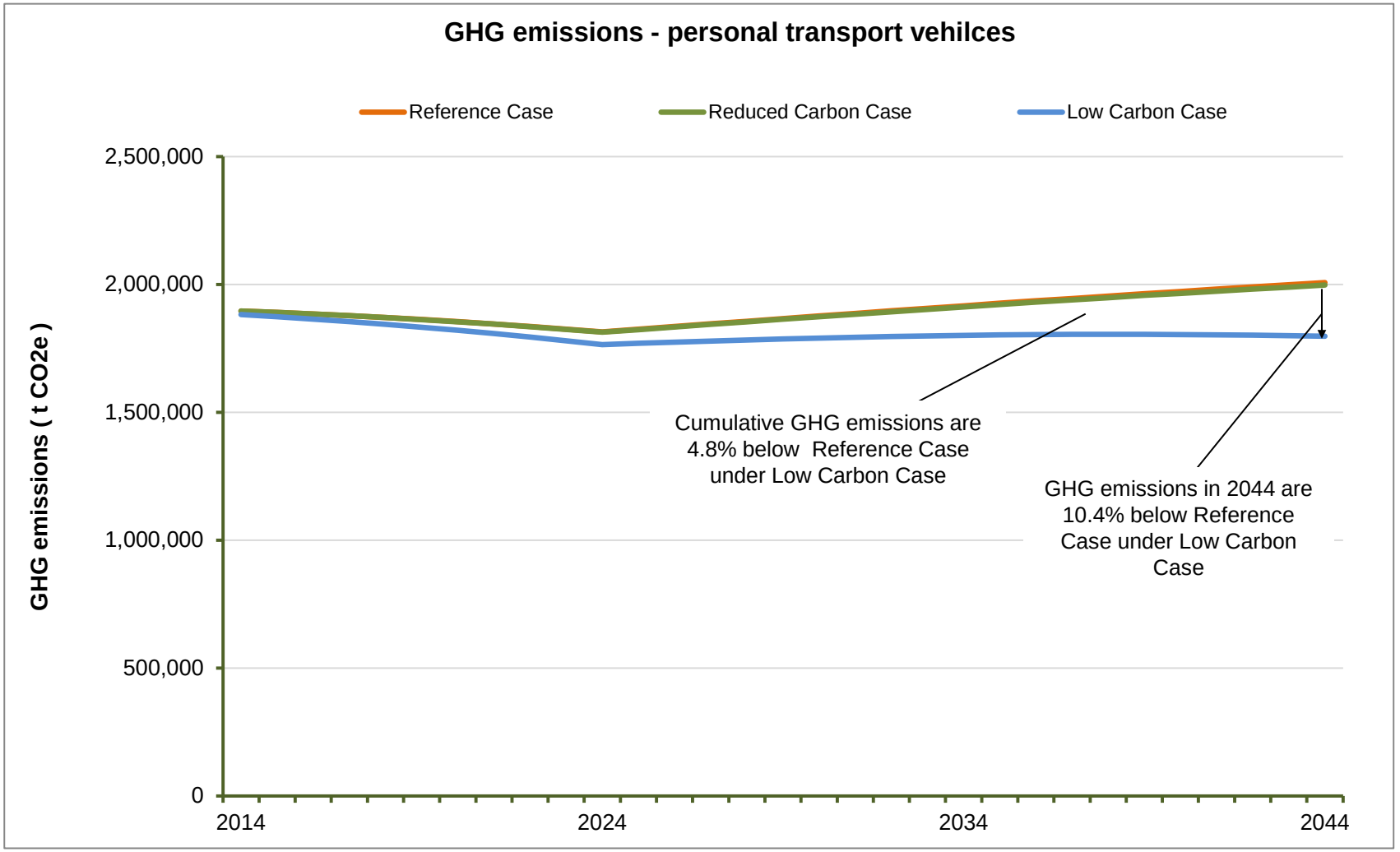
Personal Transportation: Electric Vehicles

Figure 31. Projected energy use by vehicle type under the Reference Case, the Reduced Carbon Case and the Low Carbon Case.



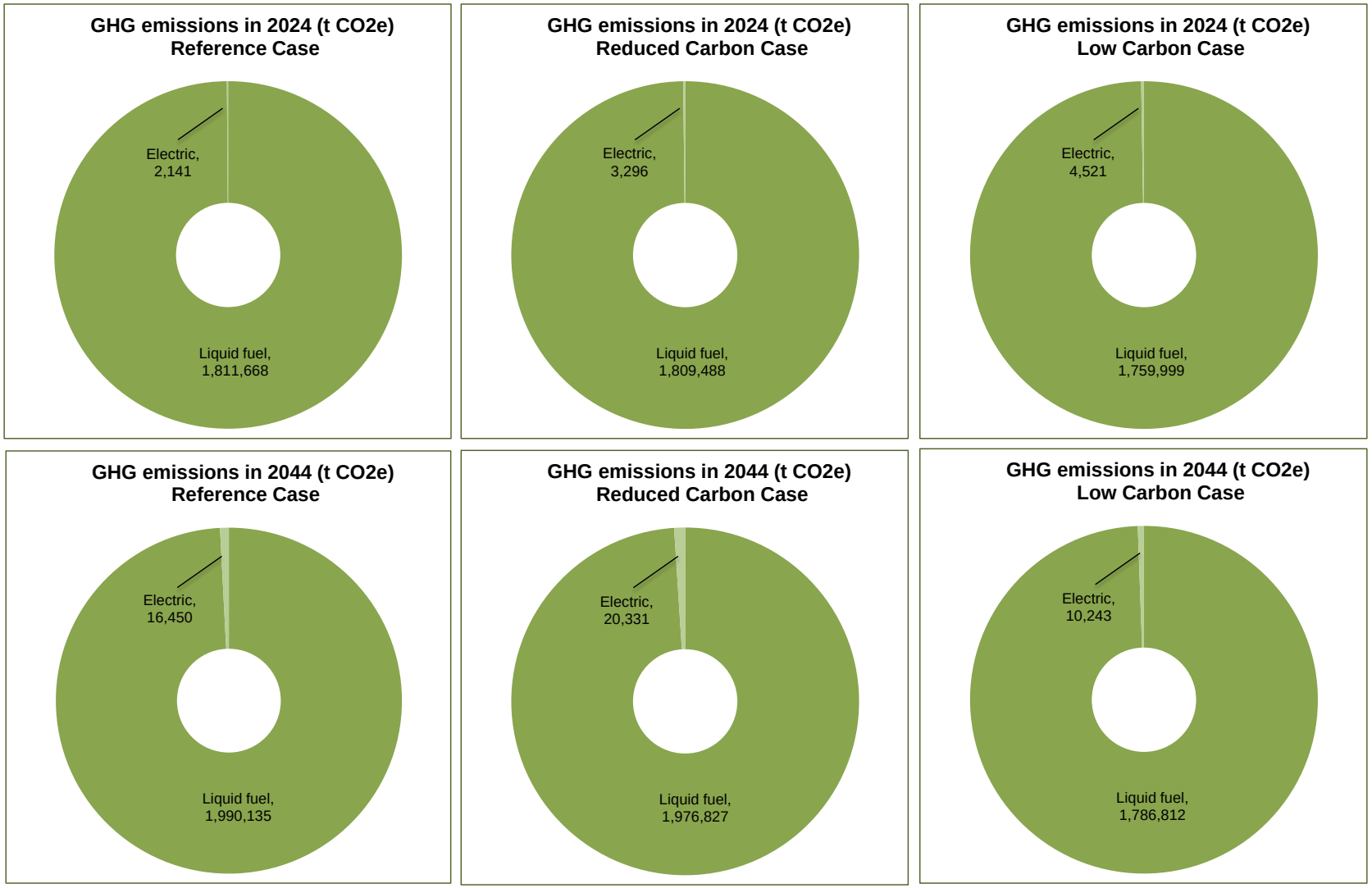
Personal Transportation: Electric Vehicles

Figure 32. Projected GHG emissions under the Reference Case, the Reduced Carbon Case, and the Low Carbon Case. Total GHG emissions in 2044 under each scenario, respectively, are about 2.3 Mt CO_2e, 2.0 Mt CO_2e, and 1.8 Mt CO_2e.



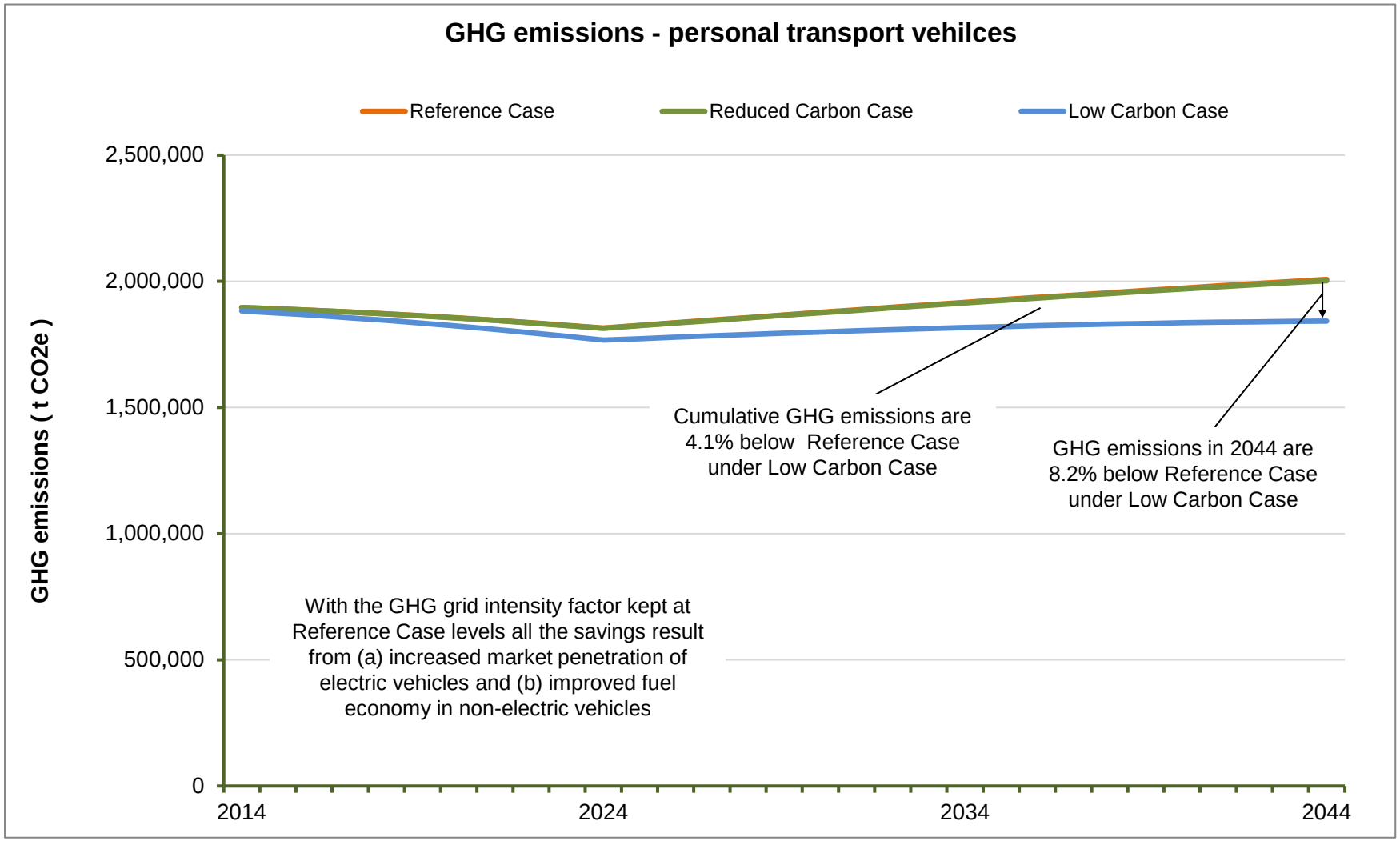
Personal Transportation: Electric Vehicles

Figure 33. GHG emissions by vehicle type under the Reference Case, the Reduced Carbon Case and the Low Carbon Case.



Personal Transportation: Electric Vehicles

Figure 34. Projected GHG emissions under the Reference Case, the Reduced Carbon Case, and the Low Carbon Case. (assuming the GHG intensity of the Alberta electricity grid does not change from Reference Case values).



Personal Transportation: Electric Vehicles

Table 15. Estimated energy savings and GHG emissions avoided under the Reduced Carbon Case and the Low Carbon Case.

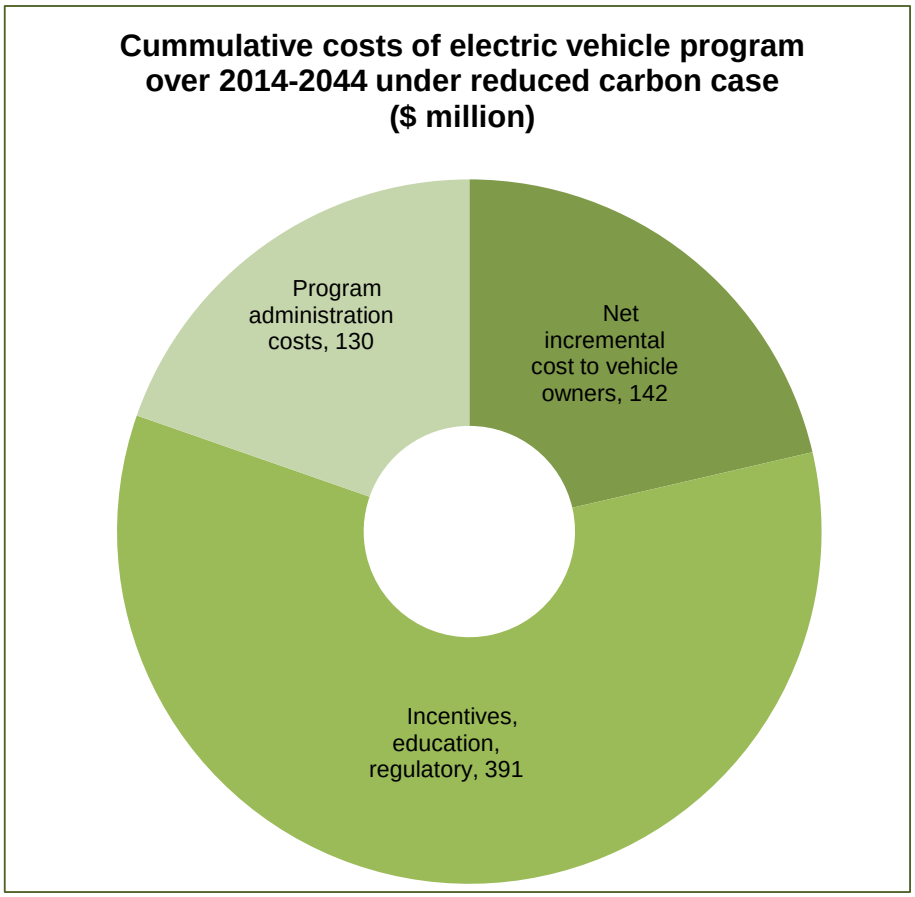
		2014	2024	2034	2044	Cumulative
Savings from energy efficiency						
Reduced carbon case vs. reference case	TJ	77	21	68	115	1,567
Low carbon case vs. reference case	TJ	1,948	657	1,466	2,425	35,309
GHG emissions avoided						
Reduced carbon case vs. reference case	kt CO2e	3	10	44	94	1,041
Low carbon case vs. reference case	kt CO2e	139	493	1,158	2,095	28,262

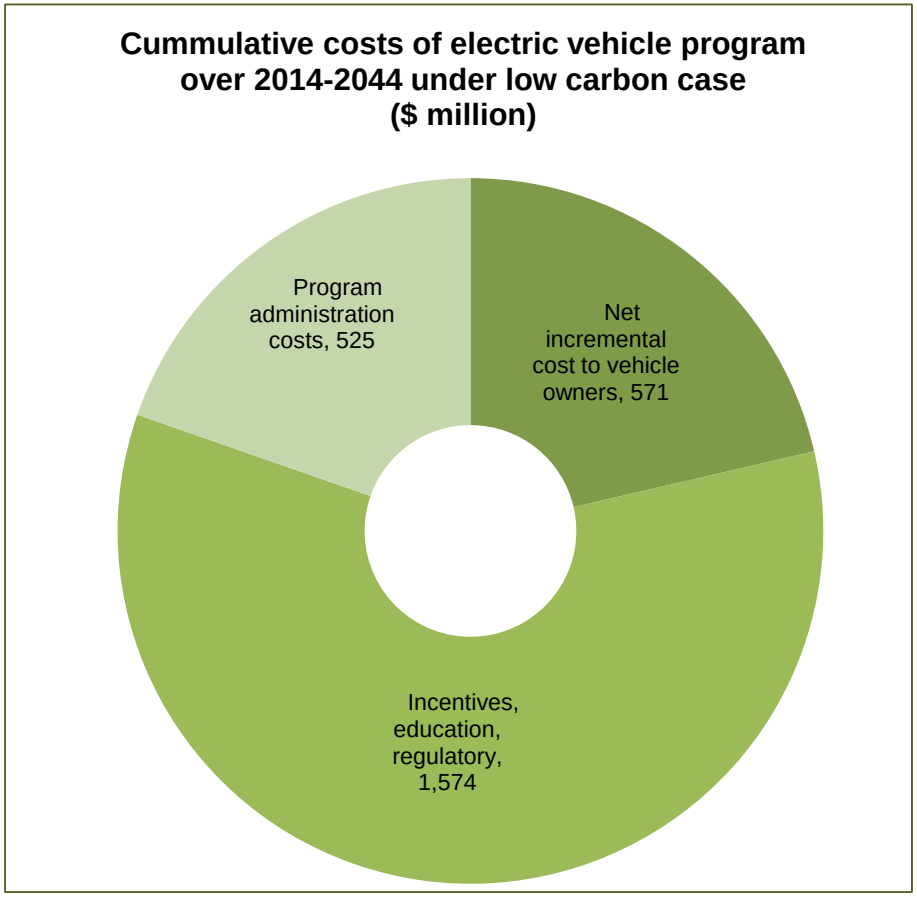
Table 16. Estimated incremental costs under the Reduced Carbon Case and the Low Carbon Case.

		2014	2024	2034	2044	Cumulative
Total cost of electric vehicle program						
Reduced carbon case vs. reference case	$ million	2	8	28	56	664
Low carbon case vs. reference case	$ million	6	23	115	237	2,669

Personal Transportation: Electric Vehicles

Figure 35. Breakdown of incremental cumulative costs for electric vehicles program under the Reduced Carbon Case and the Low Carbon Case.





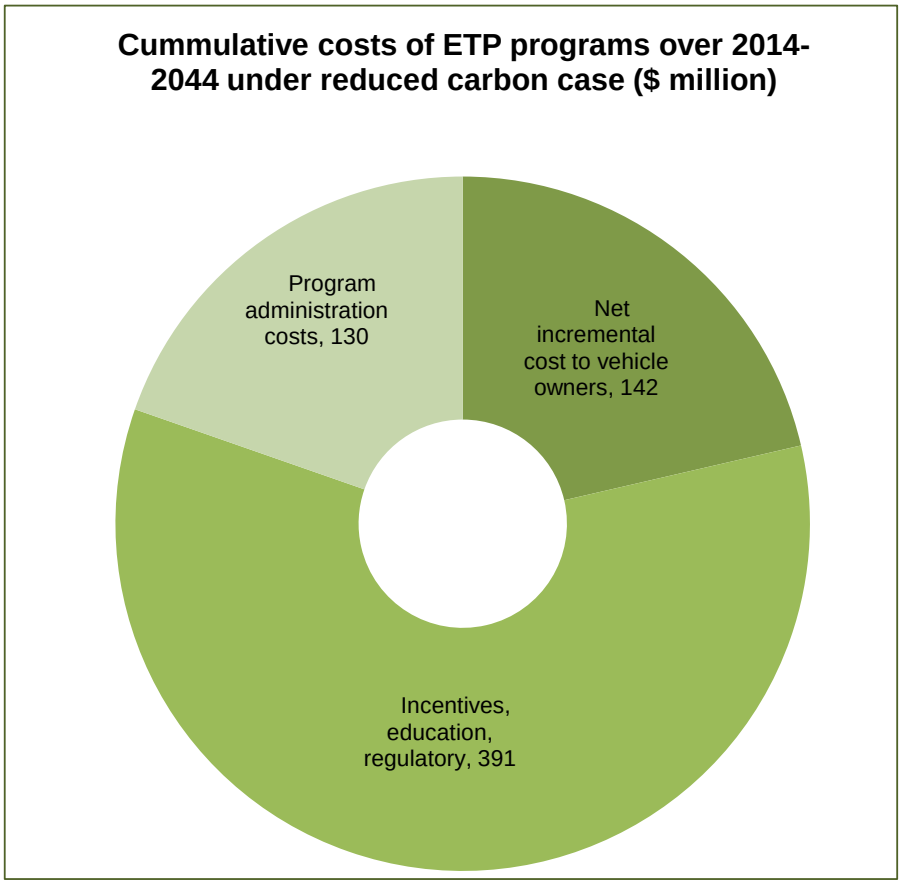
ETP: all Program Areas

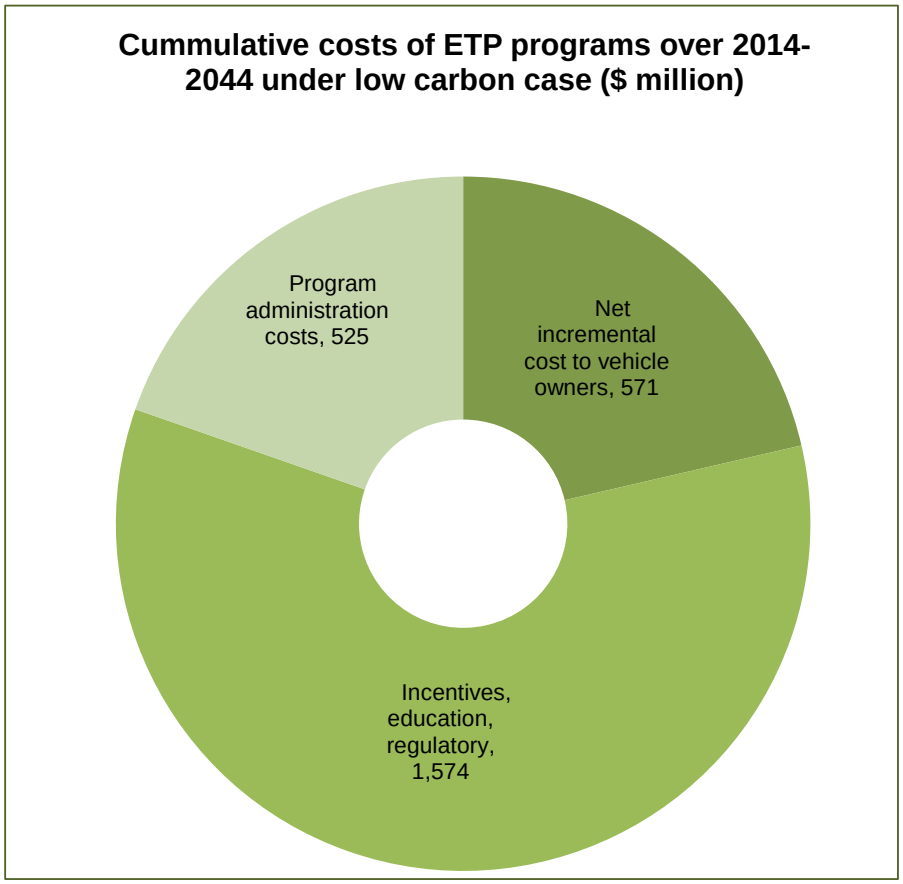
Table 17. Estimated total costs under the Reduced Carbon Case and the Low Carbon Case.

		2014	2024	2034	2044	Cumulative
Total cost of ETP programs						
Reduced carbon case vs. reference case	$ million	9	33	74	127	1,789
Low carbon case vs. reference case	$ million	57	259	413	601	10,291

ETP: all Program Areas

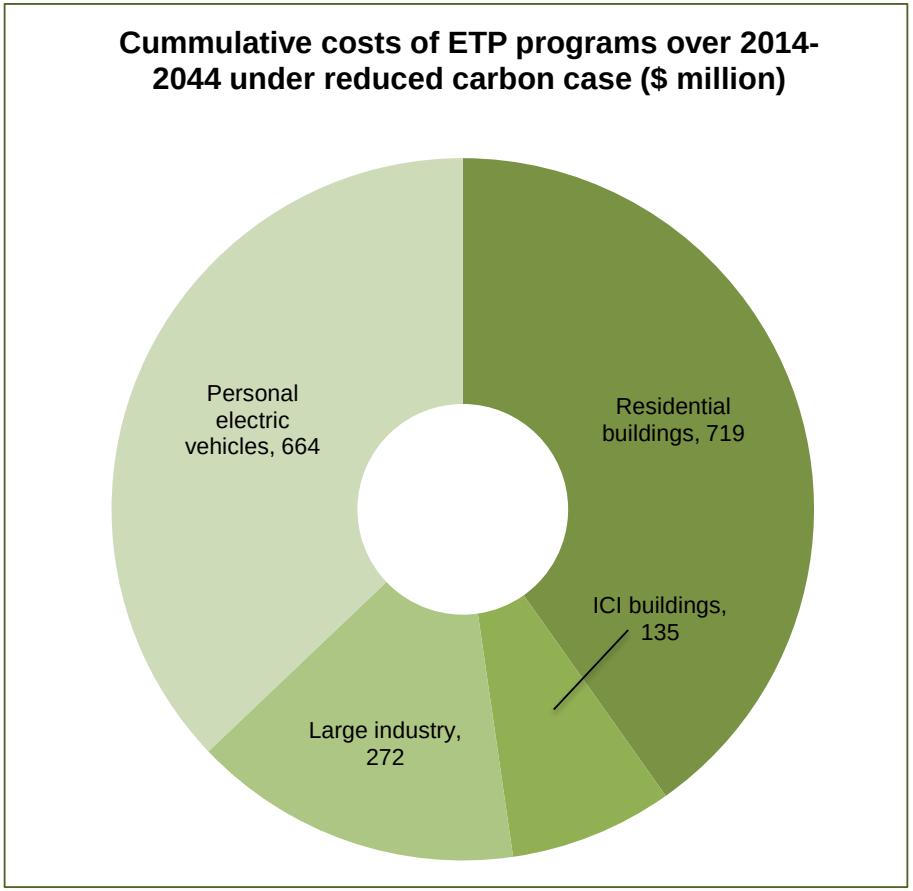
Figure 36. Breakdown of total cumulative costs for all ETP program areas under the Reduced Carbon Case and the Low Carbon Case.

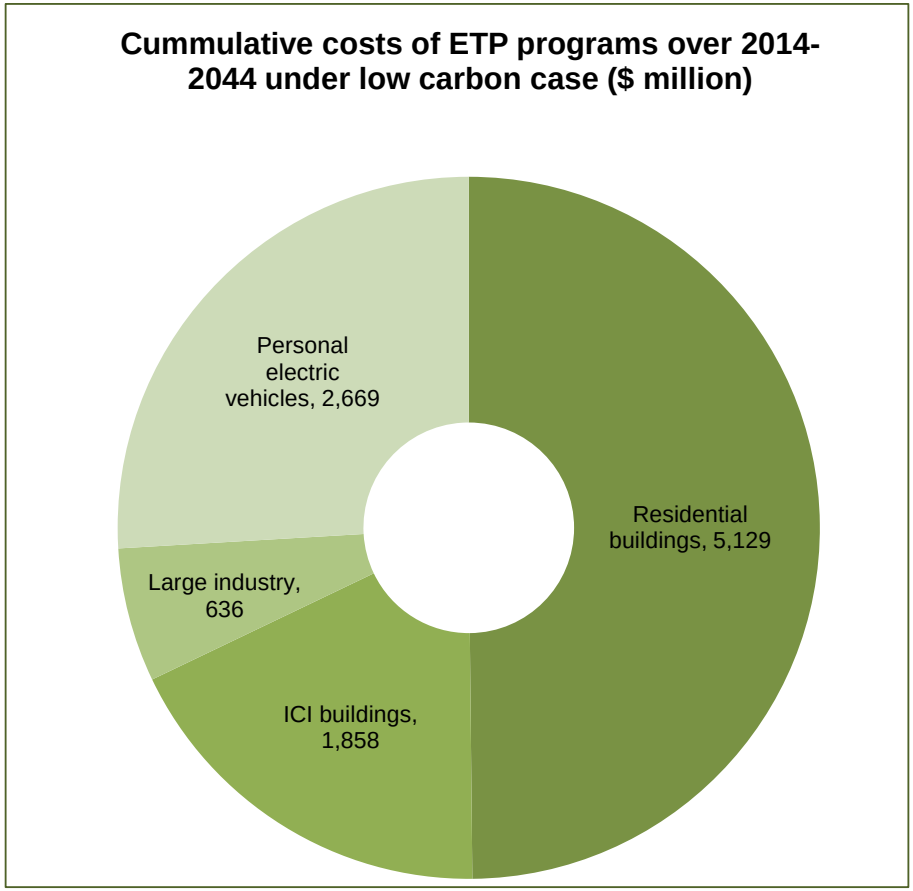




ETP: all Program Areas

Figure 36. Breakdown of total cumulative costs by ETP program area under the Reduced Carbon Case and the Low Carbon Case.





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