Energy Efficiency Alberta

2019-2038 Energy Efficiency and Small-Scale Renewables Potential Study

October 17, 2018

FINAL REPORT

Prepared for:

Energy Efficiency Alberta

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AER	Alberta Energy Regulator
AIL	Alberta Internal Load
AESO	Alberta Energy Systems Operator
AUC	Alberta Utilities Commission
BAU	Business as Usual
CAGR	Compound Annual Growth Rate
CanESS	Canadian Energy System Simulator
CAPP	Canadian Association of Petroleum Producer
CEUD	Comprehensive Energy Use Database
CFL	Compact Fluorescent Light
CHP	Combined Heat and Power
CME	Canadian Manufacturers & Exporters
COP	Coefficient of Performance
DHW	Domestic Hot Water
DOE	Department of Energy (U.S.)
DSM	Demand-Side Management
DSMSim	Demand-Side Management Simulator
EEA	Energy Efficiency Alberta
EMT	Emission Test
EUI	End-Use Intensity
EUL	Effective Useful Life
FBC CPR	FortisBC Electric Conservation Potential Review
GHG	Greenhouse Gas
HFL	Hourly Percentage of Annual Load
HVAC	Heating, Ventilation, and Air Conditioning
LED	Light-Emitting Diode
LTO	Long-Term Outlook
MEMD	Michigan Measures Energy Database
NEEA	Northwest Energy Efficiency Alliance
NEW	New Construction
NRCan	Natural Resources Canada
NSPM	National Standard Practice Manual
NTG	Net-to-Gross
PLSF	Peak Load Shape Factor
RET	Retrofit
ROB	Replace-on-Burnout
RTF	Regional Technical Forum
RTU	Rooftop Unit
RUL	Remaining Useful Life
StatsCan	Statistics Canada
TRC	Total Resource Cost Test
TRM	Technical Reference Manual
TSD	Technical Support Documents
U.S.	United States

ACKNOWLEDGEMENTS

This report was prepared by Navigant Consulting Ltd. (Navigant) for Energy Efficiency Alberta (EEA). The work presented in this report could not be completed without the support and contributions from the EEA team. Additionally, EEA worked with local stakeholders who provided their input and data; Navigant and EEA appreciate and acknowledge their contributions.

Canadian Energy Systems Analysis Research (CESAR): This research included data for describing the Alberta province for building stock, electricity, and natural gas forecasts. The conditions of its use are:

- EEA can use these data for modeling work only to the end of May 2018. If these data for any scenario modeling after that time, EEA must request for permission to discuss subsequent terms and conditions.
- If the EEA wishes to provide these data to any third-party group, EEA must inform CESAR immediately regarding the company and the individual in that company to which these data have been given. Also, EEA must ensure the third-party group agrees to the same restrictions noted above (Item 1) for the use of these data.
- Any publication or report using these data must include a statement acknowledging the data were "provided by CESAR (http://www.cesarnet.ca) using the CanESS model (http://www.whatiftechnologies.com/caness)."

Alberta Energy Systems Operator (AESO): AESO provided information to assist Navigant in the preparation of historical and forecast values for this potential study. The information was based on AESO's Long Term Outlooks for the years 2018-2038, which were current as of the dates thereof, and are subject to the assumptions and limitations contained therein, including limitations on data obtained from public sources and/or third parties that cannot always be independently verified. Calculations and forecasts based upon this information are attributable to Navigant, and AESO makes no warranties or representations (whether express or implied) as to accuracy, completeness, or fitness for any particular purpose with respect to the information contained in Navigant's potential study or supporting materials or Navigant's assumptions in the preparation thereof. The forecasts prepared by Navigant are not meant to amend or supplement any forecasts or outlooks prepared by the AESO.

DISCLAIMER

This report was prepared by Navigant Consulting Ltd. (Navigant) for Energy Efficiency Alberta (EEA). The work presented in this report represents Navigant's professional judgment based on the information available at the time this report was prepared. Navigant and EEA are not responsible for the reader's use of, or reliance upon, the report, nor any decisions based on the report. NAVIGANT AND EEA MAKE NO REPRESENTATIONS OR WARRANTIES, EXPRESSED OR IMPLIED. Readers of the report are advised that they assume all liabilities incurred by them, or third parties, as a result of their reliance on the report, or the data, information, findings and opinions contained in the report.

EXECUTIVE SUMMARY

Energy Efficiency Alberta (EEA) engaged Navigant Consulting Ltd. (Navigant or the study team) to prepare an energy efficiency and small-scale renewables potential study for electricity and natural gas across Alberta over a 20-year period, from 2019 to 2038 (EEA's fiscal year runs from April 1 to March 31 of the following calendar year). EEA's objective through this potential study is to assess the energy efficiency potential in the residential, commercial, and industrial sectors by analyzing the cost-effectiveness of energy efficiency and small-scale generation measures[1] to reduce greenhouse gas (GHG) emissions.

This study is the first of its kind in Alberta. Future studies can build off this work, adding new primary market data for additional precision in the results. EEA will use the study results as input to its own portfolio program planning and energy efficiency program design. The study can also be used to inform planning by other entities such as local emission reduction efforts, utility system planning, and load forecasting models.

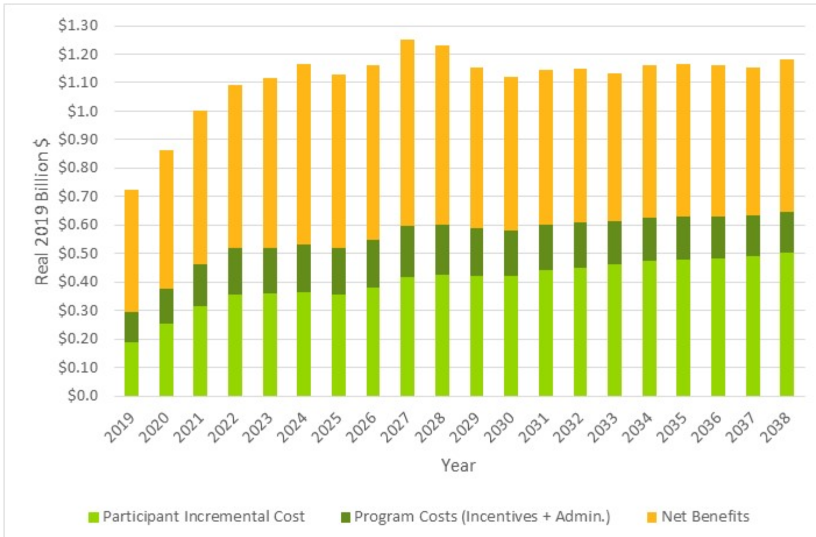
This report focuses on presenting results for all electricity and natural gas consumers in the province, excluding the oil & gas sectors (an approximation for large final emitters). At a high level, this report includes oil & gas savings, but excludes it in most of the presented results, unless otherwise indicated. Currently, a significant amount of the energy used in the oil & gas subsector (i.e., by large final emitters) is not targeted within EEA's programming, and greater data limitations exist for this sector compared with buildings and manufacturing facilities. However, this study did model the oil & gas sector and its GHG reduction potential. Therefore, results for the oil & gas sector should be considered preliminary at this time.

The potential study results indicate there is a large, cost-effective, achievable potential for Alberta projected to yield $11.11 billion ($19.96 billion including oil & gas) in net benefits (2019 real dollars[2]) over the 20-year study period, see Figure ES-1 and Figure ES-2. During this same period, Alberta has the potential to reduce greenhouse gas emissions by 8.6% (7.1% including oil & gas) below the business-as-usual (BAU)/no-programs case across the residential, commercial, and non-oil & gas industrial subsector.

[1] Measure is defined as an improvement in energy use in a facility that can involve energy conservation, cogeneration, renewable energy sources, improvements in operations and maintenance, or retrofit activities.

[2] All dollar values are provided as real 2019 dollars using a 2% inflation rate.

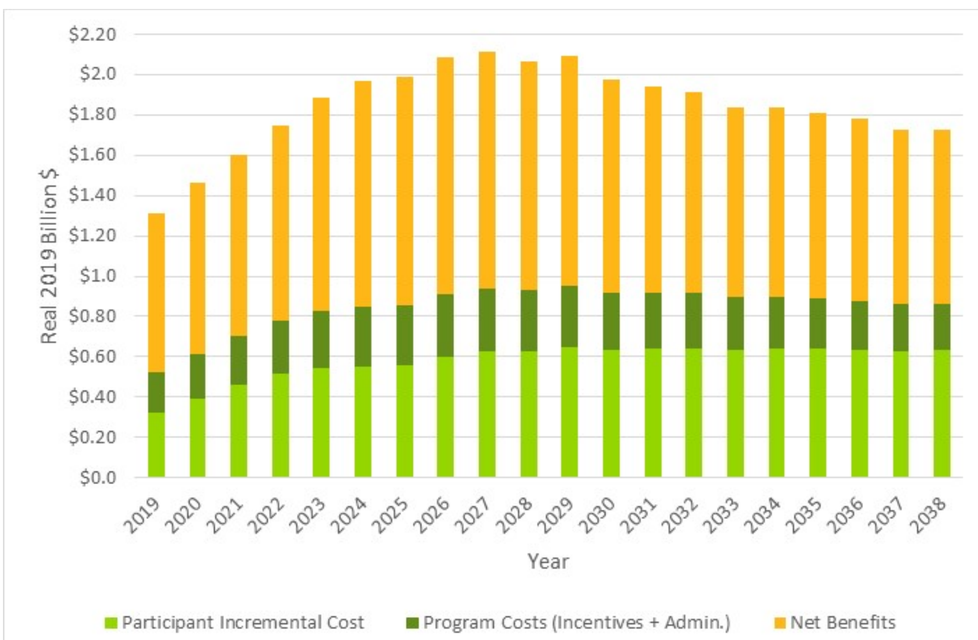
Figure ES-1. Benefits and Costs, Energy Efficiency and Solar Measures, excluding Oil & Gas Customer Segment, 2019 Real Billion Dollars



*2.0% inflation was used to convert values to real 2019 dollars

Source: Navigant analysis

Figure ES-2. Benefits and Costs, Energy Efficiency and Solar Measures, including Oil & Gas Customer Segment, 2019 Real Billion Dollars



*2.0% inflation was used to convert values to real 2019 dollars

Source: Navigant analysis

In 2038 (year 20), the cumulative[3] annual gross savings at the meter potential and corresponding carbon abatement for Alberta, including solar and the oil & gas customer segments for the reference case achievable, is presented in Table ES-1. The reference case scenario models the achievable potential most plausible (and reflects current budgetary consideration), which is the program cost of the current Alberta carbon levy of $30 per tCO_2e.[4] This scenario assumes program funding is allocated solely to reduce emissions. While this is not necessarily the approach that is or will be taken for allocating funding, it is considered a somewhat conservative approach to funding energy efficiency programs. Lifetime savings are provided in Table ES-6.

Table ES-1. Cumulative Annual Gross Savings, Over the Study Period (2019-2038) [5,6]

Value	Description	EE (Excluding Oil & Gas)	EE (Including Oil & Gas)	PV Solar	PV Solar + EE (Including Oil & Gas)
Electric Achievable Potential (GWh)	Annual GWh saved from measures installed over the study period	7,008	10,137	3,515	13,652
Electric Achievable Potential (% of Consumption[7])	GWh savings in 2038 as a percent of the forecasted consumption for 2038	13.3%	9.9%	10.5%	13.3%
Gas Achievable Potential (TJ)	Annual TJ saved from measures installed over the study period	27,892	132,036	N/A	132,036
Gas Achievable Potential (% of Consumption)	TJ savings in 2038 as a percent of the forecasted consumption for 2038	5.6%	6.3%	N/A	6.3%
Peak Winter Demand Savings, 2038 (MW)	Peak winter demand savings in 2038	919	1,337	N/A	1,337

Source: Navigant analysis

[3] The cumulative annual potential over the time period (2019-2038) is the sum of each year's annual incremental achievable potential.

[4] Program abatement cost only includes the program (administrator and incentive) costs on a per tCO_2e basis, whereas societal abatement or project abatement costs include the reduction of the energy usage.

[5] Sum of first year savings achieved each year throughout the study period

[6] As a point of clarification, the percent of consumption values for each of the below are with respect to the following customer segments and sectors:

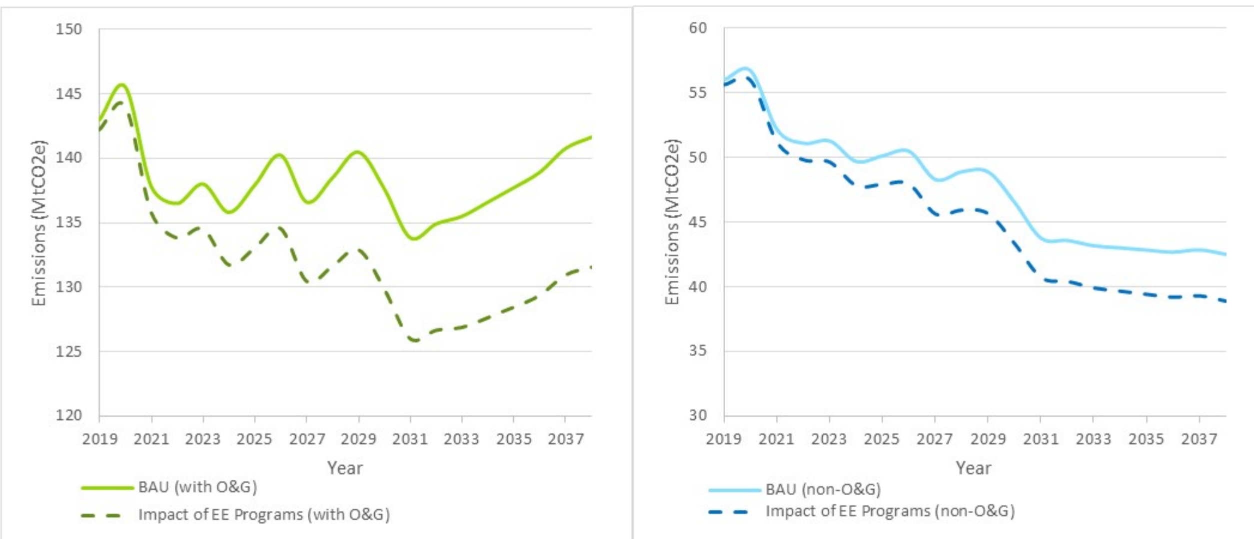
- EE (Excluding Oil & Gas): Residential, commercial, and industrial sectors (excluding oil and gas customer segments)
- EE (Including Oil & Gas): Residential, commercial, and industrial sectors (including oil and gas customer segments)
- PV Solar: Residential and commercial sectors

The savings being calculated as a percent of sector/customer segment sales is relative to the defined reference case in each of the columns even though the savings vary.

[7] The savings percent of consumption is based on the BAU consumption otherwise experienced in the year of reference. In this instance, the year of reference is 2038.

Figure ES-3 presents the emissions reductions resulting from the reference case achievable potential. These reductions as compared to the BAU case are 7.1% when including the O&G customer segments and 8.6% when excluding O&G. The reference case scenario models the achievable potential most plausible (and reflects current budgetary consideration), which is the program cost of the current Alberta carbon levy of $30 per tCO_2e.[8] This scenario assumes program funding is allocated solely to reduce emissions. While this is not necessarily the approach that is or will be taken for allocating funding, it is considered a somewhat conservative approach to funding energy efficiency programs. It should also be noted that these estimates only account for emission reductions that result from program delivery. Further emission reductions are possible from energy efficiency through the advancement of codes and standards, and other market transformation activities, which can be supported through incentive programs.

Figure ES-3. BAU Emissions Produced vs. Emissions Considering Energy Efficiency Program Impact, MtCO2e[9]



Presence of an energy efficiency (EE) program is projected to result in reductions of emissions as compared to the BAU case of 7.1% and 8.6%, when considering EE programs that include the O&G segments and EE programs without O&G, respectively.
Source: Navigant analysis

For the reference case, Navigant relied on the market price of carbon to inform the portfolio level of investment, including solar photovoltaics (PV). The portfolio cost (incentives and administrative costs) is projected to be, on average, $155 million per year (in real 2019 dollars) and is estimated to achieve GHG savings at $35/lifetime tCO_2e. The portfolio cost with oil & gas is projected to be, on average, $268 million per year (in real 2019 dollars) at $30/tCO_2e$.

EEA does not intend to use the potential study results as a point estimate in its next plan; rather, the agency will use the results as information to guide its planning efforts.

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[9] The variable nature of the BAU emissions forecast is due to the expected transition from coal-fired power plants to more natural gas and renewable energy-based power generation. This forecast estimates the year in which certain coal-fired power plants will either close or be converted to natural gas. Given these are very large facilities, the impact on the BAU forecast is very noticeable in particular years and in an overall emission forecast that reflects several year-over-year step-changes in emissions intensity of the electric grid.

This report presents the methodology, data inputs, and key assumptions Navigant used to conduct the potential study. More detailed discussions and results are included in the main body of the report.

STUDY OBJECTIVES

As a key element of Alberta's Climate Leadership Plan, EEA was created as a Crown Corporation in October 2016 to support energy efficiency in Alberta. EEA's mandate[10] is to:

- Raise awareness among energy consumers of energy use and the associated economic and environmental consequences
- Promote, design, and deliver programs and carry out other activities related to energy efficiency, energy conservation, and the development of micro-generation and small-scale energy systems in Alberta
- Promote the development of an energy efficiency services industry

EEA programs are carbon-based, with impacts measured as carbon reduction or abatement. The agency's goals also include economic and social co-benefits. Thus, EEA's programming is focused on electricity and natural gas energy efficiency and small-scale renewable energy in the built environment. In the future, there may be complementary offerings targeting the transportation sector.

Potential study objectives provide a long-range outlook on the cost-effective potential for delivering energy efficiency. Having a comprehensive review of achievable potential across Alberta provides analytical evidence of the effects efficiency and GHG reductions can have over the forecast period. The objectives of this study are to:

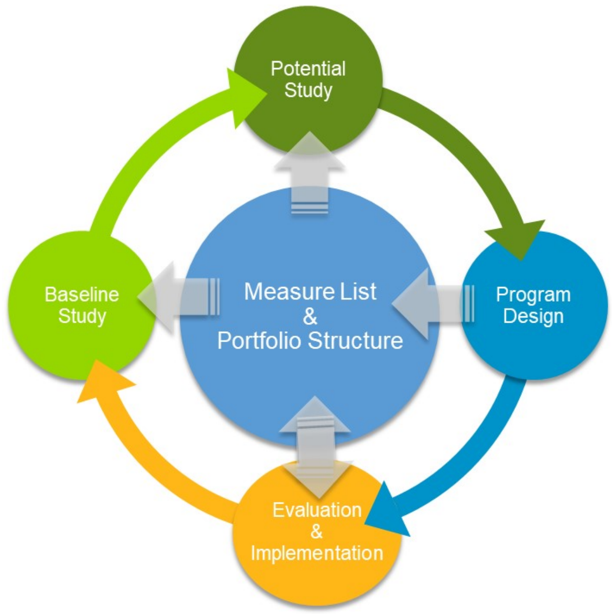
- Provide the level of detail and accuracy necessary to inform the design of EEA's current and future efficiency offerings for Albertans and have a clear understanding of the investment levels needed to cost-effectively provide energy efficiency services
- Input study results into EEA's own portfolio program planning and energy efficiency program design
- Inform planning by other entities, such as local emission reduction efforts, utility system planning, and load forecasting models

Figure ES-4 shows the interaction between the potential study and other energy efficiency activities. This figure illustrates the continuous process of defining the baseline energy use of the market through a baseline or saturation study, to forecasting the potential energy savings across a market, developing and evaluating efficiency programs designed to achieve savings, and then redefining the baseline based on programmatic impacts on efficiency improvements. This process flow ensures the market is served based on the energy consumer's needs by providing:

- Foundation for program planning
- Basis for long-term goals and targets
- Direction for the development of new services and initiatives

[10] https://www.efficiencyalberta.ca/about

Figure ES-4. Program Process Flow



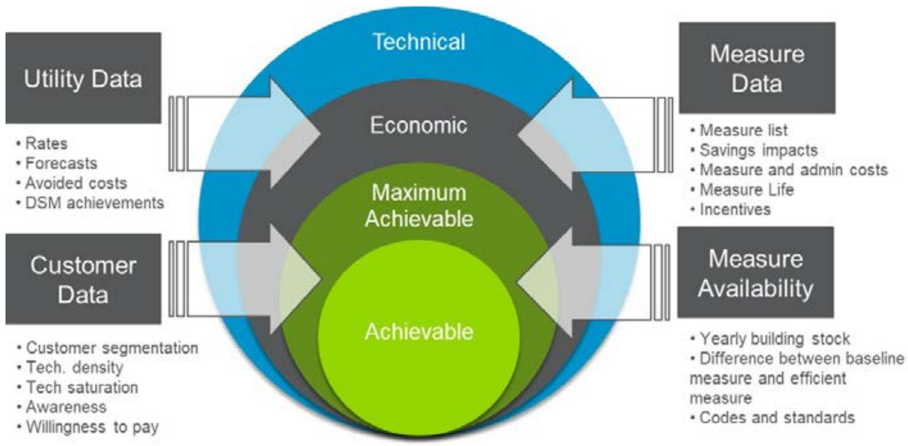
Source: Navigant

EEA has rolled out programs to jumpstart the effort to provide offerings to Albertans. This study helps inform the effort by providing additional information for future program design as identified in the program process flow above.

Approach

Navigant developed forecasts of technical, economic, and achievable electricity savings potential in Alberta from 2019 through 2038 using a bottom-up potential model (EEA's fiscal year runs from April 1 to March 31 of the following calendar year). For these efficiency forecasts, the study team relied on disaggregated estimates of building stock and electricity and natural gas energy sales before conservation, and a set of detailed measure characteristics for a comprehensive list of energy efficiency measures relevant to Alberta. This section describes the study team's approach and methodology for developing the key inputs to the potential model, as illustrated in Figure ES-5.

Figure ES-5. Potential Study Inputs



Source: Navigant

Navigant's methodology for calculating achievable potential includes quantifying the market stock and energy consumption for both the base year and BAU forecast. The study team then conducted a full measure characterization of potential energy reduction opportunities for the Alberta energy consumers. Finally, as part of the analysis, the calculation requires economic parameters such as avoided energy costs, discount rates, carbon prices, and more. At every step in this process, Navigant worked closely and collaboratively with EEA staff.

Caveats and Limitations

There are caveats and limitations associated with the study results. Potential studies are typically a bottom-up effort and are an exercise in data management and analysis to balance data abundance and data scarcity for different inputs. The study team must understand the data gaps and how to fill these to provide reasonable and realistic potential estimates for the province. The report documents what approach the team took and the decisions made when appropriate data was not available.

Base Year and Business-as-Usual Forecast

Market characterization requires defining the energy consumers in Alberta for a sales and stock base year, and BAU forecast to provide the baseline for the study. To complete this effort, Navigant collected multiple datasets from Alberta and supplemental data, as appropriate. These datasets are provided in Table ES-2.

Table ES-2. Base Year (2016) Profile Sources

Sector	Sources Used
Residential	• Canadian Energy System Simulator (CanESS) Model[11] • Natural Resources Canada (NRCan) Comprehensive Energy Use Database CEUD)[12] • Alberta Utilities Commission (AUC) 2016 sector-level residential consumption[13]
Commercial	• CanESS Model • NRCan CEUD • AUC 2016 sector-level commercial consumption[14] • FortisBC Electric Conservation Potential Review (FBC CPR) Report[15]
Industrial	• Canadian Manufacturers & Exporters (CME) Report – Improving energy efficiency for Alberta's Industrial and Manufacturing sectors[16] • Alberta Oil Sands Energy Efficiency and GHG Mitigation Roadmap[17] • Energy Return on Investment of Canadian Oil Sands Extraction from 2009 to 2015[18] • Trottier Energy Futures Project: Greenhouse Gas Emissions from the Canadian Oil and Gas Sector[19] • Statistics Canada (StatsCan) CANSIM Table 128-0016[20] • 2017 Canadian Association of Petroleum Producer (CAPP) Crude Oil Forecast, Markets & Transportation[21] • Descriptive Analysis of On-Farm Energy Analysis in Canada[22] • AUC 2016 sector-level industrial consumption, supplemented with direct-load and behind-the-fence industrial consumption from Alberta Energy Systems Operator (AESO)[23] • FBC CPR Report

Source: Navigant

Navigant worked with EEA to divide the energy consumers in each sector by segment based on existing data availability and representativeness of the unique mix of energy users in Alberta, and to appropriately define the measure and end-use characteristics, as these differ across segments. The study team

[11] whatIf? Technologies, CanESS model calibrated. Provided by CESAR (http://www.cesarnet.ca) using the CanESS model (http://www.whatiftechnologies.com/caness)

[12] Natural Resources Canada Comprehensive Energy Use Database. http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive_tables/list.cfm

[13] Annual Electricity Data Collection, Alberta Utilities Commission. http://www.auc.ab.ca/pages/annual-electricity-data.aspx

[14] Annual Electricity Data Collection, Alberta Utilities Commission. http://www.auc.ab.ca/pages/annual-electricity-data.aspx

[15] FortisBC Conservation Potential Review Report. 2017. https://www.fortisbc.com/About/RegulatoryAffairs/GasUtility/NatGasBCUCSubmissions/Documents/170915_FBC_2016_LTERP_LT_DSM_Plan_Errata_FF.pdf

[16] Improving energy efficiency for Alberta's Industrial and Manufacturing sectors. Canadian Manufacturers & Exporters. 2010. http://ab.cme-mec.ca/download.php?file=geebgbcx.pdf

[17] Alberta Oil Sands Energy Efficiency and GHG Mitigation Roadmap. Suncor. 2012.

[18] Energy Return on Investment of Canadian Oil Sands Extraction from 2009 to 2015. Wang. 2017. http://www.mdpi.com/1996-1073/10/5/614

[19] Trottier Energy Futures Project: Greenhouse Gas Emissions from the Canadian Oil and Gas Sector. Trottier Energy Futures. 2014.

[20] CANSIM Table 128-0016. Statistics Canada. 2017. http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=1280016

[21] 2017 CAPP Crude Oil Forecast, Markets & Transportation. CAPP. June 2017. http://www.capp.ca/publications-and-statistics/publications/303440

[22] Descriptive Analysis of On-Farm Energy Analysis in Canada. Canadian Agricultural Energy End Use Data and Analysis Centre. 2000. http://www.usask.ca/agriculture/caedac/pubs/Energy.PDF

[23] Alberta Utilities Commission data only includes sales data from electric distribution utilities. AESO provided Navigant with the missing industrial direct load and behind-the-fence consumption to ensure the total industrial consumption is captured as part of this analysis.

developed the base year (2016)[24], as summarized in Table ES-3 and Figure ES-6 and the BAU forecast (2019-2038) profile based on an assessment of electricity and natural gas consumption by customer sector, segment, and end use. The GHG emissions by sector in the province is shown in Figure ES-6.

The BAU forecast uses the base year profile as its foundation and applies changes in stock growth and end-use intensity (EUI) over time to develop the residential, commercial, and industrial forecasts. The BAU forecast is significant because it acts as the point of comparison (i.e., the BAU) for the calculation of technical, economic, and achievable market potential scenarios. For both the base year and BAU forecast, Navigant reconciled and calibrated the bottom-up alignment for end use, segment, and sector to Alberta's 2016 load and 2019-2038 forecast.

Table ES-3. Base Year (2016) Electricity (GWh), Natural Gas Sector Consumption (TJ), and GHG Emissions (million tCO2e)[25]

Sector	Electricity (GWh)	Natural Gas (TJ)	Electricity (% of Total)	Natural Gas (% of Total)	GHG Emissions (Million tCO2e)	Electricity GHG Emissions (% of Total)	Natural Gas GHG Emissions (% of Total)
Residential	9,925	165,115	18%	82%	16.9	49%	51%
Commercial	14,900	102,515	34%	66%	17.7	70%	30%
All Industrial	51,653	1,183,090	14%	86%	103.3	40%	60%
Non-Oil & Gas Industrial[26]	*18,288*	*184,601*	*26%*	*74%*	*24.3*	*61%*	*39%*
Total	76,477	1,450,719	16%	84%	137.8	45%	55%

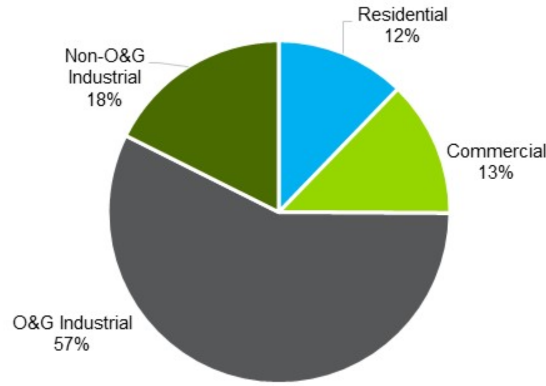
Note: Totals may not sum due to rounding
Source: Navigant analysis

[24] Navigant used 2016 as the base year because it was the first full year of data available at the beginning of this study.

[25] The study team calculated total GHG emissions for 2016 based on an electricity emissions intensity of 0.7576 tCO2e/MWh and a natural gas emissions intensity of 0.0518 tCO2e/GJ. More details on these emissions intensities are provided in Appendix B.4. The team did not include fugitive emissions.

[26] The non-oil & gas industrial subsector captures all industrial segments, excluding the oil sands and conventional oil & gas industrial operations; it is a subset of the all industrial sector.

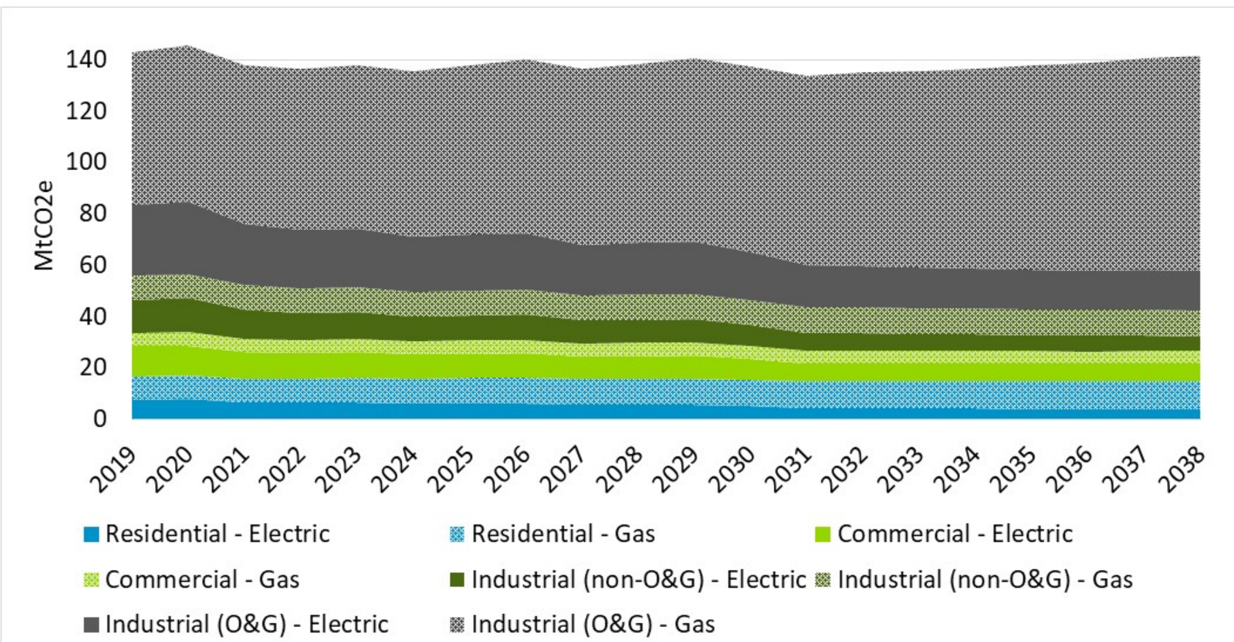
Figure ES-6. Base Year (2016) Allocation of GHG Emissions by Sector



Source: Navigant analysis

The industrial oil & gas subsector dominates emissions in Alberta. Figure ES-7 provides the sector-level emissions from the 2016 base year through 2038, absent the projected reductions from any EEA program activities.

Figure ES-7. Alberta GHG Annual Emissions by Fuel by Sector, MtCO2e, 2019-2038



Source: Navigant analysis

As shown in Figure ES-8 and Figure ES-9, more than 75% of residential sector electricity and natural gas consumption is from the single-family detached home segment. Navigant also characterized the single-family attached and apartments segments.

Figure ES-8. Base Year Residential Electricity Segment

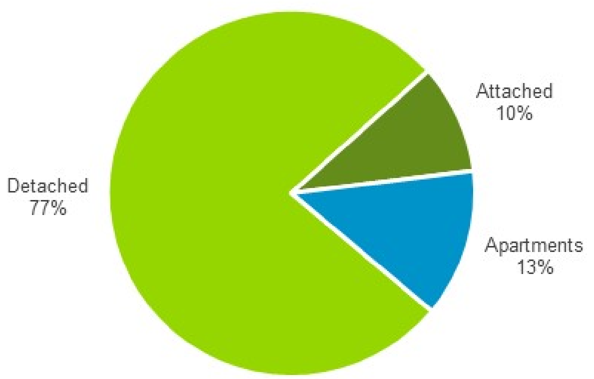
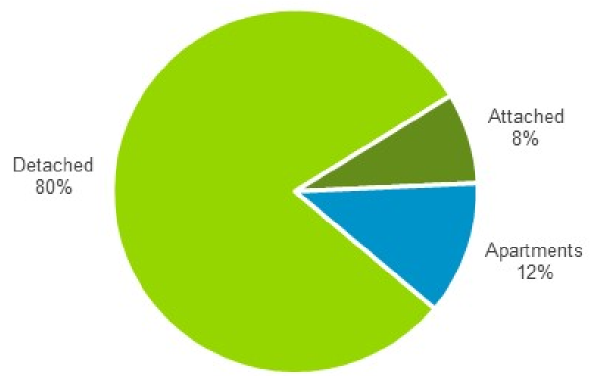


Figure ES-9. Base Year Residential Natural Gas Segment



Source: Navigant analysis

Figure ES-10 and Figure ES-11 show 2016 base year residential electricity and natural gas consumption by end use, respectively. The study found appliances, lighting, and space heating are the largest residential end uses, accounting for more than 70% of residential electricity consumption. Additionally, space heating and water heating account for almost all residential natural gas consumption. The team determined the end-use consumption allocation does not vary significantly across the segments.

Figure ES-10. 2016 Base Year Residential Electricity Consumption by End Use

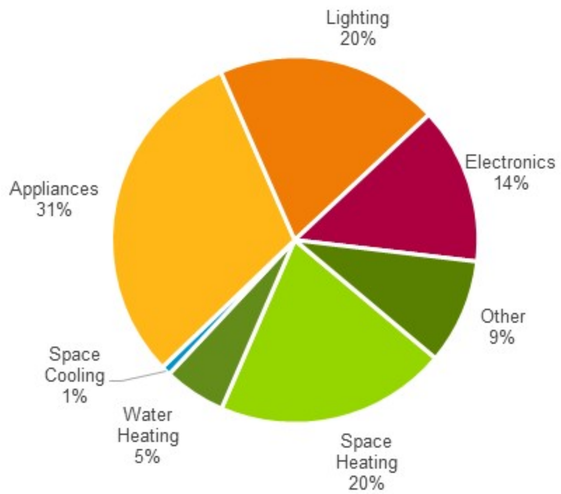
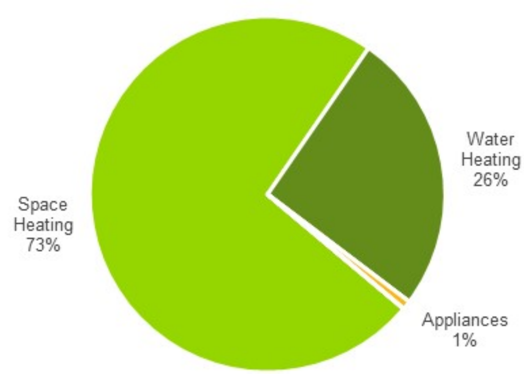


Figure ES-11. 2016 Base Year Residential Natural Gas Consumption by End Use



Source: Navigant analysis

Figure ES-12 and Figure ES-13 show 2016 base year commercial electricity consumption by end use and segment, respectively. Navigant determined lighting, HVAC (fans/pumps), and other are the largest commercial end uses, accounting for more than 75% of commercial electricity consumption. Except for offices, which account for 36% of electricity consumption, the study team found the commercial sector is much more evenly distributed across the segments.

Figure ES-12. 2016 Base Year Commercial Sector Electricity Consumption by End Use

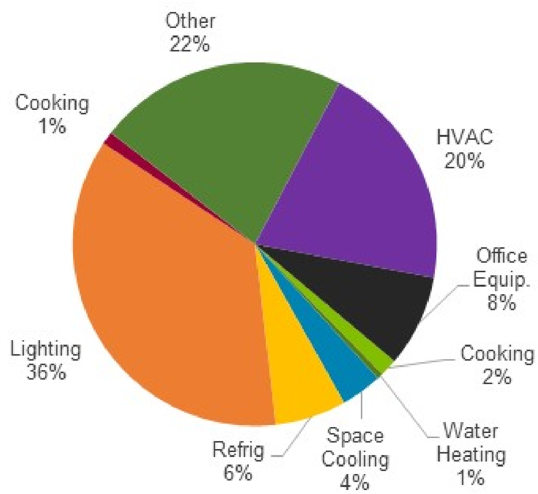
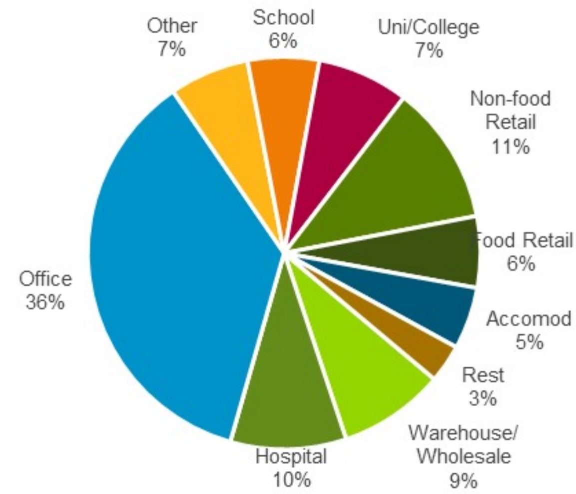


Figure ES-13. 2016 Base Year Commercial Sector Electricity Consumption by Building Type



Source: Navigant analysis

Figure ES-14 and Figure ES-15 show 2016 base year commercial natural gas consumption by end use and segment, respectively. Space heating accounts for much of natural gas consumption (89%), followed by water heating (10%). The study team found commercial natural gas consumption is also evenly distributed across segments, except for offices, which account for 36% of natural gas consumption.

Figure ES-14. 2016 Base Year Commercial Sector Natural Gas Consumption by End Use

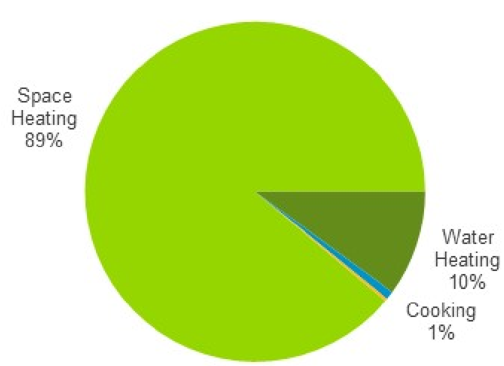
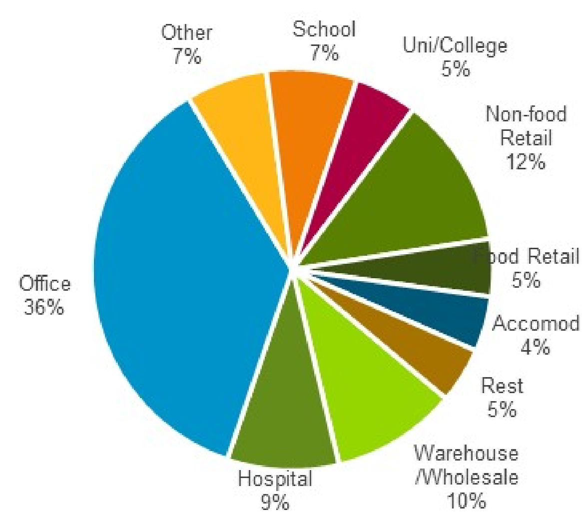


Figure ES-15. 2016 Base Year Commercial Sector Natural Gas Consumption by Building Type



Source: Navigant analysis

Figure ES-16 and Figure ES-17 show 2016 base year electricity consumption by end use and segment, respectively, for all industrial segments (including oil & gas). The study team found industrial process (32%) and pumps (19%) are the largest industrial end uses, while the oil sands (in-situ and mining) segments are the largest industrial segments, accounting for about 50% of industrial electricity consumption.

Figure ES-16. 2016 Base Year All Industrial Sector Electricity Consumption by End Use

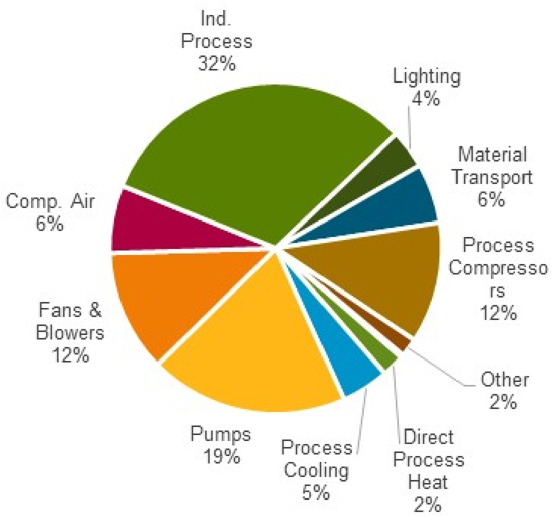
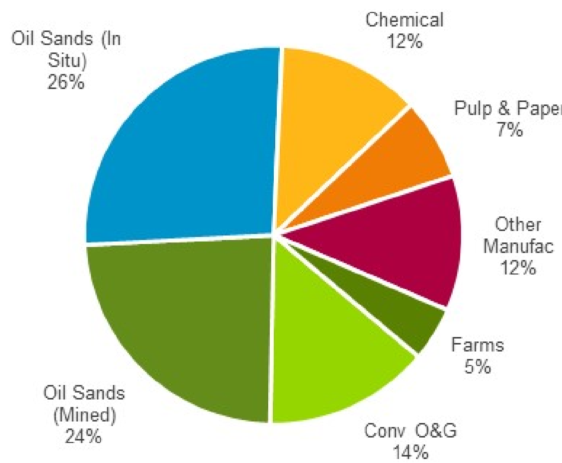


Figure ES-17. 2016 Base Year All Industrial Sector Electricity Consumption by Segment



Source: Navigant analysis

Figure ES-18 and Figure ES-19 show 2016 base year natural gas consumption by end use and segment, respectively. Indirect process heating is the largest end use. However, excluding oil & gas, the team found that direct process heating is the largest end use.

Figure ES-18. 2016 Base Year All Industrial Sector Natural Gas Consumption by End Use

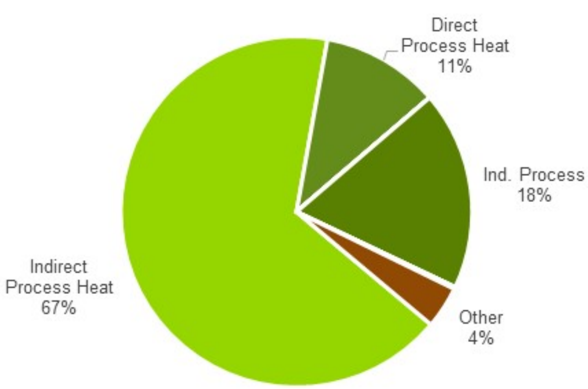
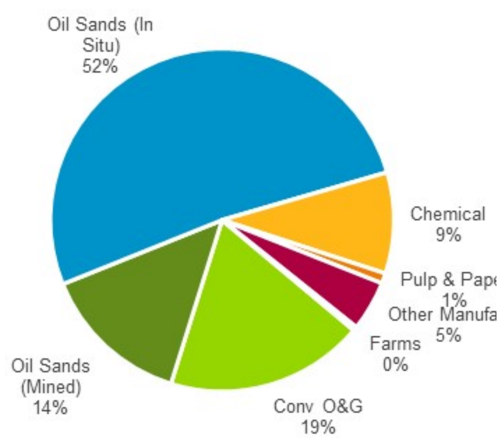


Figure ES-19. 2016 Base Year All Industrial Sector Natural Gas Consumption by Segment



Source: Navigant analysis

Measure Identification and Characterization

Navigant characterized 184 measures (or measure categories) across Alberta's residential, commercial, and industrial sectors. The study team leveraged existing measure characterizations from recently completed Navigant potential studies and supplemented the measure list with input from EEA. The team prioritized and adjusted previously characterized measures to account for Alberta-specific factors, such as weather and high impact measures with good data availability that are most likely to be cost-effective to include in Navigant's DSMSim™ potential model. The measure characterization for this current study leveraged other relevant studies. While using data from other regions, EEA and Navigant recognize there is a lack of Alberta-specific data for certain parameters, such as what energy efficiency technologies are typically installed in homes and businesses in the province, and the associated costs.

Based on a review of other Canadian jurisdictions, Navigant developed a comprehensive list of energy efficiency measures likely to provide achievable market potential by identifying energy efficiency, fuel switching, and generation measures with the highest expected economic impact. The study team worked with EEA to finalize the measure list and ensure it contained applicable industrial measures and technologies viable for future EEA program planning activities.

To identify potential electricity system peak reductions, Navigant and EEA reviewed AESO sources. This effort considered both hourly load consumption and weather effects. The peak periods the study team used to calculate demand savings are:

- **Winter Peak Period:** Hour ending 17-21 on weekdays in December and January
- **Summer Peak Period:** Hour ending 14-18 on weekdays in June through August

Estimation of Potentials

Combining market and measure characterizations provides the foundation for Navigant to calculate the savings potential for different scenarios defined by the study team. The team employed Navigant's proprietary DSMSim potential model to calculate:

- **Technical Potential:** Theoretical maximum, disregarding non-engineering constraints
- **Economic Potential:** Economically cost-effective, disregarding market barriers
- **Achievable Potential:** Realistically achieved through programs across Alberta

DSMSim is a bottom-up technology diffusion and stock tracking model implemented using a System Dynamics[27] framework. The DSMSim model explicitly accounts for different types of efficient measures, such as retrofit (RET), replace-on-burnout (ROB), and new construction (NEW), and the effects these measures have on savings potential. The model then reports the potential savings in aggregate for the service territory, sector, customer segment, end-use category, and highest impact measures.

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[27] See Sterman, John D. *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Irwin McGraw-Hill. 2000 for detail on System Dynamics modeling. Also, see http://en.wikipedia.org/wiki/System_dynamics for a high-level overview.

This study defines **technical potential** as the total energy savings available assuming all installed measures can immediately be replaced with the efficient measure/technology—wherever technically feasible (based on an assumed inventory of baseline measures and available efficient alternatives)—regardless of the cost, market acceptance, or whether a measure has failed and must be replaced.

Economic potential is a subset of technical potential, using the same assumptions regarding immediate replacement as in technical potential, but including only those measures passing the benefit-cost test selected for measure screening—in this case, the modified total resources cost (TRC) test.[28] The modifications Navigant made to the TRC test include using a societal discount rate (rather than a weighted average cost of capital), and not including program administrative costs, since the economic potential analysis identifies measures cost-effective on the margin and prior to program interventions. The team also considered the emissions test (EMT), which calculates net costs per lifetime emissions abated, when selecting measures for the economic potential. The study team also included measures for the GHG emissions reduction benefit based on a $30 per tCO2e threshold even if these did not pass the TRC threshold.

Navigant calculated the $/tCO2e for each measure based on the present value of benefits and costs over each measure's lifetime. As with the TRC, program administrator costs are only included at the sector and portfolio level (and are reflected in the achievable potential results). For the TRC and EMT tests, Navigant used a societal discount rate. Table ES-4 summarizes the economic screening tests.

Table ES-4. Screening Tests

Indicator Type	Screening	
Metric	EMT (per tCO2e)	TRC
Carbon price	Market rate*	Market rate*
Discount rate	Societal discount rate	
Uses	Assessing performance against EEA's mandate (GHG emissions reduction)	Assessing performance against EEA's level of investment

* Market rate as defined by Alberta government plans

Source: Navigant

The **achievable potential** analysis is based on measure adoption ramp rates and the diffusion of technology through the market. Figure ES-20 provides an overview of the calculation methodology.

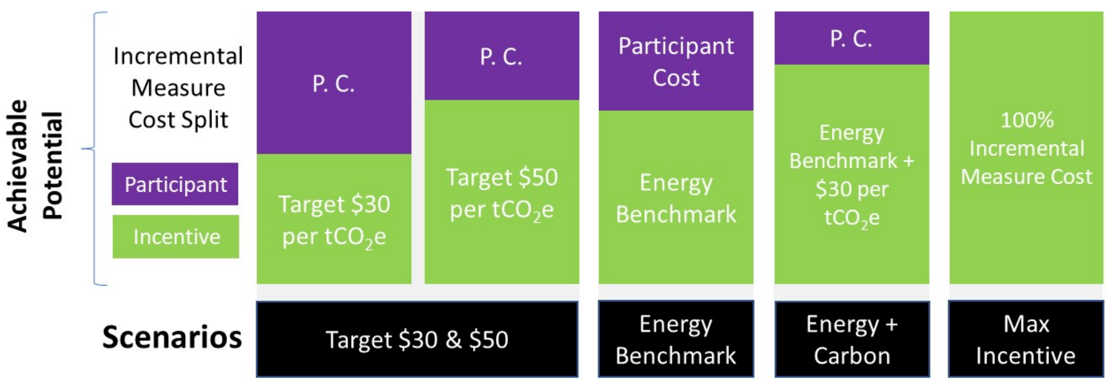
[28] Navigant used a benefit-cost ratio of 1.0 as the primary cost-effectiveness test for measures in the study. The team also included a small number of measures with a benefit-cost ratio between 0.85 and 1.0 as it is common for these measures to be included in programming to ensure program offerings reflect a well-rounded portfolio of measures attractive to participants, while maintaining a portfolio benefit-cost ratio above 1.0.

Figure ES-20. Potential Calculation Methodology

Source: Navigant

Navigant conducted multiple scenarios for achievable potential. This study uses a levelized cost threshold approach in which incentive levels are set to achieve a specified threshold spending level (on a $/levelized kWh or GJ saving basis). EEA is in a unique position to deliver energy efficiency programs by maximizing GHG reductions as opposed to electricity or natural gas savings. In North America, most of the focus centres around the TRC (or similar benefit-cost metric) cost-effectiveness. EEA identified the following potential scenarios for analysis, illustrated in Figure ES-21. The team based the scenarios on the incentive level to reduce the participant cost and the consideration of carbon.

Figure ES-21. Achievable Potential Scenarios



Source: Energy Efficiency Alberta

EEA evaluated the potential with the following considerations:

1. **Target $30 and $50 per lifetime** tCO_2e**:** Setting incentives, so that on average, the amount invested in energy efficiency is equal to the current carbon price in 2019 of $30, and following the federal government schedule in 2022, to be $50 in nominal dollars.
2. **Energy benchmark:** Incentive levels benchmarked to other jurisdictions in Canada and the United States (based primarily on the value of energy savings to the utility system).
3. **Energy + carbon:** Setting incentives that leverage the value of carbon and avoided energy costs.
4. **Maximum incentive:** Setting incentives to cover the entire incremental cost of measures. This is a theoretical scenario for comparison purposes.

Summary of Achievable Potential Results

This section provides a summary of the achievable potential results. As shown in Figure ES-21, this study considers the reference case at the current carbon price floor of $30/ tCO_2e. As the amount of available funding and the value of avoided energy costs benefits increases, the result is greater energy savings and more cost-effective carbon reductions. The study team presents all results as gross savings at the meter, and carbon emissions abated at the generator. Table ES-5 provides a summary of the study's fuel savings for the reference scenario as cumulated through 2038.

Table ES-5. Cumulative Annual Gross Savings, Over the Study Period (2019-2038) [29,30]

Value	Description	EE (Excluding Oil & Gas)	EE (Including Oil & Gas)	PV Solar	PV Solar + EE (Including Oil & Gas)
Electric Achievable Potential (GWh)	Annual GWh saved from measures installed over the study period	7,008	10,137	3,515	13,652
Electric Achievable Potential (% of Consumption[31])	GWh savings in 2038 as a percent of the forecasted consumption for 2038	13.3%	9.9%	10.5%	13.3%
Gas Achievable Potential (TJ)	Annual TJ saved from measures installed over the study period	27,892	132,036	N/A	132,036
Gas Achievable Potential (% of Consumption)	TJ savings in 2038 as a percent of the forecasted consumption for 2038	5.6%	6.3%	N/A	6.3%
Peak Winter Demand Savings, 2038 (MW)	Peak winter demand savings in 2038	919	1,337	N/A	1,337

Source: Navigant analysis

[29] Sum of first year savings achieved each year throughout the study period

[30] As a point of clarification, the percent of consumption values for each of the below are with respect to the following customer segments and sectors:

- EE (Excluding Oil & Gas): Residential, commercial, and industrial sectors (excluding oil and gas customer segments)
- EE (Including Oil & Gas): Residential, commercial, and industrial sectors (including oil and gas customer segments)
- PV Solar: Residential and commercial sectors

The savings being calculated as a percent of sector/customer segment sales is relative to the defined reference case in each of the columns even though the savings vary.

[31] The savings percent of consumption is based on the BAU consumption otherwise experienced in the year of reference. In this instance, the year of reference is 2038.

In addition to the energy savings cumulated over the study period, it is also important to consider the total costs and benefits over the lifetime of the measures installed during the study period. Table ES-6 provides such values for the reference scenario and the relevant equations used to arrive at the values (if applicable).

Table ES-6. Cumulative Lifetime Gross Savings at Meter, Carbon Abatement at Generator, and Net Benefits over the Study Period

Value	Equation	Description	EE (Excluding Oil & Gas)	EE (Including Oil & Gas)	PV Solar	PV Solar + EE (Including Oil & Gas)
[A] - Lifetime Electricity Potential (GWh)	A	Electric Lifetime Energy Saved by All Measures Installed During the Study Period	100,551	133,479	87,873	221,351
[B] - Lifetime Natural Gas Potential (TJ)	B	Natural Gas Lifetime Energy Saved by All Measures Installed During the Study Period	402,872	1,889,686	N/A	1,889,686
[C] - Lifetime Emissions Abated (Lifetime tCO2e)	C	Lifetime Emissions Reductions Provided by All Measures Installed During the Study Period	61,192,660	150,919,453	27,266,346	178,185,799
[E] - Incremental Measure Costs (2019 $ Millions)	E	Cost of the Efficient Measure Less the Cost of the Baseline Measure	$3,324	$6,834	$4,726	$11,560
[F] - Incentives (2019 $ Millions)	F	Incentive Provided to the Participant	$1,587	$3,167	$720	$3,887
[G] - Participant Cost (2019 $ Millions)	E - F	Incremental Measure Cost of the Measure Less the Incentives Provided	$1,737	$3,668	$4,005	$7,673
[H] - Administrative Costs (2019 $ Millions)	H	Admin Costs Required to Support the Program	$680	$1,357	$108	$1,465
[J] - Total Costs (2019 $ Millions)	E + H	Incremental Measure Costs + Admin Costs	$4,004	$8,192	$4,833	$13,025
[K] - Total Benefits (2019 $ Millions)	K	Lifetime Benefits of the Measures Deployed Throughout the Study Period	$12,706	$25,740	$7,240	$32,980
[L] - Net Benefits (2019 $ Millions)	K - J	Total Benefits Less Total Costs	$8,702	$17,549	$2,407	$19,956
[M] - Societal Abatement Costs (2019 $ / Lifetime tCO2e)	(J - K) / C	Societal Net Costs per Lifetime tCO2e Abated	$(142)	$(116)	$(88)	$(112)

Note: 2.0% inflation was used to convert values to real 2019 dollars.
Source: Navigant analysis

To provide some insight in to annual costs required to drive energy savings, Table ES-7 shows the fuel-specific program spending associated with its energy savings through 2028[32].

Table ES-7. Fuel-Specific Program Spending per Unit of Energy Saved, At Meter in 2028

	Description	EE (Excluding Oil & Gas)	EE (Including Oil & Gas)	PV Solar	PV Solar + EE (Including Oil & Gas)
Program $/First Year kWh	(Incentives + Admin Costs Spent on Electricity-Saving Measures through 2028) / kWh Saved in 2028	19.0¢	16.9¢	27.2¢	18.2¢
Total $/First Year kWh	(Incremental Measure Costs + Admin Costs Spent on Electricity-Saving Measures through 2028) / kWh Saved in 2028	34.7¢	30.8¢	$1.61	47.5¢
Program $/First Year GJ	(Incentives + Admin Costs Spent on Gas-Saving Measures through 2028) / GJ Saved in 2028	$31.21	$19.57	N/A	$19.57
Total $/First Year GJ	(Incremental Measure Costs + Admin Costs Spent on Gas-Saving Measures through 2028) / GJ Saved in 2028	$52.68	$34.80	NA	$34.80

Note: 2.0% inflation was used to convert values to real 2019 dollars.
Source: Navigant analysis

[32] Navigant chose to report at year 2028 since it is halfway through the study period and represents typical program costs.

In addition, Table ES-8 shows the fuel-specific program spending over the course of the study period associated with the lifetime energy savings of all measures installed.

Table ES-8. Fuel-Specific Program Spending Over Study Period per Lifetime Energy Savings, At Meter

	Description	EE (Excluding Oil & Gas)	EE (Including Oil & Gas)	PV Solar	PV Solar + EE (Including Oil & Gas)
Program $/Lifetime kWh	(Incentives + Admin Costs Spent on Electricity-Saving Measures through 2038) / Lifetime kWh Saved	1.35¢	1.34¢	0.94¢	1.18¢
Total $/Lifetime kWh	(Incremental Measure Costs + Admin Costs Spent on Electricity-Saving Measures through 2038) / Lifetime kWh Saved	2.43¢	2.44¢	5.50¢	¢3.65
Program $/Lifetime GJ	(Incentives + Admin Costs Spent on Gas-Saving Measures through 2038) / Lifetime GJ Saved	$2.25	$1.45	N/A	$1.45
Total $/Lifetime GJ	(Incremental Measure Costs + Admin Costs Spent on Gas-Saving Measures through 2038) / Lifetime GJ Saved	$3.88	$2.61	N/A	$2.61

Source: Navigant analysis

Navigant provides the following observations of the modelled potential based on a review of the costs and shown in Table ES-6, Table ES-7, and Figure ES-1.

- The study team expects the portfolio level of investment to increase annually through 2027 (achievable savings peaks in 2027, excluding oil & gas), with an average increase of 7% per year, and then a decrease close to the 2021 value in real dollars. The team expects decreases due to minimal building stock growth and because only currently known technologies were modelled.
- Avoided electricity and natural gas costs increase over the 20-year horizon based on fuel cost forecasts and inflation.
- Over the 20-year study period, the average energy efficiency (including oil & gas sector) is \$30/lifetime tCO_2e (2019 real dollars).

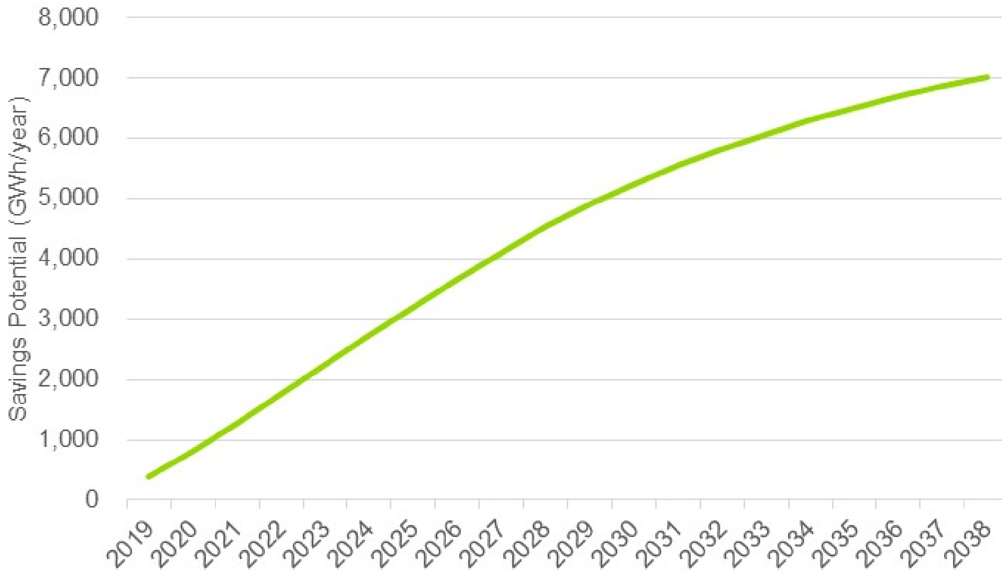
Sector- and Segment-Level Results

Electricity Potential

Figure ES-22 and Figure ES-23 presents the cumulative annual gross electricity savings potential at the meter, and the cumulative potential as a percentage of sector consumption (excluding the industrial oil & gas subsector), respectively:

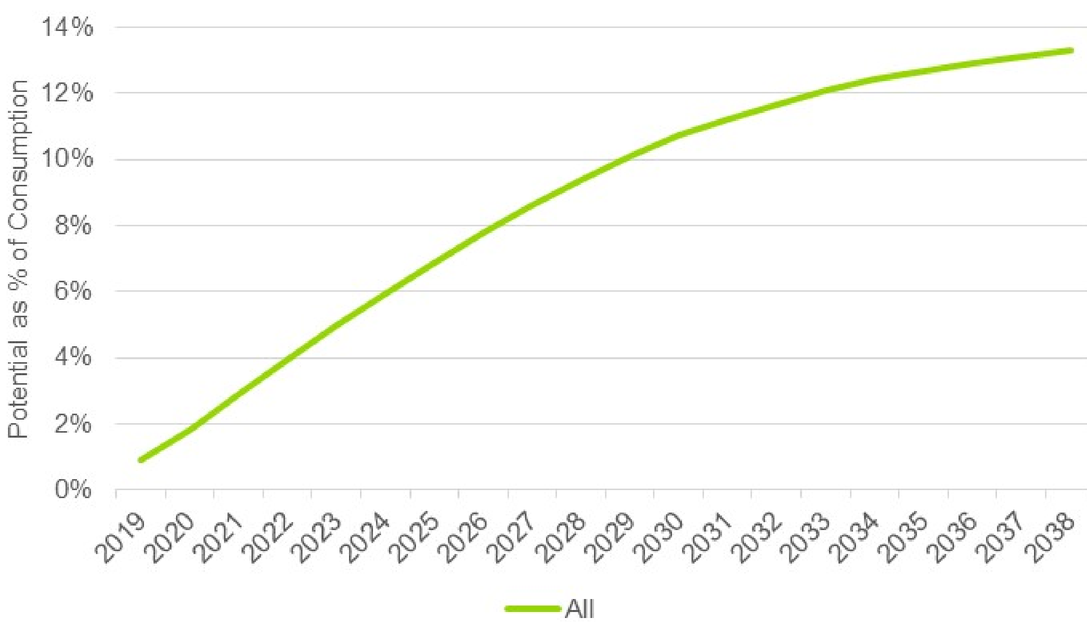
- In 2038, cumulative annual achievable potential as a percentage of total sector consumption reaches 13.3% (7,008 GWh and 919 MW), with an annual average of 0.7% (350 GWh and 46 MW) over the 20-year period (2019-2038).
- Commercial savings potential as a percentage of sector consumption grows faster than the residential or industrial sectors, reaching 19.1% by 2038, with an average annual savings of 1% over 20 years.
- Residential savings potential as a percentage of sector consumption reaches 9.0% by 2038, achieving an average annual savings of 0.45% over 20 years. The residential sector's lower percentage reflects the lower cost-effectiveness and longer payback times of the residential sector, on average.
- Industrial sector (excluding oil & gas) savings potential as a percentage of sector consumption reaches 9.8% by 2038, achieving an average annual savings of 0.49% over 20 years.

Figure ES-22. Electricity Achievable Potential, Cumulative Annual Gross Savings at Meter (Excluding Oil & Gas)



Source: Navigant analysis

Figure ES-23. Electricity Achievable Potential, Cumulative Annual Gross Savings at Meter as Percentage of Consumption (Excluding Oil & Gas)



Source: Navigant analysis

Table ES-9 presents the incremental annual gross electricity savings potential at the meter for all sectors. The annual incremental potential increases for all sectors in the early years of the study period (until around 2025) and subsequently declines in the second half of the study period. This reflects how market adoption increases over time and eventually reaches an inflection point where higher levels of market saturation decrease the annual incremental potential. It is important to note this study only quantifies impacts of known, market-ready technologies. Based on historical precedence, new technologies are introduced over time, thus it is recommended to update the potential study every three to five years.

Table ES-9. Electricity Achievable Potential, Incremental Annual Gross Savings at Meter, GWh

Year	Total (excludes Oil & Gas)	Total (includes Oil & Gas)
2019	393	539
2020	423	588
2021	464	640
2022	489	676
2023	477	682
2024	490	696
2025	464	673
2026	451	665
2027	461	657
2028	425	606
2029	364	557
2030	325	498
2031	308	454
2032	279	412
2033	243	362
2034	231	342
2035	210	313
2036	192	288
2037	164	252
2038	153	236
Total	7,008	10,137

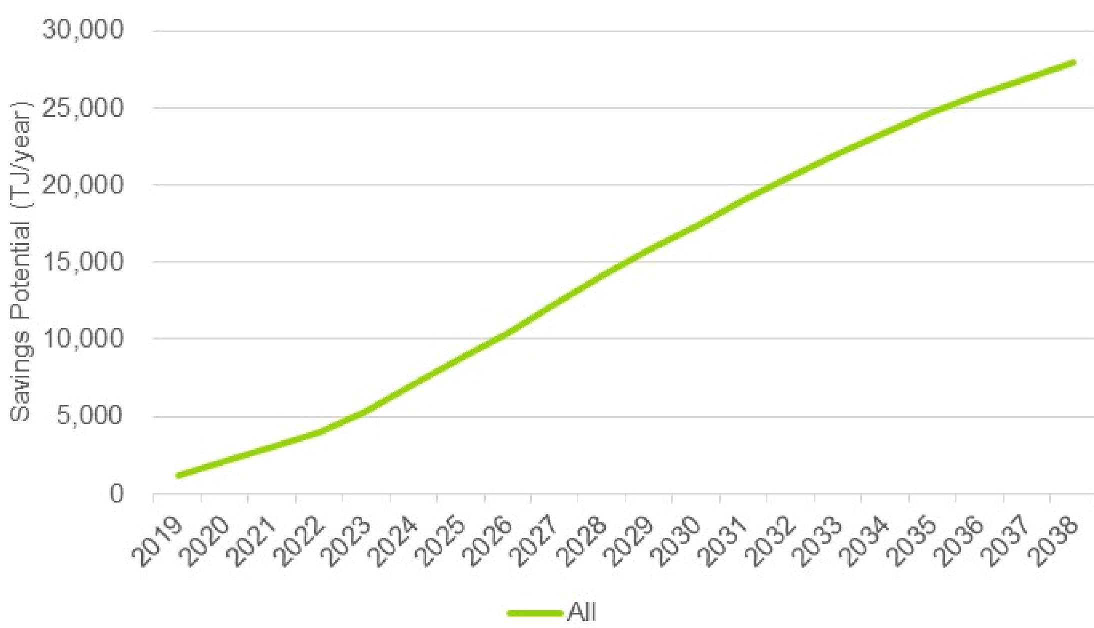
Source: Navigant analysis

Natural Gas Potential

Figure ES-24 presents the cumulative annual gross natural gas savings potential. Figure ES-25 shows the cumulative potential as a percentage of sector consumption (excluding the industrial oil & gas subsector).

- Total achievable potential as a percentage of total sector consumption reaches 5.6% with respect to an average annual BAU forecast by 2038, with average annual savings of 0.28% over the 20-year period (2019-2038). This percentage results in 29,930 TJ by 2038, an annual average of 1,497 TJ over the 20-year period.[33]
- Industrial savings potential as a percentage of sector consumption by 2038 is 6.1%, achieving an average annual savings of 0.31% over 20 years.
- Residential savings potential as a percentage of sector consumption reaches 5.6% by 2038, achieving an average annual savings of 0.28% over 20 years.
- Commercial savings potential as a percentage of sector consumption by 2038 is 5.6%, achieving an average annual savings of 0.22% over 20 years.

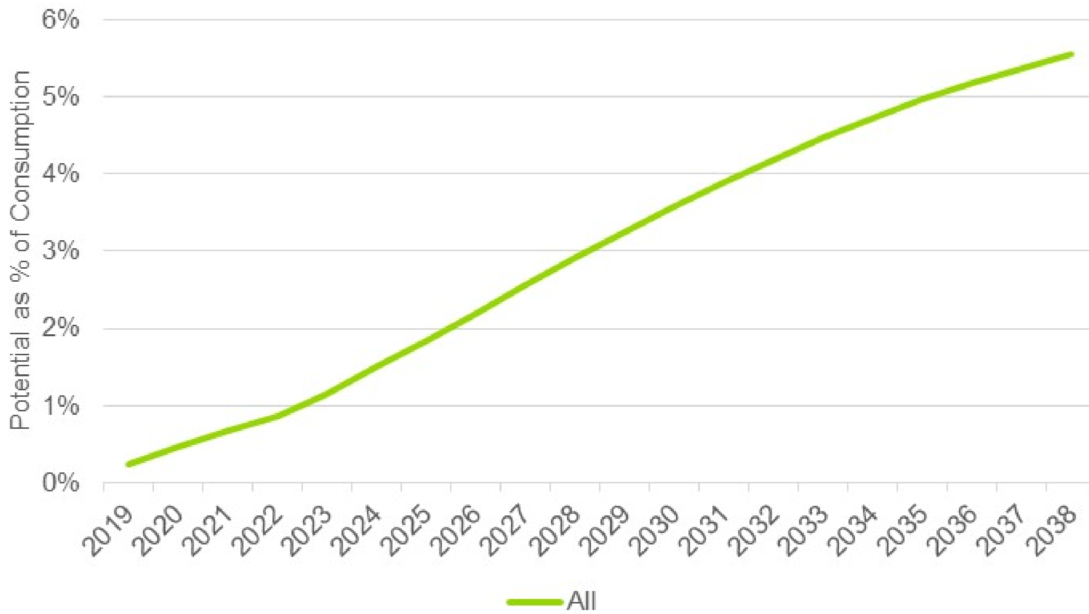
Figure ES-24. Natural Gas Achievable Potential, Cumulative Annual Gross Savings, TJ (Excluding Oil & Gas)



Source: Navigant analysis

[33] With the oil & gas segments included, the cumulative achievable potential as a percentage of total sector consumption is 6.3% (132,036 TJ) by 2038. This is higher compared to the case when oil & gas segments are excluded, because including the oil & gas segments increases the industrial savings potential as a percentage of industrial consumption.

Figure ES-25. Natural Gas Achievable Potential, Cumulative Annual Gross Savings as a Percentage of Consumption (Excluding Oil & Gas)



Source: Navigant analysis

Table ES-10 presents the incremental annual gross natural gas savings potential at the meter for all sectors. The industrial (excluding the oil & gas sector) composes the highest proportion of natural gas savings potential until 2029. From 2030 onwards, the study forecasts the residential sector to provide the greatest savings potential.

For the residential and commercial sectors, the annual incremental potential increases in the first half of the study period, and subsequently decreases in the second half of the study period. Similar to the electricity fuel type, this reflects how market adoption increases over time and eventually reaches an inflection point where higher levels of market saturation decrease the annual incremental potential. The industrial sector is also affected by these factors; however, there are some fluctuations in the industrial annual potential because of forecasted changes in the industrial natural gas BAU forecast.

Table ES-10. Natural Gas Achievable Potential by Sector, Incremental Annual Gross Savings, TJ

Year	Total (excludes Oil & Gas)	Total (includes Oil & Gas)
2019	1,121	5,987
2020	998	5,733
2021	940	5,574
2022	964	5,972
2023	1,336	7,228
2024	1,708	7,783
2025	1,654	8,139
2026	1,662	8,521
2027	1,931	8,154
2028	1,849	7,779
2029	1,602	8,165
2030	1,593	7,441
2031	1,629	7,123
2032	1,588	6,786
2033	1,412	6,107
2034	1,388	5,863
2035	1,300	5,517
2036	1,228	5,225
2037	1,029	4,605
2038	961	4,334
Total	**27,892**	**132,036**

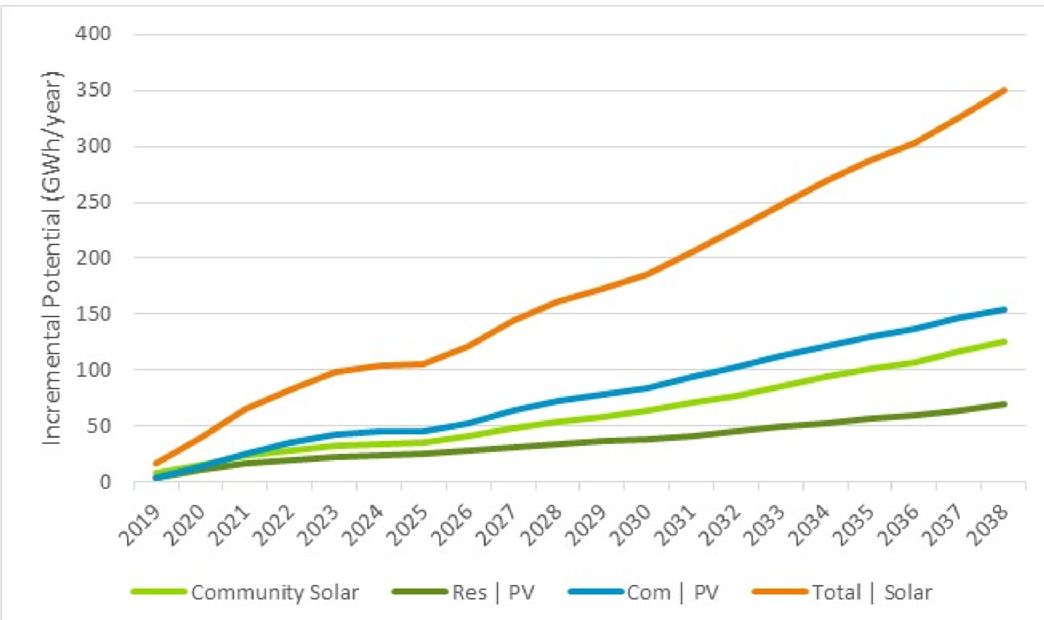
Source: Navigant analysis

Solar Photovoltaics Results

Figure ES-26 provides the incremental annual gross generation achievable potential at meter for small-scale renewables. This study has focused on solar PV generation in the residential and commercial sectors, as it is currently receiving the most attention in the marketplace. The team included other generation—combined heat and power (CHP) and solar water heating—under the energy efficiency savings estimates. More detailed evaluation of other distributed energy technologies is work that can be done to further expand upon the distributed energy potential in Alberta. Current solar forecast results are 10% of the applicable customer segment consumption by 2038.

Community solar shows high potential over the 20 years. However, Navigant recognizes this market is yet to be developed in Alberta. The financial and market adoption dynamics of this study reveal a strong potential as the industry develops to meet this demand. The study expects residential and commercial solar PV to grow over the 20 years, with the most savings from the commercial sector.

Figure ES-26. Generation Achievable Potential, Incremental Annual Gross Savings at Meter, GWh/year



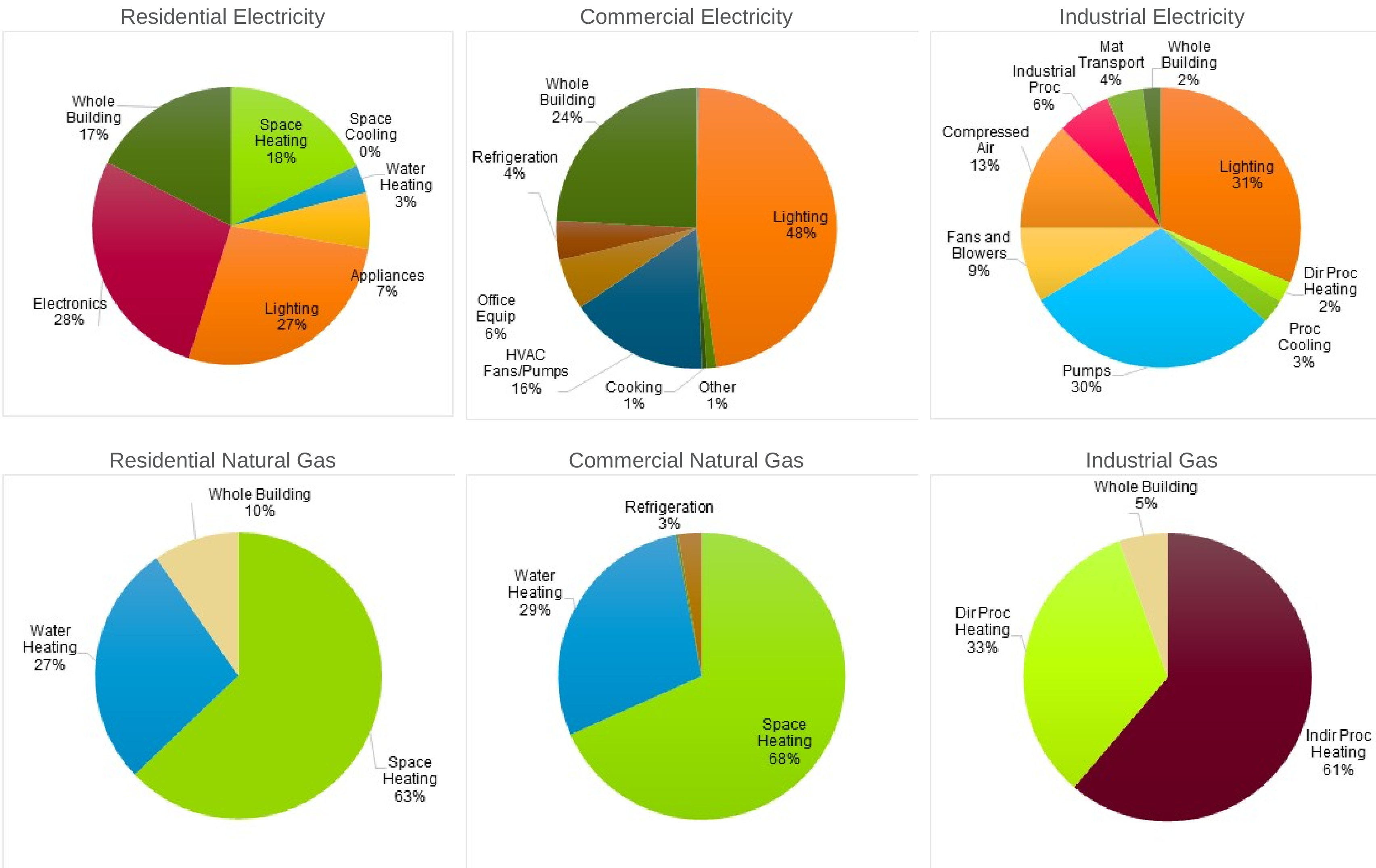
Source: Navigant analysis

Achievable Potential End-Use and Measure-Level Results

Figure ES-27 provides the end-use savings achievable potential by sector (excluding the industrial oil & gas subsector) and fuel type. Navigant presents the following specific findings by end use:

- Lighting provides the most electricity savings potential in all sectors.
- Electronics, including plug loads in residential, make up an almost equal proportion of energy savings as lighting.
- The whole building end use in both residential and commercial accounts for energy savings attributed to combined heating and cooling savings and envelope measures. Both sectors provide at least 16% savings for this end use.
- Pumps and compressed air also have high potential savings, and combined, contribute more savings than lighting in the industrial sector.
- Natural gas savings potential is highest for space heating in the residential and commercial sectors, while industrial process heating is greatest in the industrial sector.
- Similar to electricity savings, the natural gas whole building end use consists of those measures that affect more than one end use, such as building envelope.
- Industrial sector indirect process heating includes measures such as heat exchanging.

Figure ES-27. 2028 Achievable Potential, Cumulative Gross Savings at Meter, by End Use



Source: Navigant analysis

Table ES-11 lists the top 20 measures across all sectors (excluding oil & gas) ranked in order of avoided lifetime GHG emissions over the 20-year study. Cost-effective savings are achieved in every sector and for a broad range of measures.

- Like other jurisdictions, lighting provides the highest savings potential and emissions potential reduction, representing five of the measures in the top 20.
- Residential savings are dominated by the natural gas consumption of both furnaces and basement insulation.
- Residential lighting savings would have been higher; however, general service lamps are impacted by a change in baseline due to 2020 federal regulations requiring a minimum lamp efficacy (lumens per watt). Networked lighting controls have slower adoption in this sector than in the commercial and industrial sectors.
- Industrial (non-oil & gas) natural gas measures' GHG emissions reductions potential is lower than from residential measures but is still potentially a strong contributor to avoiding emissions. However, including oil & gas, the industrial sector has the largest emissions reductions potential.

Table ES-11.Top 20 Measures for Reducing GHG Avoided Emissions (Lifetime tCO_2e), Excluding Oil & Gas Sectors, 2028

Measure	End Use	GHG Avoided Emissions in Million Lifetime tCO_2e	Percentage of Total Emissions Savings
Com | Interior LED tube	Lighting	3.81	6.2%
Res | Furnace Early Retirement Only	Space Heating	3.73	6.1%
Com | Building Controls and Automation Systems - Electric	Whole Building	3.20	5.2%
Com | VSD on Fans and Pumps	HVAC Fans/Pumps	2.77	4.5%
Ind | Network Lighting - Low Impact Application	Lighting	2.49	4.1%
Com | Interior Recessed LED Downlighting (Troffer LEDs)	Lighting	2.30	.3.8%
Res | Basement or Crawlspace Insulation - G	Space Heating	1.83	3.0%
Ind | High Efficiency Ovens & Dryers	Direct Process Heating	1.37	2.2%
Com | Wall Insulation	Space Heating	1.35	2.2%
Com | Building Controls and Automation Systems - Gas	Whole Building	1.34	2.2%
Com | Interior LED MR/PAR lamps	Lighting	1.22	2.0%
Ind | Improved Condensate Return	Indirect Process Heating	1.21	2.0%
Ind | Regenerative Catalytic Oxidizer	Direct Process Heating	1.01	1.7%
Res | Low Flow Showerheads Gas Only	Water Heating	0.97	1.6%
Ind | Improved Fan Systems	Fans and Blowers	0.92	1.5%
Com | Gas Furnace - High Efficiency	Space Heating	0.91	1.5%
Ind | Heat Recovery Systems - Gas	Indirect Process Heating	0.90	1.5%
Com | Duct Insulation, Gas	Space Heating	0.89	1.5%
Res | LED (General Service Lamps) <= 10 Watt LED	Lighting	0.88	1.4%
Res | Home Energy Reports - Electric	Whole Building	0.84	1.4%

Source: Navigant analysis

Observations and Insights

The results of this potential study are intended to further EEA's ability to develop and target energy efficiency services for Albertans leading to significant GHG emissions reductions and bill savings by energy users (excluding transportation at this time). The potential study planning horizon provides directional information for 20 years, from 2019 through 2038. The near-term data will support portfolio and program planning over the next several years.

Program Planning

Through this potential study, Navigant has provided EEA with a wealth of data to support its energy efficiency and distributed small-scale generation program planning efforts. This data ranges from measure characterization to load shape profiles for peak demand savings calculations, each providing building blocks to help inform program planning.

The study team derived projected savings goals and the corresponding level of investment in tandem with the potential study results. EEA's portfolio consists of programs, which are comprised of measures. The buildup of measures into programs and into a portfolio results in a plan to achieve a defined goal at a certain level of investment. The potential study does not provide program-level potential; thus, programmatic design, such as delivery method and marketing strategies, will have implications to the overall savings goals and level of investment. Additionally, near-term savings potential or actual achievable goals at the measure level will vary. The overall mix of measures is directionally considered with the review of historical program participation and an understanding of current Alberta market conditions (with the team members with boots on the ground) to inform the potential study.

To inform program planning, Navigant provides the following observations on the potential study's results:

- **Lighting:** Typically, lighting is a high percentage of electricity efficiency portfolios. This study has similar findings; however, there is a move toward LED lighting with advanced lighting controls in all sectors. The remaining potential in residential LED lamps is limited due to projected updates in federal standards. Commercial and industrial lighting provides a large savings potential.
- **Community Solar:** The potential study indicates a significant potential starting in 2019. However, the study team recognizes a pipeline of projects does not yet readily exist in Alberta. Achievable potential is modelled based on known technical and economic conditions in the study period's early years, but does not account for other market barriers to implementation.
- **Financing:** Incorporating financing for energy efficiency measures amounts to electricity savings of 1.7% of total consumption (116 GWh) and natural gas savings of 5.4% (1,629 TJ) across all sectors, except oil and gas. Actual acceptance and adoption of financing within Alberta may differ, and the study team's estimates are based on customer acceptance rates to increase adoption from other studies.

Additional Measures

It is important to note this study was limited in scope since it did not include agricultural and transportation measures. Additionally, this study had limited Alberta-based data regarding specific measure inputs and measures. There are also measures Navigant did not include, but that should be considered for future studies, such as additional financing opportunities, exploring deeper the opportunities for advanced lighting options, benchmarking programs, competition programs, pay for performance programs (such as new home construction exceeding a target or deep retrofits in commercial buildings), waste heat recovery, advanced HVAC retrofits, and industrial process improvements. Future studies can either include specific measures or more broad-based measures to cover holistic savings reductions, such as advanced lighting controls disaggregated to networked/connected lighting controls, and luminaire light level controls. Note the study team did not qualify advanced lighting controls here because it was not in the selected referenced potential studies. Nonetheless, this study limitation should not limit EEA programs from including such emerging technology measures.

1. INTRODUCTION

As a key element of Alberta's Climate Leadership Plan, Energy Efficiency Alberta (EEA) was created as a Crown Corporation in October 2016 to support energy efficiency in the province. EEA's mandate is to:

- Raise awareness among energy consumers of energy use and the associated economic and environmental consequences
- Promote, design, and deliver programs and carry out other activities related to energy efficiency, energy conservation, and the development of micro-generation and small-scale energy systems in Alberta
- Promote the development of an energy efficiency services industry[34]

EEA programs are designed to reduce greenhouse gas (GHG) emissions, while contributing to the agency's goals of delivering economic and social co-benefits. Currently, EEA's programming is focused on electricity and natural gas energy efficiency and small-scale renewable energy in the built environment. In the future, there may be complementary offerings targeting the oil & gas and transportation sectors.

1.1 Energy Efficiency Potential Study Background and Goals

EEA engaged Navigant Consulting Ltd. (Navigant or the study team) to prepare an energy efficiency and small-scale renewables potential study for electricity and natural gas in Alberta from 2019 to 2038.[35,36] This potential study will inform future EEA investments to enhance current programs in the market and implement new programs. The study's objectives are to assess energy efficiency potential using secondary research in the residential, commercial, and industrial sectors to reduce Alberta's GHG emissions. Future studies can build off this one, a first of its kind in Alberta, by using new primary market data to provide additional precision to the results. In the energy efficiency potential analysis, Navigant provided input data to its Demand-Side Management Simulator (DSMSim™) model, which calculates the following:

- Technical potential (theoretical maximum, disregarding non-engineering constraints)
- Economic potential (economically cost-effective, disregarding market barriers)
- Achievable potential (realistically achieved through programs)

EEA may use these results as inputs to its own demand-side management (DSM) planning, long-term conservation goals, and energy efficiency program design. This study can be shared with other Alberta-based entities for future collaboration efforts and to inform local emissions reduction efforts, utility system management, and load forecasting models.

[34] Energy Efficiency Alberta, "About Us," https://www.efficiencyalberta.ca/about/.

[35] The last full year of Alberta load data available is for 2016. The potential extrapolates 2017 and 2018 to begin the analysis for 2019.

[36] This study does not include efficiency measures for fuels such as coal, wood, diesel, and propane for energy consumers.

1.2 Report Organization

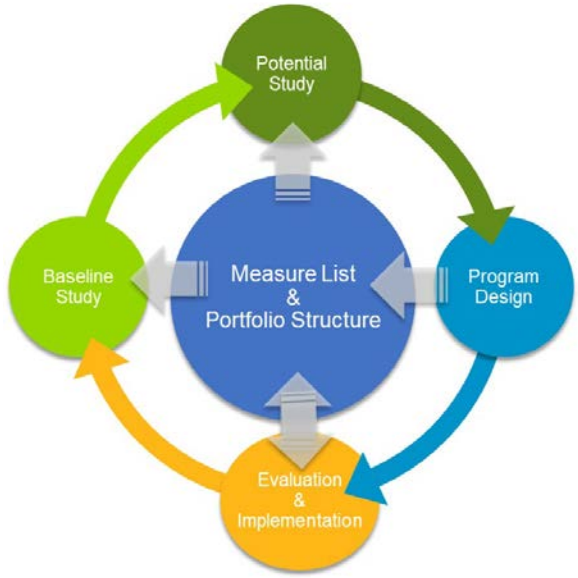
- Section 2 describes the methodologies and approaches Navigant used to estimate energy efficiency and GHG emissions reductions potential, and discusses the base year calibration, the business-as-usual (BAU) case forecast, and measure characterization.
- Section 3 presents the technical potential savings forecast for Alberta and the methods to estimate technical potential.
- Section 4 presents the economic potential savings forecast for Alberta and the methods to estimate economic potential.
- Section 5 includes the achievable potential savings forecast for Alberta, the methods to estimate achievable potential, and the modeling results by customer segment and end use.
- Section 6 summarizes the possible next steps for EEA to consider that result from developing the potential study.
- Appendices A to H provide detailed context for Navigant's modeling assumptions.

1.3 Why Complete a Potential Study?

Potential studies provide a long-range outlook on the cost-effective potential for delivering energy efficiency and GHG reductions. Alberta's potential study focuses on delivering GHG reductions. As more regions work to define a value proposition for energy efficiency as a source for GHG reductions and as a grid resource, having a comprehensive view of achievable potential validates the effects the lowest cost energy resource, energy efficiency, can provide over the forecast period. The detail and accuracy of the current study will allow EEA to develop energy efficiency resources as part of the Provincial Climate Leadership Plan,[37] inform the design of EEA's current and future programs and have a clear understanding of the investment needed to provide energy efficiency services. Figure 1-1 shows the interaction between the potential study and other energy efficiency activities and illustrates the continuous process of defining baseline energy use, forecasting potential energy savings, developing and evaluating efficiency programs designed to capture that savings, and then redefining the baseline as efficiency improvements are made.

[37] The Provincial Climate Leadership Plan, https://www.alberta.ca/climate-leadership-plan.aspx, provides the direction for EEA.

Figure 1-1. Potential Study Process Flow



Source: Navigant

1.4 Study Objectives

EEA's objectives of this potential study are to provide input values for planning and long-term energy conservation goals, and to inform existing and future energy efficiency and GHG reduction programs. Table 1-1 details these objectives and presents Navigant's approach to meeting each objective. The intent of this report and the accompanying Excel workbook is to ensure transparency in the study methods and assumptions.

Table 1-1. Navigant's Approach to Addressing EEA's Objectives

Objective	Navigant's Approach
1. Provide inputs for program planning and long-term conservation goals and targets	Inform the planning and the establishment of long-term conservation targets and goals with potential study output results
2. Develop new energy efficiency and conservation programs and initiatives	Present savings potential by measure to inform the development of new energy efficiency programs and initiatives that capture the most significant savings opportunities available within Alberta
3. Complete flexibility for sensitivities and scenarios, including maximum achievable potential	Develop an unconstrained investment scenario that can be used to estimate maximum achievable potential
4. Develop the tools, methodology, and assumptions to construct the potential study transparent	Provide transparent methodology, assumptions, and inputs at each stage of the project and in the report
5. Identify the most sensitive assumptions and inputs	Focus on the most impactful (in terms of GHG emissions reductions) assumptions and inputs

Source: Navigant

1.5 Caveats and Limitations

There are caveats and limitations associated with the study results. Potential studies are typically a bottom-up effort and an exercise in data management and analysis to balance data abundance and scarcity for different inputs. The study team must understand the data gaps and how to fill these to provide reasonable and realistic potential estimates for the province. The report documents what approach the study team took and the decisions made when appropriate data was not available.

1.5.1 Forecasting Limitations

The Navigant and EEA team relied on publicly-available datasets specific to Alberta.[38] Each of the sector forecasts (residential, commercial, and industrial) contain assumptions, methodologies, and exclusions. The study team leveraged available forecasts as much as possible in the development of the BAU forecast stock and energy demand projections. Navigant developed independent projections in cases where sufficient and detailed information could not be extracted. The study team based these independent projections on secondary data resources produced in collaboration with EEA. Secondary resources and any underlying assumptions are referenced throughout this report.

1.5.2 Segmentation

Navigant obtained available data from publicly-available sources and from its internal databases to segment the three sectors in the study's scope (residential, commercial, and industrial). Some of this data supplemented additional analysis to ensure the team mapped sales and stock data to the appropriate segments (subsectors such as single-family, multifamily, offices, etc.). The segments allow for granularity in measure characterization and program delivery considerations.

1.5.3 Measure Characterization

Energy efficiency potential studies can employ a variety of primary data collection techniques (e.g., customer surveys, onsite equipment saturation studies, and telephone interviews) to enhance the accuracy of results—though not without associated costs and time requirements. The scope of this study did not include primary data collection. Over time, building on the work using Alberta-specific data, the study accuracy will improve.

The study team used many secondary sources to inform the study, specifically the inputs to the DSMSim model. These sources included data from other regional efficiency programs and Canadian utilities, Natural Resources Canada (NRCan), and technical reference manuals (TRMs) from various U.S. regions, such as the U.S. states of Pennsylvania, Illinois, Massachusetts, and the mid-Atlantic U.S. states.

The measure list Navigant and EEA developed for this study focused on technologies likely to have the highest impact on savings potential over the 20-year study horizon. The team gathered input for this list based on known Alberta opportunities and feedback from EEA's first program year. However, there is always the possibility energy use could change in unanticipated ways due to new or emerging technologies. Broader societal changes may arise that could increase savings opportunities over the forecast horizon and may affect energy use levels in ways not anticipated by this study.

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[38] In some cases, EEA and Navigant received additional granularity (i.e., the underlying data used to develop the reported data).

Because of the limited timeframe available to conduct the study, Navigant used measure characterizations from other (non-Alberta) potential studies and made key adjustments to reflect specific conditions in Alberta such as climate, fresh momentum for new technologies like rooftop and community solar, and codes and standards updates. The study team characterized rooftop solar, community solar, combined heat and power (CHP), heat recovery ventilation, networked-connected light-emitting diode (LED) lamps and luminaries, and solar thermal[39] technologies.

1.5.4 Measure Interactive Effects

This study incorporates each energy efficiency measure independently. As a result, the total aggregated energy efficiency potential estimates may be different than the actual potential available to customers for installing multiple measures in a home or business. Multiple measure installations at a single site generate two types of interactive effects: (1) within end-use interactive effects, and (2) cross end-use interactive effects. An example of a within end-use interactive effect is when a customer implements temperature control strategies and a more efficient heating unit. Installing controls on a more inefficient unit will save more energy than one controlling an efficient unit. An example of a cross end-use interactive effect is when a homeowner replaces heat-producing incandescent light bulbs with efficient LEDs. This influences the cooling and heating load of the space by increasing the amount of heat and decreasing the amount of cooling generated by the heating, ventilation, and air conditioning (HVAC) system, which is included in the potential savings analysis.

Navigant employed the following methods to account for measure interactive effects:

- Where measures compete for the same application (e.g., natural gas storage water heater and natural gas tankless water heater), competition groups were created to eliminate the potential double counting of energy savings. The study team chose one measure and eliminated the other measure while calculating the potential for that application. This does not account for real-world applications where a small minority might choose the second-best measure with less potential. Refer to Section 3.1.3 for more detail.
- For measures with significant interactive effects (e.g., HVAC control upgrades and building automation systems), the team adjusted applicability percentages to reflect varying degrees of interaction.
- Wherever cross end-use interactive effects were appreciable (e.g., lighting and HVAC), the team characterized interactive effects for same fuel (e.g., lighting and electric heating) and cross-fuel (e.g., lighting and natural gas heating) applications.

Appendix C discusses the challenges involved with accurately determining interactive effects.

[39] Navigant also characterized block heater timers for this study, but the data on applicability was insufficient to appropriately model for Alberta.

1.5.5 Measure-Level Results

This report includes a high-level account of savings potential across Alberta. Navigant based measure-level results on assumptions reflecting what a typical application may save. The study team aggregated the savings values to the provincial level using assumptions for building or facility suitability, equipment density (number of units per building or facility), and existing energy efficiency saturation levels (percentage of measures already efficient).

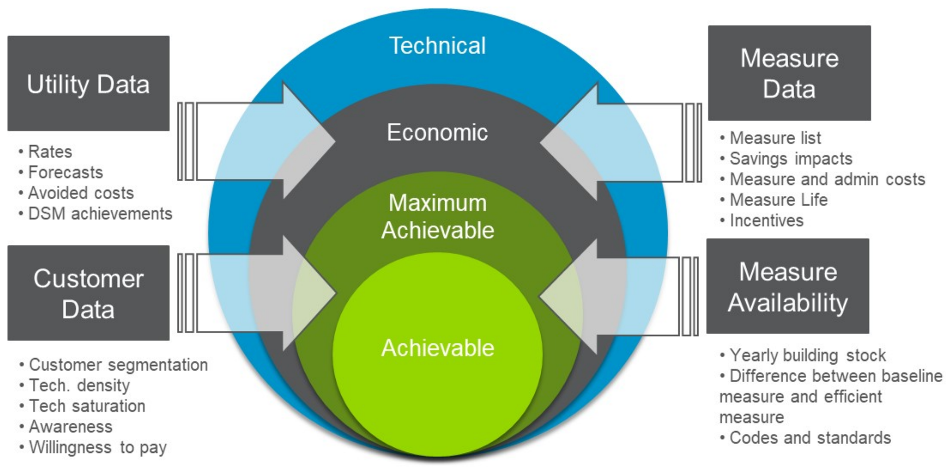
1.5.6 Interpreting Results

The study relies on secondary data sources with adjustments made based on the effect of energy efficiency programming in other provinces. This study provides directional and order of magnitude level of potential impacts that can be used for GHG emissions reductions estimates and energy efficiency program planning.

2. APPROACH AND INPUTS TO ESTIMATE GREENHOUSE GAS EMISSIONS REDUCTION POTENTIAL

Navigant developed forecasts of technical, economic, and achievable electric and natural gas energy savings potential in Alberta using bottom-up modeling. The forecast timeframe covers a 20-year period from 2019 through 2038. The energy efficiency forecasts build on disaggregated estimates of building stock and electric energy sales before conservation, and detailed measure characteristics for a comprehensive list of energy efficiency measures relevant to Alberta. This section details the approach and methodology Navigant used to develop the key inputs to the potential model, as illustrated in Figure 2-1.

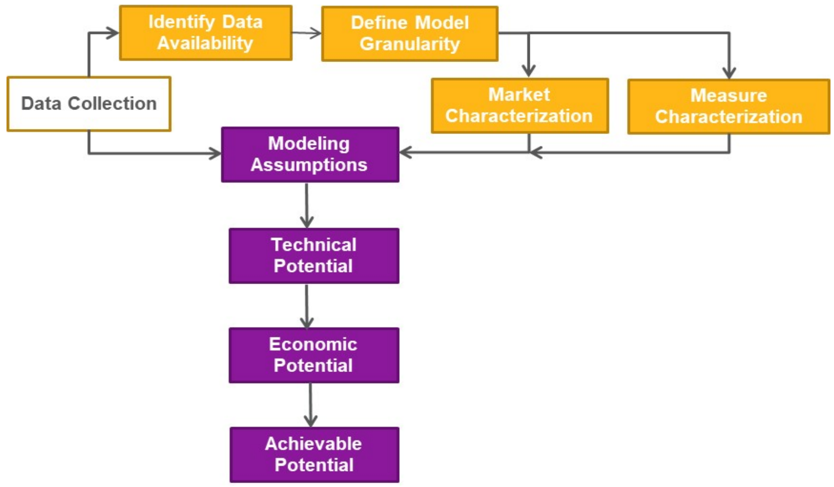
Figure 2-1. Potential Study Inputs



Source: Navigant

Navigant's methodology to calculate achievable potential includes several elements, such as base year calibration, a BAU forecast, and full measure characterizations. The base year calibration and BAU forecast make up the market characterization. Figure 2-2 shows how these elements interact to result in the achievable savings potential. Data collection is critical to define the project dimensionality and data sources. Aggregating the data, selecting the sources, identifying the gaps, and filling in data gaps is critical to define the market segments and measures characterized for the study and described in this section. This approach culminates into the market and measure characterization. These elements and other variables, such as end user billing rates, discount rates, etc. feed into Navigant's modeling assumptions.

Figure 2-2. High Level Overview of Potential Study Methodology

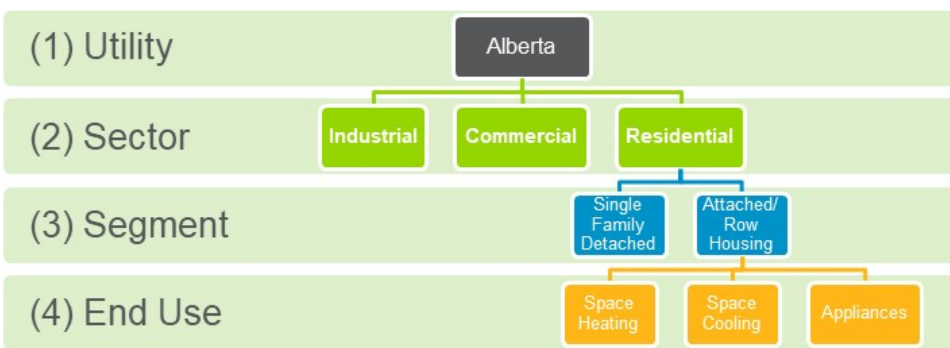


Source: Navigant

2.1 Base Year Profile

This section describes the approach the study team used to develop the base year (2016) profile of electricity and natural gas use in Alberta, a key input to the potential model. The objective of the base year is to create a detailed profile of electricity and natural gas consumption by customer sector, segment, and end use (Figure 2-3). The model uses the base year as the foundation to develop the BAU forecast of electricity and natural gas demand to develop results from 2019 through 2038.[40]

Figure 2-3. Base Year Electricity Profile – Residential Example



Source: Navigant

Navigant developed the base year profile primarily using publicly-available sources. These included NRCan's Comprehensive Energy Use Database (CEUD) and internal Navigant data sources.[41] Table 2-1 lists the main data sources the study team used to develop the sectoral base year profiles.

[40] The project scope for potential analysis is reported for a 20-year period, 2019-2038. The study base year is 2016 as this was the last year with a full year of data available at the start of this study.

[41] The study team's internal data sources include data and expertise Navigant has accumulated through prior potential study engagements in North America.

Table 2-1. 2016 Base Year Profile Sources

Sector	Sources Used
Residential	• Canadian Energy System Simulator (CanESS) Model[42] • NRCan CEUD[43] • Alberta Utilities Commission (AUC) 2016 sector-level residential consumption[44]
Commercial	• CanESS Model • NRCan CEUD • AUC 2016 sector-level commercial consumption[45] • FortisBC Electric Conservation Potential Review (FBC CPR) Report[46]
Industrial	• Canadian Manufacturers & Exporters Report – Improving energy efficiency for Alberta's Industrial and Manufacturing sectors [47] • Alberta Oil Sands Energy Efficiency and GHG Mitigation Roadmap[48] • Energy Return on Investment of Canadian Oil Sands Extraction from 2009 to 2015[49] • Trottier Energy Futures Project: Greenhouse Gas Emissions from the Canadian Oil and Gas Sector[50] • Statistics Canada (StatsCan) CANSIM Table 128-0016[51] • 2017 Canadian Association of Petroleum Producer (CAPP) Crude Oil Forecast, Markets & Transportation[52] • Descriptive Analysis of On-Farm Energy Analysis in Canada[53] • AUC 2016 sector-level industrial consumption, supplemented with direct load and behind-the-fence industrial consumption from AESO[54] • FBC CPR Repo

Source: Navigant

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[42] whatIf? Technologies, CanESS model calibrated. Provided by CESAR (http://www.cesarnet.ca) using the CanESS model (http://www.whatiftechnologies.com/caness).

[43] Natural Resources Canada Comprehensive Energy Use Database, http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive_tables/list.cfm.

[44] Alberta Utilities Commission, "Annual Electricity Data Collection," http://www.auc.ab.ca/market-oversight/Annual-Electricity-Data-Collection/Pages/default.aspx.

[45] Alberta Utilities Commission, "Annual Electricity Data Collection," http://www.auc.ab.ca/market-oversight/Annual-Electricity-Data-Collection/Pages/default.aspx.

[46] FortisBC, *FortisBC Conservation Potential Review*, 2017, https://www.fortisbc.com/About/RegulatoryAffairs/GasUtility/NatGasBCUCSubmissions/Documents/170915_FBC_2016_LTERP_LT_DSM_Plan_Errata_FF.pdf.

[47] Canadian Manufacturers & Exporters, *Improving Energy Efficiency for Alberta's Industrial and Manufacturing Sectors*, Canadian Manufacturers & Exporters, 2010, http://ab.cme-mec.ca/download.php?file=geebgbcx.pdf.

[48] Suncor, "Alberta Oil Sands Energy Efficiency and GHG Mitigation Roadmap," 2012.

[49] Ke Want, *Energy Return on Investment of Canadian Oil Sands Extraction from 2009 to 2015*, 2017, http://www.mdpi.com/1996-1073/10/5/614.

[50] Trottier Energy Futures, *Trottier Energy Futures Project: Greenhouse Gas Emissions from the Canadian Oil and Gas Sector*, 2014.

[51] Statistics Canada, "CANSIM Table 128-0016," 2017, http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=1280016.

[52] CAPP, *2017 CAPP Crude Oil Forecast, Markets & Transportation,* June 2017, http://www.capp.ca/publications-and-statistics/publications/303440.

[53] Canadian Agricultural Energy End Use Data and Analysis Centre, *Descriptive Analysis of On-Farm Energy Analysis in Canada*, 2000, http://www.usask.ca/agriculture/caedac/pubs/Energy.PDF.

[54] AUC data only includes sales data from electric distribution utilities. AESO provided Navigant with the missing industrial direct-load and behind-the-fence consumption, to ensure the total industrial consumption is captured as part of this analysis.

For the residential and commercial sectors, Navigant sourced the electricity and natural gas consumption data from the NRCan CEUD. For the industrial sector, the team sourced electricity and natural gas consumption data from the mix of sources described in Table 2-1**.** Subsequent sections of this report explain how Navigant used each of these sources to develop the base year profile.

2.1.1 Customer Sectors and Segments

The base year calibration required disaggregating the three main sectors into specific customer segments. Customer segmentation is based on several factors, including data availability and level of detail. Table 2-2 lists the segmentation used for the residential, commercial, and industrial sectors. The following subsections provide additional detail for each sector.

Table 2-2. Customer Segments by Sector

Residential (3)	Commercial (10)	Industrial (7)
Single-Family Detached Homes	Office	Conventional Oil & Gas
Attached/Row Housing	Food Retail	Oil Sands (Mining)
Apartments/Condos	Non-Food Retail	Oil Sands (In-situ)
	Hospital	Chemical
	Accommodation	Pulp and Paper
	Restaurant	Other Manufacturing
	School	Farms
	University/College	
	Warehouse/Wholesale	
	Other[55]	

Source: Navigant

[55] The “Other” commercial segment primarily consists of recreational and cultural commercial buildings.

2.1.1.1 Residential Segments

The residential sector was divided into three customer segments, which are described in Table 2-3. The segmentation is consistent with whatIf? Technologies' CanESS model used by CESAR (CESAR model) to take stock of households in Alberta. A mobile/manufactured home segment was considered, but the study team decided these should be included in the single-family detached segment. This is because the segment represents only 5% of Alberta's households (NRCan CEUD).

Table 2-3. Description of Residential Segments

Segment	Description
Single-Family Detached Homes	Detached, duplex, and mobile home residential dwellings.
Attached/Row Housing	Attached, row, and/or townhouse residential dwellings.
Apartments/Condos	Apartment units located in low- or high-rise apartment buildings.

Source: Navigant

2.1.1.2 Commercial Segments

The commercial sector was divided into 10 customer segments, described in Table 2-4. These segments were constructed to represent Alberta's population of commercial customers. Navigant developed this categorization by leveraging the commercial segments used by the NRCan CEUD, the CESAR model, and prior Navigant potential studies. Alberta-specific commercial stock (quantified in floor space area units, m^2) and end-use energy consumption was derived from NRCan CEUD and the CESAR model, and mapped to the Navigant segments. A detailed description of the segment mapping process is described in Appendix A.1.3.

Table 2-4. Description of Commercial Segments

Segment	Description
Office	Administration, clerical services, consulting, professional, or bureaucratic work not including retail sales.
Food Retail	Engaged in retailing general or specialized food and beverage products.
Non-Food Retail	Engaged in retailing services and distribution of merchandise, not including food and beverage products.
Hospital	Diagnostic and medical treatment services such as hospitals, clinics, long-term care facilities.
Accommodation	Short-term accommodation, includes small, medium, and large hotels and motels.
Restaurant	Establishments engaged in preparation of meals, snacks, and beverages for immediate consumption including restaurants, taverns, and bars.
School	Primary and secondary schools (K-12) and miscellaneous educational centres.
University/College	Post-secondary educational facilities, such as colleges, universities, related training centres.
Warehouse/Wholesale	Warehouse/storage facilities for general merchandise, refrigerated goods, and other wholesale distribution.
Other	Establishments not categorized under any other sector including but not limited to recreational, cultural, and other miscellaneous activities.

Source: Navigant

2.1.1.3 Industrial Segments

Alberta's industrial sector in Alberta is its most energy intensive, being mostly oil & gas production and associated businesses. Given the predominance of oil & gas production in Alberta, the study team modelled three segments related to that sector:

- Oil Sands (Mining)
- Oil Sands (In-situ)
- Conventional Oil & Gas

The remaining non-oil & gas industrial sector was divided into four segments, which are described in Table 2-5.

Table 2-5. Description of Industrial Segments

Segment	Description
Conventional Oil & Gas	Operations that explore, operate, or develop oil & gas resources through non-oil sands operations in Alberta. This includes the extraction of conventional oil & gas, tight gas, light oil, and tight oil.
Oil Sands (Mining)	Operations engaged in the production of oil & gas from oil sands through open pit mines. This segment accounts for oil sands upgrading and refining operations pertaining to oil sands (mining) operations.
Oil Sands (In-situ)	Operations engaged in the production of oil & gas from oil sands in-situ technology through cyclic steam simulation or steam-assisted gravity drainage. This segment accounts for oil sands upgrading and refining operations related to oil sands (in-situ) operations.
Chemical	Industrial facilities producing industrial and consumer chemicals including paints, synthetic materials, pesticides, fertilizers, and pharmaceuticals.
Pulp and Paper	Pulp and paper industrial facilities dedicated to the chemical kraft process, the thermomechanical pulp, and associated production of wood products such as lumber, plywood, veneer, boards, panel boards, and pellets.
Other Manufacturing	Industrial facilities engaging in light and heavy manufacturing processes including but not limited to fabricated metal, metal manufacturing (such as iron and steel), machinery, refined petroleum products, and food manufacturing.
Farms[56]	Farming operations engaged in growing crops, raising animals, irrigation, ranches, hatcheries, etc.

Source: Navigant

Several industries were not segmented for several reasons:

- Cement manufacturing was not included because historical electricity and natural gas consumption data is not publicly available. In 2015, cement manufacturing accounted for 0.7% of total industrial GHG emissions in Alberta.[57]

[56] This segment does not include the food packaging and processing industry.

[57] Natural Resources Canada, "Comprehensive Energy Use Database - Alberta," available at: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=agg&juris=ab&rn=2&page=0.

- Similarly, historical electricity and natural gas consumption for the forestry industry was not publicly available. The primary source of GHG emissions for this industry is automotive motor fuels, which is beyond the scope of this study.
- Historical electricity consumption data for the construction industry is not publicly available. The construction industry accounts for about 1% of total industrial GHG emissions in Alberta[58] and less than 1% of the total industrial natural gas consumption of the modelled industrial segments.

2.1.2 End Uses

The next step in the base year analysis was to establish end uses for each customer sector. The study defines end uses as a specific activity or customer need that requires energy—such as space cooling, appliances, and water heating—without specifying the equipment used to satisfy the need.

Table 2-6 shows the list of end uses included for each sector in the study, with definitions provided in Appendix A.1.1. Navigant selected these end uses because they represent categories to report potential savings. Each energy efficiency measure is associated with an end use, and measure savings can be rolled up and reported by category. For example, savings from ENERGY STAR refrigerators and freezers are reported under the appliance's end use.

Table 2-6. End Uses by Sector

Residential (7)	Commercial (9)	Industrial (11)
Space Heating	Space Heating	Compressed Air
Space Cooling	Space Cooling	Fans & Blowers
Water Heating	Water Heating	Industrial Process
Appliances	Cooking	Lighting
Lighting	HVAC Fans/Pumps	Material Transport
Electronics	Lighting	Direct Process Heating
Other	Office Equipment	Indirect Process Heating
	Refrigeration	Process Compressors
	Other	Pumps
		Process Cooling
		Other

Source: Navigant analysis

One category used in reporting savings and not included here is Whole Building. Whole Building is used to report measure savings affecting electricity and natural gas consumption across an entire facility. For example, home energy reports for residential customers is a behavioural measure that can reduce an entire home's electricity or natural gas consumption. In other words, the savings are applicable across all end uses.

[58] Natural Resources Canada, "Comprehensive Energy Use Database - Alberta," available at: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CP&sector=agg&juris=ab&rn=2&page=0.

2.1.3 Base Year Consumption Inputs

This section summarizes electricity and natural gas consumption at the sector level, segment level, and end-use level. The base year consumption estimates are direct inputs to the potential model as illustrated in Table 2-7. Appendix A provides sources and assumptions and a detailed description of the methodology used to develop the estimates.

Figure 2-4, Figure 2-5 and Figure 2-6 show electricity and natural gas consumption by sector and the corresponding GHG emissions. Approximately two-thirds of total electricity consumption is from the industrial sector (67%), with the remainder from the commercial (20%) and residential (13%) sectors.

Most of the natural gas consumption is from the industrial sector (82%), with the commercial (7%) and residential (11%) sectors with much less. GHG emissions by sector follows the same distribution as natural gas consumption by sector, with most emissions coming from the industrial sector (82%).

Table 2-7. 2016 Base Year Electricity and Natural Gas Sector Consumption and GHG Emissions

Sector	Electricity (GWh)	Natural Gas (TJ)	GHG Emissions (million tCO_2e[59])
Residential	9,925	165,115	16.87
Commercial	14,900	102,515	17.71
Non-Oil & Gas Industrial[60]	18,288	184,601	24.30
Oil & Gas Industrial	33,365	998,489	78.96
Total	76,477	1,450,719	137.84

Note: Totals may not sum due to rounding
Source: Navigant analysis

[59] The study team calculated total GHG emissions for 2016 based on an electricity emissions intensity of 0.7576 tCO_2e/MWh and a natural gas emissions intensity of 0.0518 tCO_2e/GJ. More details on these emissions intensities can be found in Appendix B.4.

[60] The non-oil & gas industrial sector captures all industrial segments, excluding the oil sands and conventional oil & gas industrial operations, and is a subset of the all industrial sector.

Figure 2-4. 2016 Base Year Electricity Consumption by Sector, GWh

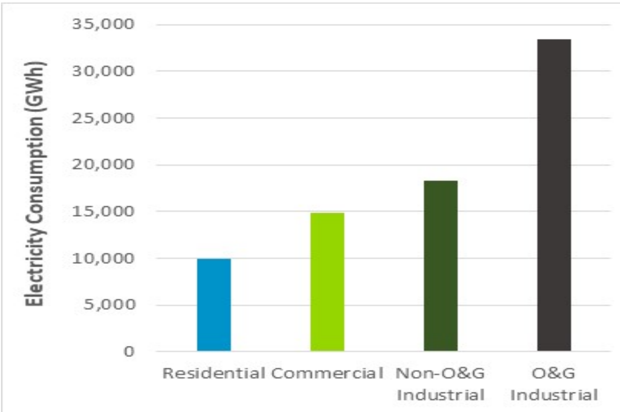
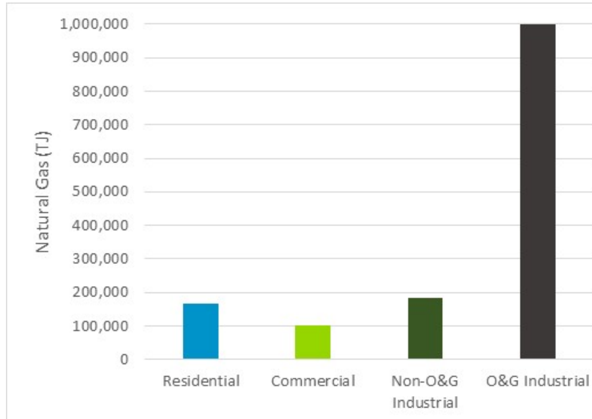
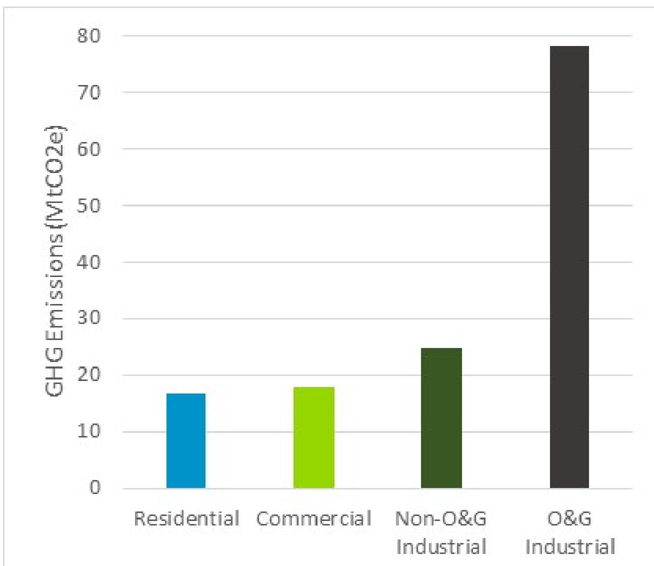


Figure 2-5. 2016 Base Year Natural Gas Consumption by Sector, TJ



Source: Navigant analysis

Figure 2-6. 2016 Base Year GHG Emissions by Sector, $MtCO_2e$



Source: Navigant analysis

2.1.3.2 Residential Sector

Table 2-8 shows base year residential stock (households), electricity and natural gas consumption, and average electricity and natural gas usage per household by residential segment.[61] Alberta-specific base year stock by segment was taken directly from the CESAR model. To ensure that the CESAR model's estimates are representative of Alberta, Navigant compared it to the Alberta Energy Regulator's (AER) marketable natural gas demand values for the base year (2016) and found there is good alignment between the two sources.[62] The base year residential stock is almost 1.7 million households, which accounts for around 10,000 GWh of electricity consumption and 165,000 TJ of natural gas consumption annually.[63]

Table 2-8. 2016 Base Year Residential Consumption by Segment, Electricity, GWh, and Natural Gas

Segment	Stock (Households, HH)	Electricity (GWh)	Electricity (kWh per HH)	Natural Gas (TJ)	Natural Gas (GJ per HH)
Single-Family Detached Homes[64]	1,117,700	7,671	6,863	132,279	118
Attached/Row Housing	217,800	957	4,395	13,316	61
Apartments/Condos	357,561	1,296	3,626	19,520	55
Total or *Average*	1,693,062	9,925	*5,862*	165,115	*98*

Note: Totals may not sum due to rounding.

Source: Navigant analysis

[61] Navigant made the conservative assumption that one residential household equates to one residential customer. Vacant households may result in the total number of residential customers being slightly lower than the total number of residential households. Accounting for vacant households that are not residential customers would have a negligible impact on the results, as these households constitute a very small portion of total residential stock; thus, this has not been considered as part of this analysis.

[62] The AER marketable natural gas demand for 2016 and subsequent years (up till 2027) can be found here: https://www.aer.ca/data-and-publications/statistical-reports/natural-gas-demand

[63] The study team sourced total residential natural gas consumption from the CESAR model and the total residential electricity consumption from AESO; the AESO data is available on the AUC's website: http://www.auc.ab.ca/market-oversight/Annual-Electricity-Data-Collection/Pages/default.aspx.

[64] Includes mobile homes, which make up approximately 5% of total Alberta households according to the NRCan CEUD.

Figure 2-7 and Figure 2-8 show the base year residential electricity consumption by end use and segment, respectively. Appliances, lighting, and space heating are the largest residential end uses and account for about 71% of residential electricity consumption. The single-family detached segment is the largest segment and accounts for 77% of total electricity consumption.

Figure 2-7. 2016 Base Year Residential Electricity Consumption by End Use

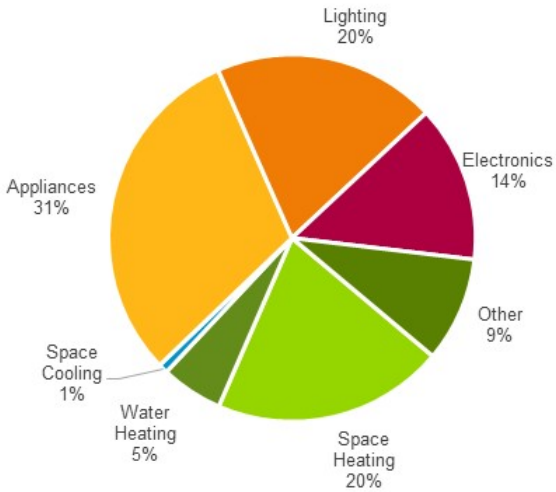
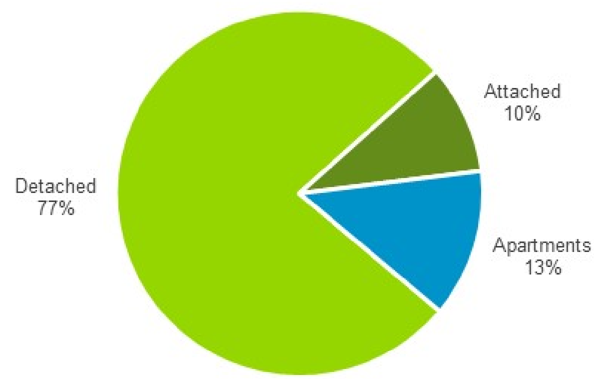


Figure 2-8. 2016 Base Year Residential Electricity Consumption by Segment



Source: Navigant analysis

Figure 2-9 and Figure 2-10 show base year residential natural gas consumption by end use and segment, respectively. Space heating and water heating are the largest residential end uses, accounting for 99% of residential natural gas consumption. Single-family detached is the largest segment, accounting for 80% of natural gas consumption.

Figure 2-9. 2016 Base Year Residential Natural Gas Consumption by End Use

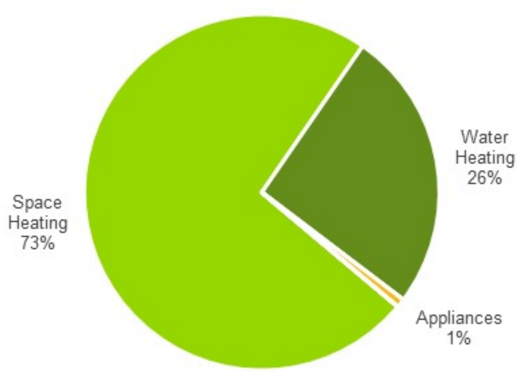
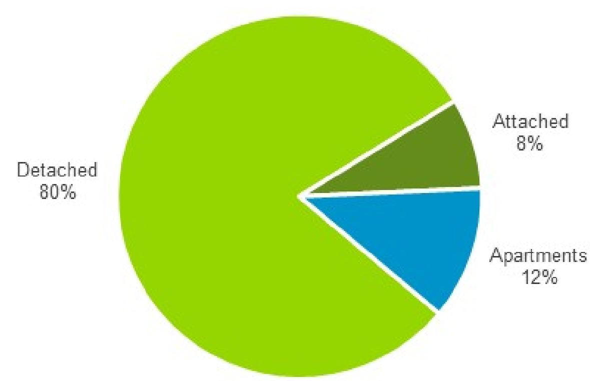


Figure 2-10. 2016 Base Year Residential Natural Gas Consumption by Segment



Source: Navigant analysis

2.1.3.3 Commercial Sector

Table 2-9 shows the base year commercial stock (million m^2 of floor space), electricity and natural gas consumption, and average electricity and natural gas usage per m^2 by commercial segment. Like the residential sector, commercial floor space stock was available through the CESAR model. However, the CESAR model's commercial segments had to be mapped to Navigant's commercial segments. Details on the methodology employed to achieve this are described in Appendix A.1.3. Commercial floor space stock is estimated at approximately 118 million m^2 and contributes approximately 15,000 GWh of electricity and 102,500 TJ of natural gas consumption.[65] To ensure that the CESAR model's estimates are representative of Alberta, Navigant compared it to the AER's marketable natural gas demand values for the base year (2016) and found that there is alignment between the two sources.[66]

Table 2-9. 2016 Base Year Commercial Consumption by Segment

Segment	Stock (million m^2)	Electricity Use (GWh)	Electricity (kWh per m^2)	Natural Gas Use (TJ)	Natural Gas (GJ per m^2)
Warehouse/Wholesale	12.16	1,307	107	10,390	0.85
Hospital	8.88	1,423	160	9,234	1.04
Office	47.66	5,363	113	36,997	0.78
Other	7.52	980	130	6,745	0.90
School	9.93	877	88	7,496	1.26
University/College	6.51	1,124	173	5,195	0.73
Non-Food Retail	16.22	1,717	106	12,558	0.46
Food Retail	2.35	878	373	4,743	2.21
Accommodation	4.73	762	161	4,570	0.97
Restaurant	1.73	469	271	4,586	2.65
Total or *Average*	117.69	14,900	*127*	102,515	*0.87*

Note: Totals may not sum due to rounding.

Source: Navigant analysis

[65] The study team sourced commercial floor space data and total commercial gas consumption from the CESAR model (see Appendix E for more detail) and total commercial electricity consumption from AESO; the AESO data is available on the AUC's website: http://www.auc.ab.ca/market-oversight/Annual-Electricity-Data-Collection/Pages/default.aspx.

[66] The AER marketable natural gas demand for 2016 and subsequent years (up till 2027) can be found here: https://www.aer.ca/data-and-publications/statistical-reports/natural-gas-demand

Figure 2-11 and Figure 2-12 show base year commercial electricity consumption by end use and segment, respectively. Lighting, HVAC (fans/pumps), and other are the largest commercial end uses and account for more than 75% of commercial electricity consumption. Unlike the residential sector, commercial sector consumption is much more evenly distributed across segments, except for offices, which account for 36% of electricity consumption.

Figure 2-11. 2016 Base Year Commercial Electricity Consumption by End Use

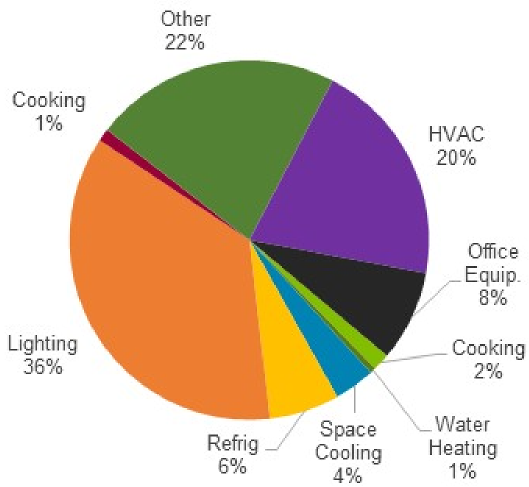
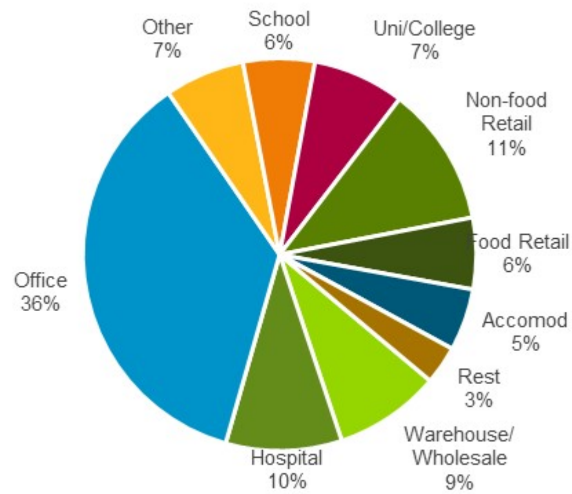


Figure 2-12. 2016 Base Year Commercial Electricity Consumption by Segment



Source: Navigant analysis

Figure 2-13 and Figure 2-14 show base year commercial natural gas consumption by end use and segment, respectively. Space heating accounts for 89% of natural gas consumption, followed by water heating with 10% of total natural gas consumption; space cooling is several orders of magnitude smaller because it is provided by electricity instead of natural gas. Commercial natural gas consumption is evenly distributed across segments, except for offices, which account for 36% of natural gas consumption.

Figure 2-13. 2016 Base Year Commercial Natural Gas End Use

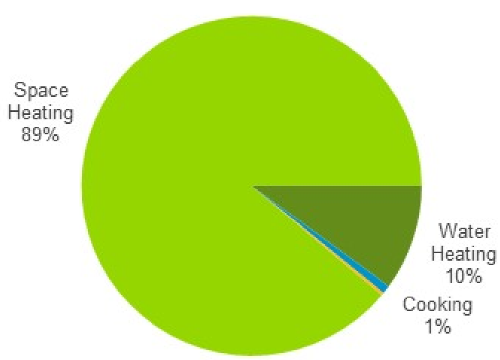
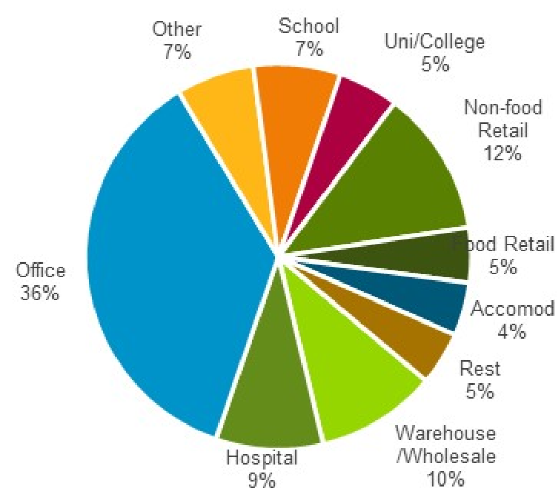


Figure 2-14. 2016 Base Year Commercial Natural Gas by Segment



Source: Navigant analysis

2.1.3.4 Industrial Sector

Table 2-10 shows the base year industrial electricity consumption by segment. Total industrial electricity and natural gas consumption is about 51,700 GWh and 1,180 PJ,[67] respectively.[68]

Table 2-10. 2016 Base Year Industrial Consumption by Segment, GWh and TJ

Segment	Electricity Use (GWh)	Natural Gas Use (TJ)
Conventional Oil & Gas	7,337	221,301
Oil Sands (Mining)	12,318	166,714
Oil Sands (In-situ)	13,710	610,474
Chemical	6,312	112,805
Pulp and Paper	3,615	11,501
Other Manufacturing	5,972	55,884
Farms	2,389	4,411
Total	51,653	1,183,090

Source: Navigant analysis

[67] 1 PJ = 1,000 TJ

[68] Total industrial electricity consumption was provided by the AESO. Industrial electricity consumption (without behind-the-fence or on-site generation) can be found on the AUC's website here: http://www.auc.ab.ca/market-oversight/Annual-Electricity-Data-Collection/Pages/default.aspx; total industrial natural gas consumption was developed using many different sources. See Appendix A.1.4 for more details.

Figure 2-15 and Figure 2-16 show base year electricity consumption by end use and segment, respectively, for all industrial segments. Industrial process (32%) and pumps (19%) are the largest industrial end uses. The oil sands (in-situ and mining) segments are the largest industrial segments, accounting for about 50% of industrial electricity consumption.

Figure 2-15. 2016 Base Year All Industrial Electricity Consumption by End Use

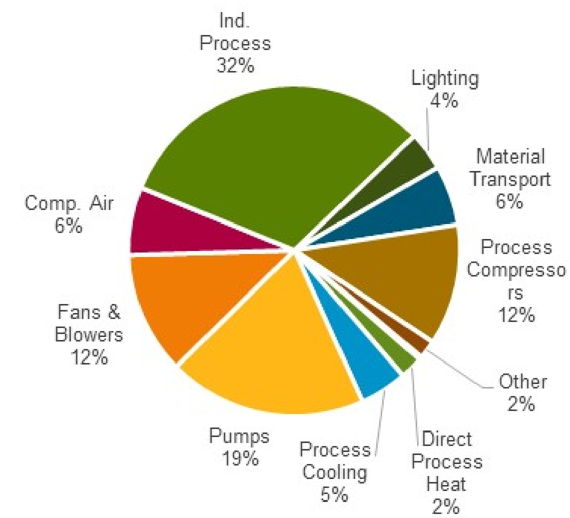
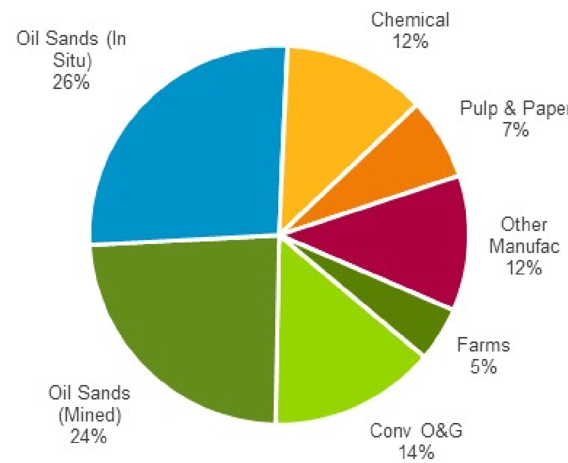


Figure 2-16. 2016 Base Year All Industrial Electricity Consumption by Segment



Source: Navigant analysis

Figure 2-17 and Figure 2-18 show base year natural gas consumption by end use and segment, respectively, for all industrial segments. Indirect process heat (67%) and industrial process (18%) are the largest industrial end uses. The oil sands (in-situ and mining) segments are the largest natural gas-consuming industrial segments, accounting for about 66% of industrial natural gas consumption.

Figure 2-17. 2016 Base Year All Industrial Natural Gas Consumption by End Use

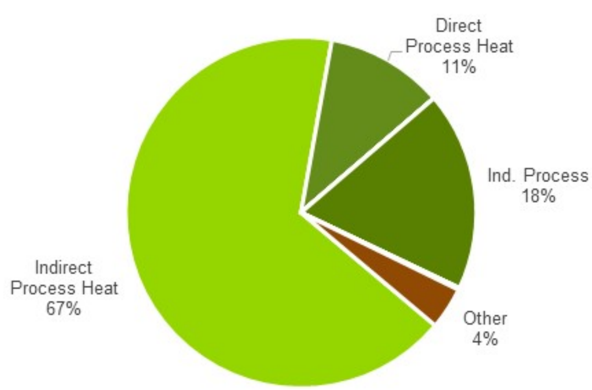
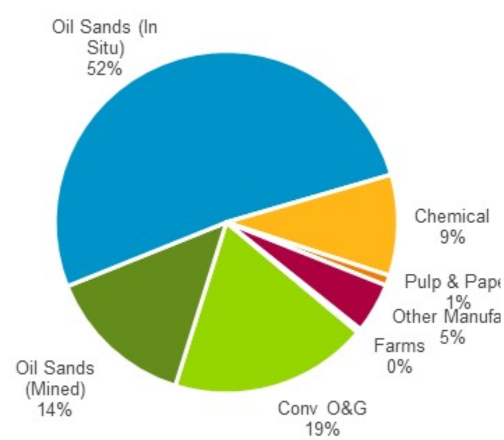


Figure 2-18. 2016 Base Year All Industrial Natural Gas Consumption by Segment



Source: Navigant analysis

Figure 2-19 and Figure 2-20 show base year electricity and natural gas consumption by end use for non-oil & gas industrial segments only. For the non-oil & gas industrial segments, the largest electricity end uses are industrial process (26%) and pumps (18%), similar to the whole industrial sector. On the other hand, the largest natural gas end uses for the non-oil & gas industrial segments are direct process heat (54%) and indirect process heat (35%).

Figure 2-19. 2016 Base Year Non-Oil & Gas Industrial Electricity Consumption by End Use

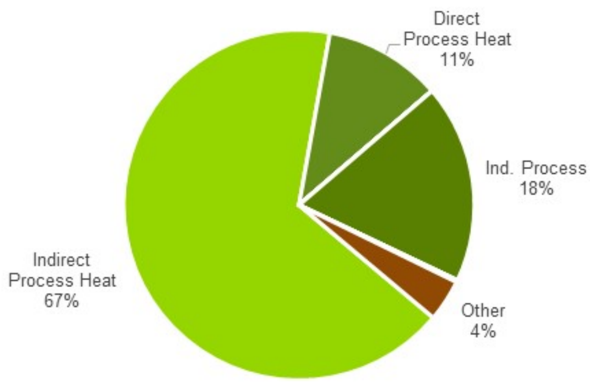
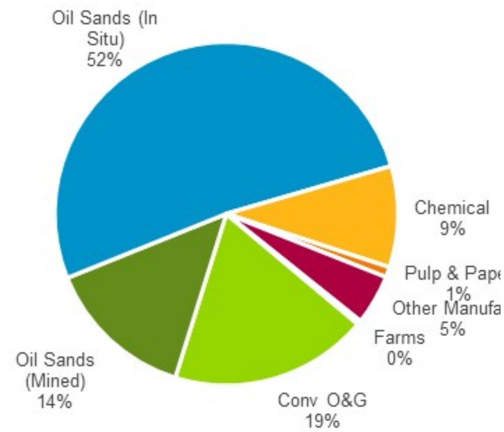


Figure 2-20. 2016 Base Year Non-Oil & Gas Industrial Natural Gas Consumption by End Use



Source: Navigant analysis

2.2 Business-as-Usual Forecast

This section presents the BAU forecast from 2019 to 2038.[69] The BAU forecast represents the expected level of electricity and natural gas consumption over the study period absent incremental DSM activities or load impacts from rates. Navigant calibrated the electricity consumption in the BAU forecast to the modified Alberta Energy System Operator (AESO) 2017 Long-Term Outlook (LTO) load forecast.[70] In this context, calibration means scaling the electricity BAU forecast consumption at the segment level, such that the aggregate sector-level consumption sums to the modified AESO 2017 load forecast. Similarly, the study team calibrated the natural gas consumption in the BAU forecast to the CESAR model's natural gas consumption forecast. [71] The BAU forecast is significant because it acts as the starting point of comparison for the calculation of technical, economic, and achievable market potential scenarios.

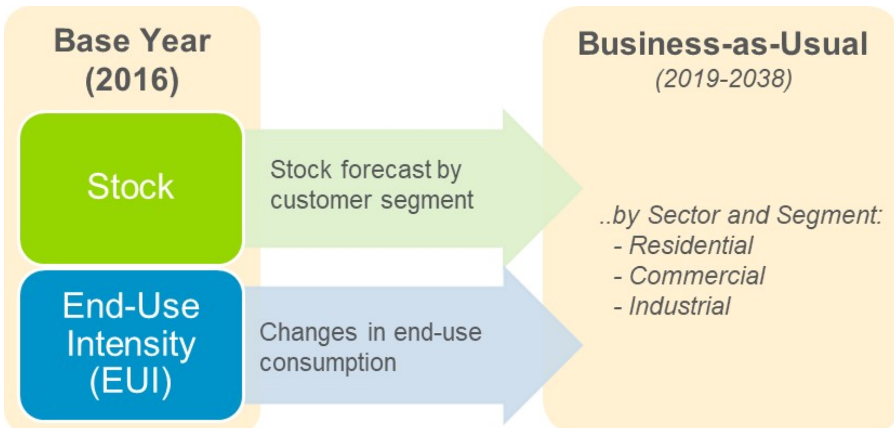
[69] A forecast of 20 years was chosen because it is standard practice and captures the typical lifetime of longer-lived measures. Forecasting beyond 20 years would introduce too much uncertainty into the analysis.

[70] See Appendix E for more details on how Navigant modified the AESO's 2017 LTO load forecast to develop sector-level load forecasts and adjust for embedded assumptions on energy efficiency.

[71] See Appendix A.1.1 for more details on the electricity and natural gas calibration process.

Figure 2-21 illustrates the process Navigant used to develop the BAU forecast. The BAU forecast uses the base year profile as its foundation and applies changes in stock growth and end-use intensity (EUI) over time to develop the residential, commercial, and industrial forecasts. The study team then compared this forecast to the AESO and the CESAR model forecast for electricity and natural gas, respectively.

Figure 2-21. Schematic of BAU Forecast



Source: Navigant

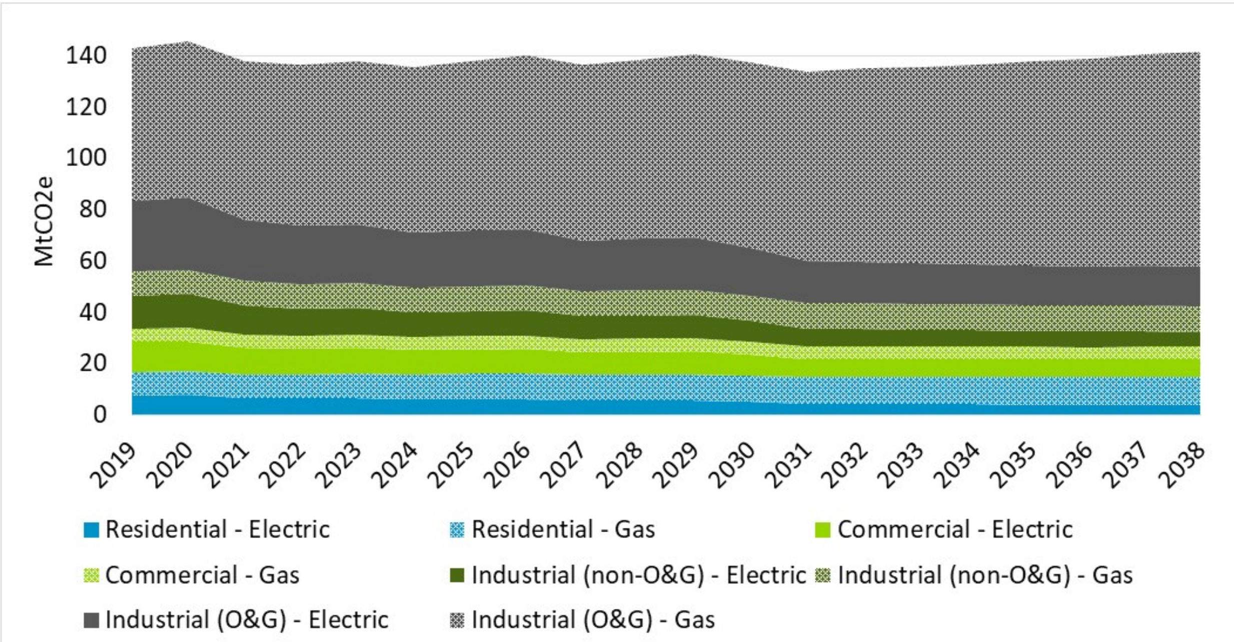
Navigant constructed the BAU forecast using two different approaches, one for the residential and commercial sectors and the second for the industrial sector.

- **Residential and commercial:** For the residential and commercial sectors, Navigant used two inputs: stock growth rates and EUI trends. The study team used the stock growth projections of residential households and commercial floor area provided in the CESAR model and estimated the change in end-use consumption over time.
- **Industrial:** For the industrial sector, Navigant developed the base year industrial profile for each segment/end-use combination by disaggregating segment-level industrial consumption using end-use allocation factors.[72] Subsequently, the industrial BAU forecast was built at the segment-level using Canadian Association of Petroleum Producer's (CAPP's) forecast of oil sands production and the modified AESO 2017 load forecast. Industrial stock is not an input in developing the base year profile or BAU forecast; thus, Navigant did not develop stock forecasts or EUI changes (i.e., end-use consumption per unit of industrial stock) for the industrial sector.

[72] See Appendix A.1.4 for more detail on how the industrial end-use allocation factors were used.

The summary of the BAU forecast is provided in Figure 2-22. The following sections describe the approach and assumptions Navigant used to develop the BAU forecast.

Figure 2-22. Alberta GHG Annual Emissions by Fuel and Sector, $MtCO_2e$, 2019-2038

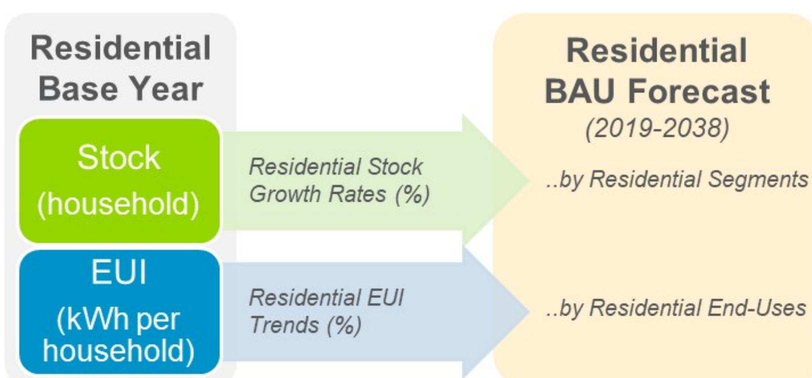


Source: Navigant analysis

2.2.1 Residential BAU forecast

Navigant built the residential BAU forecast by using a forecast of residential stock and EUI trends and applying them to the base year profile. Figure 2-23 illustrates this process.

Figure 2-23. Residential BAU forecast Schematic



Source: Navigant

Navigant used the CESAR model's residential segment-level stock forecast in this study. Table 2-11 shows the growth in residential stock from 2019 to 2038. Residential stocks are projected to increase at a compound annual growth rate (CAGR) of 1.1% from approximately 1.7 million households in 2019 to 2.2 million households by 2038.

Table 2-11. Residential BAU forecast Stock Forecast by Segment, Households

Segment (Households)	2019	2038
Single-Family Detached Homes	1,159,561	1,395,899
Attached/Row Housing	232,798	333,510
Apartments/Condos	370,876	449,354
Total	1,763,236	2,178,763

Note: Totals may not sum due to rounding.

Source: Navigant analysis

After developing the stock forecast, the study team developed the residential EUI trends. To accomplish this, the team used the sector-level residential electric load forecast from AESO and the sector-level residential natural gas load forecast from the CESAR model to develop the EUI trends.[73]

Using AESO's residential electric load forecast, the team calculated a sector-level EUI trend for the load forecast. To do this, Navigant first calculated sector-level EUIs by dividing the total electricity consumption by the total number of households in Alberta for each year. Then, the team calculated a compound annual growth rate (CAGR) to determine the mean annual change in EUIs from 2016 (the base year) to 2038.[74] Navigant applied the CAGR as an EUI trend for each of the electricity end uses. This produced a forecast of EUIs at the segment/end-use level, which the team then applied to the segment-level stock forecast to produce a forecast of electricity consumption at the segment/end-use level. The final step was to calibrate the BAU forecast so it aligned with the AESO residential load forecast. The team completed this by calibrating the EUI trends at the segment/end-use level. Additional details on the BAU forecast calibration methodology can be found in Appendix A.1.4.

To develop residential natural gas EUI trends, Navigant employed the same methodology described above using the CESAR model's natural gas load forecast. As completed for the electricity EUI trends, the study team calibrated the natural gas EUI trends to ensure the BAU forecast aligned with the CESAR model's residential natural gas load forecast.

Table 2-12 shows the resulting EUIs by residential end use. After calibrating the electricity and natural gas EUI trends, the electricity end uses decrease in consumption at a CAGR of -0.05%, while the natural gas end uses decrease in consumption at a CAGR of -0.02%. As the change in EUIs is dependent on the change in the load forecast and in the stock forecast, minimal changes in end-use consumption over time indicate that the load and stock forecasts are changing at approximately the same rate year every year.

[73] The study team developed sector-level electric load forecasts using AESO's 2017 LTO load forecast and several other sources. See Appendix A.1.2 for more detail.

[74] After calculating sector-level EUIs, Navigant found that the year-over-year change in sector-level EUIs varied from year to year. This is expected because sector-level EUIs are dependent on the growth rates of both the sector-level load forecast and the growth in stock, which do not necessarily align. To ensure a smooth calibration of the BAU case to the sector-level load forecast, which is more reflective of how EUIs would change over time, Navigant decided to use the CAGR methodology.

Table 2-12. Residential BAU forecast Energy Use Intensity Forecast by Segment, kWh and GJ per Household

Segment	End Use	Electricity (kWh per Household)		Natural Gas (GJ per Household)	
		2019	2038	2019	2038
Single-Family Detached Homes	Space Heating	1,520	1,505	88.91	88.65
	Space Cooling	66	65	-	-
	Water Heating	350	347	28.34	28.26
	Appliances	1,952	1,933	0.85	0.85
	Lighting	1,492	1,477	-	-
	Electronics	879	870	-	-
	Other	586	580	-	-
	Total	6,845	6,776	118.10	117.76
Attached/Row Housing	Space Heating	586	580	39.80	39.69
	Space Cooling	27	27	-	-
	Water Heating	285	282	20.52	20.46
	Appliances	1,775	1,757	0.68	0.68
	Lighting	734	726	-	-
	Electronics	621	615	-	-
	Other	355	351	-	-
	Total	4,383	4,339	61.01	60.83
Apartments/ Condos	Space Heating	545	539	36.63	36.52
	Space Cooling	8	8	-	-
	Water Heating	242	240	17.23	17.18
	Appliances	1,279	1,266	0.62	0.62
	Lighting	327	323	-	-
	Electronics	704	697	-	-
	Other	512	507	-	-
	Total	3,616	3,579	54.48	54.32
Total		14,844	14,694	233.60	232.91

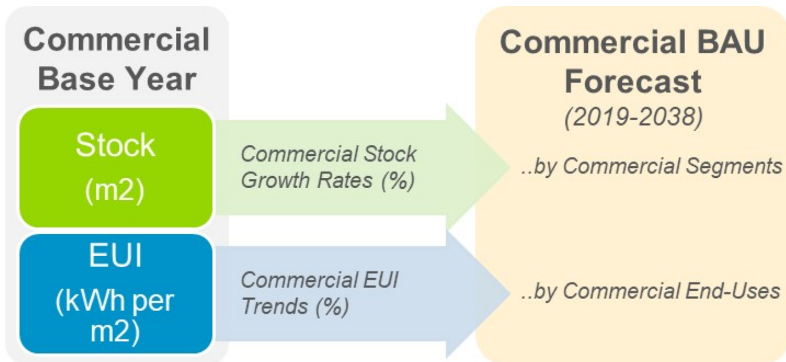
Note: Totals may not sum due to rounding.

Source: Navigant analysis of base year EUIs

2.2.3 Commercial BAU forecast

Navigant built the commercial BAU forecast by using a forecast of commercial stock and EUI trends and applying them to the base year profile. Figure 2-24 illustrates this process.

Figure 2-24. Commercial BAU forecast Schematic



Source: Navigant

Navigant used the CESAR model's commercial stock forecast as the foundational dataset to inform the building stock growth rates in the province. Table 2-13 shows the growth in commercial stock between 2019 and 2038. Total commercial floor space is projected to increase at a CAGR of 1.1% from approximately 121 million m^2 in 2019 to 147 million m^2 by 2038. The fastest growing commercial segment is hospitals (CAGR of 2.3%), followed by schools and university/colleges (CAGR of 1.4% each).

Table 2-13. Commercial BAU forecast Stock (Floor Space) Forecast by Segment, million m^2

Segment (million m^2)	2019	2038
Warehouse/Wholesale	12.08	12.98
Hospital	9.67	14.77
Office	48.16	54.82
Other	7.79	9.51
School	10.34	13.47
University/College	6.77	8.83
Non-Food Retail	16.90	21.42
Food Retail	2.45	3.11
Accommodation	4.93	6.26
Restaurant	1.80	2.29
Total	120.89	147.46

Source: Navigant analysis

Typically, Navigant develops commercial EUI trends by analyzing trends in commercial fuel shares and equipment shares from province-wide end-use survey data.[75] In absence of sufficient information[76], the team leveraged the sector-level commercial electric load forecast from AESO and the sector-level commercial natural gas load forecast from the CESAR model to develop the EUI trends.[77]

Navigant developed electricity and natural gas EUI trends using the same approach it used to develop residential EUI trends, as described in Section 2.2.1. The study team calculated a CAGR for 2016-2038 using sector-level EUIs from AESO's commercial load forecast and the commercial natural gas forecast in the CESAR model. Navigant found the commercial electricity EUI trend produced by this approach was not appropriate for the commercial lighting end use. While it is possible to see commercial electricity EUIs increase in magnitude over time for the non-lighting end uses (driven by commercial electricity demand growing more quickly than commercial floor space), Navigant is confident that the commercial lighting EUI will decrease over time. This is primarily due to the increasing levels of LED penetration that are taking place in markets across North America. Thus, the team applied a more appropriate lighting EUI trend of -1.0% each year, indicating that the lighting EUI decreases in magnitude by 1.0% each year over the study period. The study team developed the lighting EUI trend based on Navigant's experience conducting potential studies in other jurisdictions in Canada.

Navigant then applied the EUI trends to the electricity and natural gas end uses, respectively, and calibrated to ensure each fuel type's BAU forecast aligned with its respective sector-level load forecast. The study team calibrated the commercial BAU forecast in the same fashion as the residential BAU forecast, described in Appendix A.1.3. Table 2-14 shows the resulting EUIs by commercial end use. The CAGR rates used are shown in Table A-19.

Table 2-14. Commercial BAU forecast Energy Use Intensity Forecast by Segment, Electricity, kWh/m^2 and Natural Gas, GJ/m^2

Segment	End Use	Electricity (kWh/m^2)		Natural Gas (GJ/m^2)	
		2019	2038	2019	2038
Warehouse/ Wholesale	Space Heating	2.1	2.7	0.753	0.556
	Space Cooling	3.9	5.2	0.002	0.002
	Water Heating	0.5	0.6	0.058	0.043
	Cooking	0.5	0.6	0.004	0.003
	HVAC Fans/Pumps	26.9	35.6	-	-
	Lighting	45.6	37.7	-	-
	Office Equipment	1.7	2.3	-	-
	Refrigeration	7.4	9.8	-	-
	Other	18.9	25.0	-	-

[75] Fuel shares refer to the percentage of floor space within a segment that use a fuel type for an end use (e.g., the percentage of office floor space that uses natural gas for space heating). Equipment shares refer to the percentage of floor space within a segment that uses a specific type of equipment for an end use (e.g., the percentage of office floor space that uses low efficiency natural gas boilers for space heating).

[76] Navigant reviewed NRCan's CEUD but did not find sufficient fuel share and equipment share information for Alberta to develop EUI trends for all end uses considered within this study.

[77] The study team developed sector-level electric load forecasts using AESO's 2017 LTO load forecast and several other sources. See Appendix A.1.1 for more detail.

Segment	End Use	Electricity (kWh/m²)		Natural Gas (GJ/m²)	
		2019	2038	2019	2038
	Total	107.4	119.5	0.816	0.604
Hospital	Space Heating	2.4	3.9	0.840	0.621
	Space Cooling	7.9	10.4	0.006	0.006
	Water Heating	1.1	1.6	0.139	0.103
	Cooking	3.2	4.3	0.008	0.006
	HVAC Fans/Pumps	32.1	42.5	-	-
	Lighting	54.2	44.8	-	-
	Office Equipment	3.5	4.6	-	-
	Refrigeration	2.5	3.3	-	-
	Other	53.9	71.4	-	-
	Total	160.8	186.8	0.993	0.736
Office	Space Heating	1.8	2.8	0.663	0.490
	Space Cooling	4.0	5.3	0.003	0.003
	Water Heating	0.6	0.8	0.070	0.052
	Cooking	0.9	1.2	0.006	0.004
	HVAC Fans/Pumps	22.8	30.2	-	-
	Lighting	38.6	31.9	-	-
	Office Equipment	16.8	22.3	-	-
	Refrigeration	0.7	1.0	-	-
	Other	26.8	35.4	-	-
	Total	112.9	130.9	0.741	0.549
Other	Space Heating	2.0	3.3	0.765	0.566
	Space Cooling	5.3	7.0	0.004	0.004
	Water Heating	0.7	0.9	0.081	0.060
	Cooking	0.8	1.1	0.007	0.005
	HVAC Fans/Pumps	26.3	34.9	-	-
	Lighting	44.6	36.8	-	-
	Office Equipment	1.5	2.0	-	-
	Refrigeration	28.9	38.3	-	-
	Other	20.7	27.4	-	-
	Total	130.8	151.7	0.857	0.634
School	Space Heating	1.5	2.4	0.657	0.485
	Space Cooling	2.5	3.3	-	-
	Water Heating	0.2	0.3	0.061	0.045
	Cooking	1.2	1.6	0.004	0.003
	HVAC Fans/Pumps	13.3	17.6	-	-
	Lighting	29.0	23.9	-	-

Segment	End Use	Electricity (kWh/m²)		Natural Gas (GJ/m²)	
		2019	2038	2019	2038
	Office Equipment	4.5	6.0	-	-
	Refrigeration	0.1	0.2	-	-
	Other	36.5	48.3	-	-
	Total	88.7	103.6	0.721	0.533
University/ College	Space Heating	2.6	3.9	0.654	0.483
	Space Cooling	5.0	6.6	-	-
	Water Heating	1.3	1.8	0.100	0.074
	Cooking	3.0	4.0	0.009	0.006
	HVAC Fans/Pumps	42.5	56.2	-	-
	Lighting	62.1	51.3	-	-
	Office Equipment	28.2	37.4	-	-
	Refrigeration	2.8	3.7	-	-
	Other	25.8	34.1	-	-
	Total	173.2	199.1	0.762	0.563
Non-Food Retail	Space Heating	2.3	3.6	0.682	0.504
	Space Cooling	5.0	6.6	-	-
	Water Heating	0.5	0.7	0.054	0.040
	Cooking	0.4	0.5	0.003	0.002
	HVAC Fans/Pumps	25.2	33.4	-	-
	Lighting	44.3	36.6	-	-
	Office Equipment	2.2	2.9	-	-
	Refrigeration	0.9	1.1	-	-
	Other	25.1	33.3	-	-
	Total	105.8	118.7	0.739	0.546
Food Retail	Space Heating	1.2	2.7	1.580	1.168
	Space Cooling	4.1	5.4	-	-
	Water Heating	2.0	2.8	0.312	0.231
	Cooking	1.6	2.1	0.035	0.026
	HVAC Fans/Pumps	50.2	66.4	-	-
	Lighting	73.9	61.0	-	-
	Office Equipment	0.1	0.1	-	-
	Refrigeration	217.1	287.6	-	-
	Other	27.6	36.6	-	-
	Total	377.7	464.9	1.928	1.424
Accommodation	Space Heating	3.1	4.7	0.809	0.598
	Space Cooling	5.6	7.5	-	-
	Water Heating	0.7	1.0	0.110	0.081
	Cooking	2.4	3.1	0.004	0.003

Segment	End Use	Electricity (kWh/m²)		Natural Gas (GJ/m²)	
		2019	2038	2019	2038
	HVAC Fans/Pumps	38.0	50.3	-	-
	Lighting	63.5	52.4	-	-
	Office Equipment	23.1	30.6	-	-
	Refrigeration	4.2	5.5	-	-
	Other	20.7	27.4	-	-
	Total	161.2	182.5	0.923	0.682
Restaurant	Space Heating	3.0	5.5	2.113	1.562
	Space Cooling	20.4	27.0	-	-
	Water Heating	3.4	4.8	0.349	0.258
	Cooking	21.0	27.8	0.069	0.051
	HVAC Fans/Pumps	45.9	60.7	-	-
	Lighting	79.5	65.6	-	-
	Office Equipment	1.8	2.5	-	-
	Refrigeration	18.8	25.0	-	-
	Other	78.9	104.5	-	-
	Total	272.6	323.4	2.532	1.871

Note: Totals may not sum due to rounding. *Source: Navigant analysis*

2.2.4 Industrial BAU forecast

Navigant developed the industrial BAU forecast using the 2017 oil sands production forecast from CAPP and the modified AESO industrial load forecast.[78] Because the industrial sector is characterized differently than the other sectors (its energy consumption is typically not correlated to building size), Navigant did not calculate industrial stock or EUI trends.

Navigant followed the below steps to develop the industrial electricity and natural gas BAU forecast:

1. Calculate the growth rate in oil sands (mining) and oil sands (in-situ) production using the 2017 CAPP oil sands forecast.[79]
2. Apply the production growth rate of each oil sands segment to the oil sands base year segment-level electricity and natural gas consumption.[80] This produces a forecast of electricity and natural gas consumption for each of the oil sands segments over the analysis period.

[78] CAPP, "2017 CAPP Crude Oil Forecast, Markets & Transportation," https://www.capp.ca/publications-and-statistics/publications/303440.

[79] As the CAPP forecast is only available till 2030, Navigant extrapolated the forecast till 2038. The team used the average annual growth rate from 2026 to 2030 to estimate oil sands production from 2031 to 2038.

[80] See Appendix A.1.4 for more detail on how the study team calculated the base year (2016) electricity and natural gas consumption of oil sands segments.

3. Calculate the difference between the AESO's industrial sector-level load forecast and the forecast consumption of both oil sands segments to estimate the segment-level electricity consumption of the remaining industrial segments.
4. Calculate the growth rate of the non-oil sands industrial load forecast and apply this growth rate to the base year electricity consumption for the remaining industrial segments (chemical, pulp and paper, other manufacturing, conventional oil & gas, farms).
5. Apply the growth rate in step 4 to the base year natural gas consumption of the non-oil sands industrial segments to build the natural gas BAU forecast for the non-oil sands segments. This assumes industrial natural gas and electricity consumption for the non-oil sands segments grow at the same rate.

Table 2-15 summarizes the industrial electricity and natural gas BAU forecast. Industrial electricity consumption is forecast to grow by 25% from just over 55,000 GWh in 2019 to about 69,000 GWh in 2038. Industrial natural gas consumption shows higher percentage growth than electricity consumption, increasing by 36% from 1,300 PJ in 2019 to about 1,800 PJ in 2038. Both oil sands segments, especially oil sands (in-situ), are projected to show the greatest increase in consumption over the forecast period relative to other industrial segments.

Table 2-15. Industrial BAU forecast by Segment, Electricity, GWh and Natural Gas, TJ

Segment	Electric (GWh)		Natural Gas (TJ)	
	2019	2038	2019	2038
Conventional Oil & Gas	7,132	7,702	215,132	232,327
Oil Sands (Mining)	13,914	16,415	188,317	222,159
Oil Sands (In-situ)	16,498	25,807	734,630	1,149,107
Chemical	6,136	6,626	109,660	118,425
Pulp and Paper	3,515	3,796	11,180	12,074
Other Manufacturing	5,806	6,270	54,326	58,669
Farms	2,322	2,508	4,288	4,631
Total	**55,323**	**69,123**	**1,317,534**	**1,797,392**

Note: Totals may not sum due to rounding.
Source: Navigant analysis

2.3 Measure Characterization

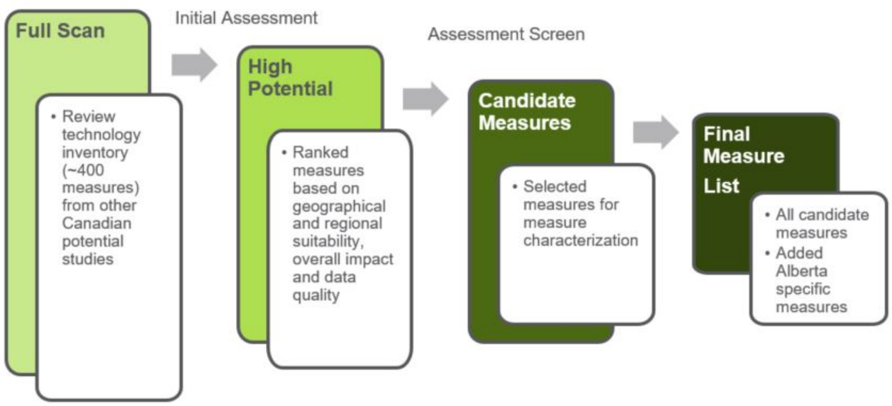
Navigant characterized 184 measures across Alberta's residential, commercial, and industrial sectors. The study team used existing measure characterizations from recently completed Navigant potential studies in other provinces and supplemented the measure list with input from the EEA team. The team adjusted the previously characterized measures for Alberta-specific factors, such as cooling degree days, heating degree days, equivalent full load hours, and end-use consumptions and intensities. Navigant also adjusted the resulting high impact measures with good data availability that are most likely to be cost-effective for inclusion into the DSMSim potential model.

2.3.1 Measure List

The study team reviewed other provinces in Canada to identify the energy efficiency, fuel switching, and generation measures with the highest expected economic impact. From this review, the team developed a comprehensive list of the energy efficiency measures likely to contribute to achievable market potential. Navigant worked with EEA to finalize the measure list and ensure it contained applicable industrial measures and technologies viable for future EEA program planning activities.

Figure 2-25 shows the process implemented to refine the measure list.

Figure 2-25. Measure Screening Process



Source: Navigant

Several measures from other Canadian potential studies were included in the initial and assessment screens that were ultimately not included in the final study.

- **Whole Building/Home New Construction Measures:** Navigant excluded new construction measures, such as whole buildings or home new construction, from the study. All measures part of a New Construction Home or Commercial Building are characterized as the NEW replacement type and account for new construction stock. To avoid double counting potential, Navigant characterized new construction measures individual as the NEW replacement type only, and whole building new construction measures were considered the aggregate of these new construction measures. It should be noted this approach may underestimate the overall savings potential for new construction from efforts resulting in aggressive energy efficiency building design and equipment, such as zero net energy homes.
- **Lighting Measures:** These measures include compact fluorescent lamps (CFLs) and T8/T5 lamps. The market has moved away from these measures with the advent of LED lamps and tubes. Therefore, Navigant excluded CFLs and T8/T5 tubes from the study. LED street lighting was also excluded as these retrofits are already underway in Alberta.
- **Industrial Measures:** Navigant conducted significant research to finalize the industrial measure list given the unique characteristics of industrialization in Alberta. The study team assigned relevant measures to the oil sands and oil & gas segments, a classification unique to this potential study.

The team excluded a few measures typically found in other potential studies to avoid double counting savings potential. For example, the improved fan systems measure replaced two separate measures, premium fan and fan energy management.

- **Other Measures:** The study team excluded several measures, including HVAC control upgrades and make-up air units, to avoid overlap with building automation controls and rooftop units (RTUs). The team also excluded measures such as synchronous belts, heat reflectors, and server virtualization due to the lack of data availability and quality for characterizing these measures for Alberta. Navigant excluded ENERGY STAR TVs, LED displays, and desktops because the strong market adoption of these technologies does not require any additional interventions.
- **Fuel Switching Measures:** Navigant included measures that switch fuel use from natural gas to electricity, such as water and spacing heating measures. The study team excluded measures that switch fuel use from natural gas to electric resistance, or wood to electric resistance from the study scope due to negligible use of electric resistance in Alberta and because this would result in increased GHG emissions. Because natural gas is relatively low cost in the province and electricity production is a relatively high carbon emitter, Navigant conducted analysis that concluded these measures are currently neither cost-effective nor net-positive in GHG reductions. The team excluded fuel switching measures, such as gas storage water heater to CO_2 heat pump water heater or water-to-water heat pump, and RTU or boiler to all electric heat pump, because these measures have negligible penetration in Alberta.

2.3.1.1 Key Parameters

The measure characterization consisted of defining approximately 50 individual parameters for each of the 184 measures included in this study. This section defines the key parameters for province-wide potential savings estimates.

1. **Measure Definition:** Navigant used the following variables to qualitatively define each characterized measure:
    - ***Replacement Type*:** Replacing the baseline technology with the efficient technology can occur in three variations (note any adjustments to baselines due to code changes are reflected globally to all applicable measures):
        i. **Retrofit (RET):** The model considers the baseline to be the existing equipment and uses the energy and demand savings between the existing equipment and the installed technology during technical potential calculations. RET applies the full installed cost of the efficient equipment during the economic screening. RET measures, commonly referred to as advancement or early retirement measures, are replacements of existing equipment before the equipment fails.

        ii. **Replace-on-Burnout (ROB):** The model considers the baseline to be the code-compliant technology option and uses the energy and demand savings between the current code (or efficiency standard) option and the efficient technology during technical potential calculations. ROB applies the incremental cost between the efficient and code-compliant equipment during the economic screening. Any potential salvage value remaining is not included in the incremental cost calculation because it is assumed the inefficient equipment is removed from service permanently.[81]

iii. **New Construction (NEW):** The model considers the baseline to be the least-cost, code-compliant option. It uses the energy and demand savings between the specific, current code option and the efficient technology during technical potential calculations. NEW applies the incremental cost between the efficient and code-compliant equipment during the economic screening.

- ***Baseline Definition*:** Describes the baseline technology.
- ***Energy Efficiency Definition*:** Describes the efficient technology used to replace the baseline technology.
- ***Unit Basis*:** The normalizing unit for energy, demand, cost, and density estimates.

Navigant developed measure definitions, including baseline and efficient definitions, and replacement types for other Canadian potential studies. The team revised these for Alberta-specific applications as appropriate.

2. **Sector and End-Use Mapping:** The team mapped each measure to the appropriate end uses, customer segments, and sectors across Alberta. Section 2.1.1 describes the customer segments within each sector.

3. **Annual Energy Consumption:** The annual energy consumption in electricity (kWh) and natural gas (MJ) for each base and energy efficient technology. Sources included:

- NRCan
- StatsCan
- Weather data from the Government of Canada
- US Department of Energy (DOE)
- Northwest (US) Power and Conservation Council's Regional Technical Forum (RTF)
- ENERGY STAR Standards
- TRMs from Illinois, Pennsylvania, Minnesota, and Massachusetts
- Michigan Measures Energy Database (MEMD)
- British Columbia, Nova Scotia, and Ontario study data
- US Industrial Assessment Center database
- Oil sands report[82]
- Pacific Northwest National Laboratory data

4. **Fuel Type Applicability Multipliers:** Applies an adjustment to the total equipment stock to account for the proportion applicable to a given measure's fuel type. For example, a measure replacing a baseline efficiency electric resistance water heater with a more efficient unit is only applicable to existing electric resistance water heaters. Navigant used this multiplier to restrict the existing water heater equipment stock to only those that use electricity. These multipliers were developed using NRCan's CEUD. Table 2-16 provides the fuel share splits.

[81] It is considered best practice for energy efficiency programs to require the permanent removal of any replaced equipment from operation.

[82] A Greenhouse Gas Reduction Roadmap for Oil Sands Prepared for CCEMC May 2012, SunCor Energy JACOBS Consultancy.

Table 2-16. Fuel Shares for Domestic Hot Water (DHW) and Space Heating by Segment

Segment	DHW Electric Only	DHW Natural Gas Only	Space Heating Electric Only	Space Heating Natural Gas Only
Single-Family Detached Homes	7%	90%	7%	90%
Attached/Row Housing	7%	90%	5%	93%
Apartments/Condos	7%	90%	5%	93%
Accommodation	3%	97%	1%	99%
Non-food Retail	2%	98%	0%	100%
Office	3%	97%	1%	99%
Other	3%	97%	1%	99%
Restaurant	2%	98%	1%	99%
School	3%	97%	1%	99%
University/College	1%	99%	1%	99%
Warehouse/Wholesale	4%	96%	1%	99%
Food Retail	3%	97%	1%	99%
Hospital	3%	97%	1%	99%

Source: Navigant analysis, NRCAN CEUD

5. **Measure Lifetime:** The lifetime in years for the base and energy efficient technologies. The base and energy efficient measure lifetimes only differ in instances where the two cases represent inherently different technologies, such as LEDs compared to a baseline incandescent bulb. Measure lifetime is sourced from various TRMs (including the U.S. states of Illinois, Pennsylvania, Minnesota, Michigan and Massachusetts), U.S. Northwest Regional Technical Forum (RTF), NRCan, U.S. DOE, and other Navigant potential studies.

6. **Incremental Costs:** The incremental cost between the assumed baseline and efficient technology using the following variables:

    - ***Base Costs:*** The cost of the base equipment, including both material and labor costs.
    - ***Energy Efficient Costs*****:** The cost of the energy efficient equipment, including both material and labor costs.

    Navigant relied on secondary research and other publicly available cost data such as NRCan data, TRMs (including Illinois, Pennsylvania, Minnesota, Michigan, and Massachusetts), U.S. DOE data, ENERGY STAR website, Canadian retail websites such as Home Depot Canada, California Database of Energy Efficiency Resources data, ex ante measure cost studies, and previous Navigant potential studies.

    The study team also used cost multipliers to capture the decreasing cost of solar PV technology over the years. Navigant examined the U.S. Energy Information Administration's 2017 Annual Energy Outlook to inform these multipliers.

7. **Saturation:** The study defines saturation as the penetration of the baseline and efficient technologies across the service territory.

    - ***Base Initial Saturation:*** The initial saturation of the baseline equipment for a given customer segment as defined by the fraction of the end-use stock that has the baseline equipment installed.

- ***Energy Efficiency Initial Saturation*:** The initial saturation of the efficient equipment for a given customer segment as defined by the fraction of the end-use stock that has the efficient measure installed.
  1. **Residential:** Saturations are on a per-home basis.
  2. **Commercial:** Saturations are per 1,000 m^2 of building space.
  3. **Industrial:** Saturations are based on energy consumption.

8. **Measure Density:** Used to characterize the occurrence or count of a baseline or energy efficient measure within a residential household or within 1,000 m^2 of a commercial building. Density has the same unit as saturation of a measure, as detailed in the saturation bullet above.
   - ***Total Maximum Density:*** The total number of both the baseline and efficient units for a given technology.

   Navigant developed both density and saturation values based on a variety of data sources. Most of these sources were not Alberta-specific because data was unavailable. The study team used the following as sources for determining these values: NRCan data, ENERGY STAR shipment reports, Canadian Jurisdiction density and saturation data, U.S. Manufacturing Energy Consumption Survey, Northwest Energy Efficiency Alliance (NEEA) Residential Building Stock Assessment and NEEA Commercial Building Stock Assessment, Navigant potential studies, and engineering assumptions.
9. **Technology Applicability:** The percentage of the base technology that can be reasonably and practically be replaced with the specified efficient technology. For instance, occupancy sensors are only practical for certain interior lighting fixtures (an applicability of less than 1.0), while all existing incandescent exit signs can be replaced with efficient LED signs (an applicability of 1.0).
10. **Competition Group:** The team combined efficient measures competing for the same baseline technology density into a single competition group to avoid double counting of savings. Section 3.1.2 provides further explanation on competition groups.

2.3.2 Approaches and Sources

This section provides the approaches and sources for the main measure characterization variables.

2.3.2.1 Energy Savings

Navigant employed three bottom-up approaches to analyze residential and commercial measure energy savings:

1. **Publicly-available sources:** Unit energy savings calculations, wherever possible, leveraged public data.
2. **Standard algorithms:** Navigant used standard algorithms for unit energy savings calculations for most measures. To supplement this, the team also used NRCan data, U.S. DOE Appliance Standards and Rulemakings supporting documents, U.S. Northwest RTF measure workbooks, and TRMs.
3. **Engineering analysis:** The study team used engineering algorithms to calculate energy savings for any measures not included in available TRMs, and internal expertise and experience with potential studies to calculate the energy savings.

2.3.2.2 Peak Demand Savings

Grid operators manage electric load for the province and regional level by sizing supply needs to meet the electricity demand (MW) load. Therefore, it is important to quantify the potential impacts energy efficiency may have on the peak demand. Peak demand is typically defined to be coincident with the system peak. Appendix D.1 defines the province's winter and summer peak periods.

This section describes the calculation methodology for the winter and summer electricity peak demand in kilowatt-hours (kWh) for each technology. To calculate peak demand, it is important to define the peak period and then quantify the potential load during this peak period.

Navigant developed 8,760[83] hourly load shapes for peak electricity demand savings. The study team developed load shapes for each segment and end use. Navigant mapped measures to appropriate load shape. Appendix D.2 provides a description of the development of the hourly end-use load shapes by segment.[84] Appendix D.4 provides a description of how the team calculated peak demand savings. The Methodology for Peak Savings workbook includes the calculations of the peak load shape factors (PLSFs) used for this study.

For this study, the peak period hours are:[85]

- **Winter:** Hours ending 17-21 on weekdays in December-January
- **Summer:** Hours ending 14-18 on weekdays in June-August

Prescriptive vs. Custom Peak Demand Savings Calculation

For the potential study analysis, all measures use the PLSF analysis approach for defining peak demand savings. This approach is for planning and forecasting use. However, it is recognized some measures, such as variable speed drives and occupancy sensors, alter the end-use load shape. Because the study team developed load shapes based on a prototypical building and its operation, these are assumed to be a good approximation of the existing load shape and are deemed applicable to these subsets of measures. In practice, it is highly recommended to use a customized calculation for the peak demand savings of some of the measures, especially the custom (industrial) measures. The customized peak demand savings calculations should either be based on impact load shapes, which could be derived by modeling measures within the standard building prototypes, or via industry standard protocols for measurement and verification.[86]

2.3.2.3 Building Stock and Densities

Navigant developed building stock estimates for the residential sector in terms of residential household counts and for the commercial sector in terms of commercial floor space. The approach the team used to develop the base year and BAU forecast building stock assumptions is described in Section 3.

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[83] There are 8,760 hours per year (52 weeks per year, 7 days per week, and 24 hours per day).

[84] For the industrial sector, the load shapes are characterized for lighting and non-lighting only based on the limited data availability.

[85] Navigant reviewed and reconciled these defined periods alongside AESO-established periods.

[86] http://www.pjm.com/-/media/documents/manuals/m18b.ashx is the PJM Manual 18b: Energy Efficiency Measurement & Verification 2016. The document provides industry accepted guidelines on calculating the peak demand reduction value of the energy efficiency resource.

2.3.2.4 Industrial Measures

The study team defined a high-level approach for industrial sector measure characterization, which differs from the residential and commercial sectors. Navigant characterized industrial measures as a percentage reduction of the customer segment and end-use consumption. These descriptions help frame the analysis for the potential study, as the Alberta industrial load is significant relative to the residential and commercial sectors.

2.3.2.5 Fuel Switching

The study looked at fuel switching as an opportunity to reduce GHG emissions in the province. The study limited its analysis to gas-to-electricity because Alberta's baseline penetration of natural gas water and space heating is very high (see Table 2-16), and because this type of fuel switching can provide emissions benefits over their lifetime. To consider gas-to-electricity opportunities, the makeup of the electric grid needs to be where the emissions intensity is sufficiently low that switching from natural gas to electricity results in reduced GHG emissions. This is expected to occur in future years.

Navigant added measures that replace a natural gas space or water heating measure in the commercial or residential sectors to calculate the fuel switching potential capable of reducing GHG emissions in Alberta. The team focused on space heating and water heating end uses, as natural gas consumption within these end uses composes greater than 90% of the total natural gas consumption within the residential and commercial sectors (see Figure 2-9 and Figure 2-13).

These measures have the same source for savings and costs as the corresponding energy efficiency natural gas or electric space and/or water heating measures. Navigant took the densities and saturation values for these measures from other Canadian potential studies. Although fuel switching measures compete among themselves for potential, these do not compete with the relevant energy efficiency measures. For example, an electric storage water heater and a heat pump water heater will compete to replace a base natural gas storage water heater, but these measures will not compete with a more efficient natural gas storage water heater, to minimize potential influence of the energy efficiency potential calculating by fuel type.

2.3.2.6 Alberta-Specific Measures

Navigant, with EEA's assistance, characterized the following measures.

- Block heater timers[87]
- Solar water heater
- Solar rooftop PV
- Community solar
- CHP
- District energy systems (not modelled within DSMSim)

[87] Eventually, block heater timers were removed from the study since EEA and Navigant did not find reliable sources of data to properly characterize the effectiveness of this measure in Alberta.

2.3.3 Codes and Standards Adjustments

NRCan publishes all federal energy efficiency regulations. Amendment 15[88] states its intent is to "align with energy efficiency standards in force or expected to be in force in the US." The US DOE Technical Support Documents (TSD)[89] contain information on energy and cost impacts for each appliance standard. Engineering analysis is available in Chapter 5 of the TSD, energy use analysis in Chapter 7, and cost impact in Chapter 8.

As codes and standards take effect, the energy savings from existing measures impacted by the relevant codes and/or standards decline. This change affects the overall potential of the measure beyond the year the code and/or standard goes into effect. Navigant accounts for the effect of codes and standards through baseline energy and cost multipliers (sourced from the DOE's analysis), which reduce the baseline equipment consumption starting from the year a code or standard takes effect. The baseline cost of an efficient measure affected by codes and standards will often increase upon implementation of the code. For example, Navigant incorporated the 2020 incandescent/halogen lighting provision in this study, which results in the baseline for general service lighting changing from an incandescent/halogen to a CFL-level wattage in 2020. Accordingly, the model accounts for a reduction in energy consumption and an increase in cost in 2020 for the baseline technology through the codes and standards multipliers. Navigant also incorporated the cost decline for refrigerators and freezers as outlined in the NRCan rulemaking. As such, computed measure-level potential is net of these adjustments from codes and standards implemented after the first year of the study.

2.3.4 Measure Quality Control

Navigant fully vetted and characterized each measure in terms of energy savings, costs, and applicability. The study team then screened the measures to readily integrate them with the DSMSim model. The characterization includes the following:

- Measure descriptions and baseline assumptions
- Energy savings and cost associated with the measure
- Cost of conserved energy, including operations and maintenance costs
- Lifetime of the measure: effective useful life (EUL) and remaining useful life (RUL)
- Applicability factors, including initial energy efficient market penetration and technical suitability
- Measure end use
- Replacement type of measure

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[88] Natural Resources Canada, *Amendment 15 to the Energy Efficiency Regulations*, http://www.nrcan.gc.ca/energy/regulations-codes-standards/19384.

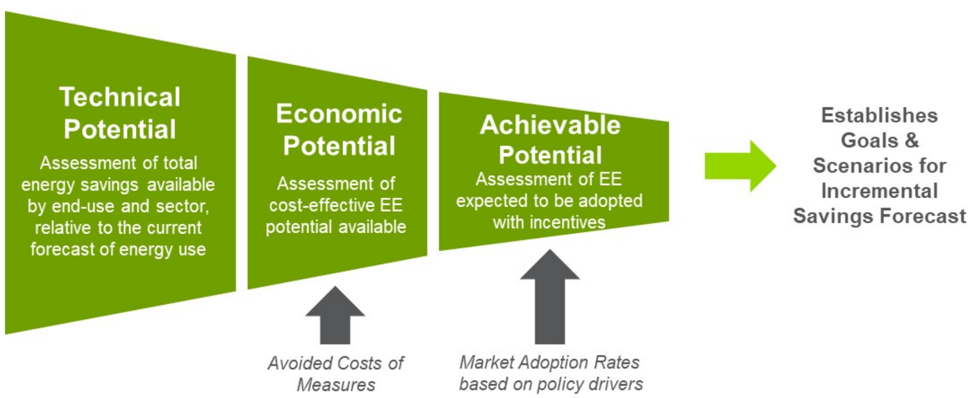
[89] Appliance standards rulemaking notices and TSD can be found at: http://energy.gov/eere/buildings/current-rulemakings-and-notices.

2.4 Overall Potential Methodology

Navigant employed its proprietary DSMSim™ potential model to estimate the technical, economic, and achievable savings potential for electric energy, electricity demand, and natural gas across Alberta. DSMSim is a bottom-up technology diffusion and stock tracking model implemented using a System Dynamics framework.[90] The DSMSim model explicitly accounts for different types of efficient measures—such as RET, ROB, and NEW—and the effects these measures have on savings potential. The model reports the technical, economic, and achievable potential savings in aggregate for the service territory, sector, customer segment, end-use category, and highest impact measures.

This study defines **technical potential** as the total energy savings available assuming all installed measures can immediately be replaced with the efficient measure/technology—wherever technically feasible—regardless of the cost, market acceptance, or whether a measure has failed and must be replaced. **Economic potential** is a subset of technical potential, using the same assumptions regarding immediate replacement as in technical potential but including only those measures passing the benefit-cost test chosen for measure screening—in this case, the total resource cost (TRC) test. There are some exceptions for measures that pass the emissions test (EMT) regardless of the TRC result. Finally, the **achievable potential** is analyzed based on the measure adoption ramp rates and the diffusion of technology through the market. Figure 2-26 provides an overview of the methodology.

Figure 2-26. Potential Calculation Methodology



Source: Navigant

Savings reported in the study are gross rather than net. Providing gross potential is advantageous because it permits a reviewer to more easily calculate net potential when new information about net-to-gross (NTG) ratios are available.[91] Once the potential results and scenarios are analyzed, the output can be used to define the portfolio and program energy savings goals, level of investment, and forecast. The potential study does not dictate (or limit) the measures and projects included in EEA's portfolio of services.

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[90] John D. Sterman, *Business Dynamics: Systems Thinking and Modeling for a Complex World,* Irwin McGraw-Hill, 2000, for detail on System Dynamics modeling. See http://en.wikipedia.org/wiki/System_dynamics for a high-level overview.

[91] The NTG is a measure of program participation free ridership and spillover. Gross savings are claimed savings. Net savings equals the gross savings x NTG, where NTG = 1 - % of free ridership + % spillover savings.

The project scope for potential analysis is reported for a 20-year period, 2019-2038. The study base year is 2016. 2017 and 2018 data were not yet available for use in the study, which necessitated forecasting data to the study period start year (2019). In Alberta, the fiscal year starts April 1. The study analysis period is independent of calendar start date since a full year of analysis is necessary for reporting annual potential.

3. TECHNICAL POTENTIAL FORECAST

This section describes Navigant's approach to calculating technical potential and presents the results for Alberta.

3.1 Approach to Estimating Technical Potential

This study defines technical potential as the total energy savings available assuming all installed measures can immediately be replaced with the efficient measure/technology—wherever technically feasible—regardless of the cost, market acceptance, or whether a measure has failed and must be replaced.

Navigant used DSMSim, its bottom-up technology diffusion and stock tracking model implemented using a System Dynamics framework,[92] to estimate the technical potential for Alberta. Navigant's modeling approach considers an energy efficient measure to be any change made to a building, piece of equipment, process, or behaviour that can save energy.[93]

Savings can be defined in numerous ways depending on which method is most appropriate for a given measure.

1. **Per-Unit:** Measures like efficient water heaters are best characterized as some fixed amount of savings per water heater.
2. **Intensity:** Measures like commercial automated building controls are typically characterized as a percentage of customer segment consumption or per m^2.
3. **Per-Consumption:** Measures like industrial ventilation heat recovery are characterized as a percentage of end-use consumption.

The model can appropriately handle savings characterizations for all three methods.

In this study, the calculation of technical potential differs depending on the assumed measure replacement type. Technical potential is calculated on a per-measure basis and includes estimates of savings per unit, measure density (e.g., quantity of measures per household), and total building stock in each service territory. The study accounts for three replacement types, where potential from RET and ROB measures are calculated differently from potential for NEW measures. The formulae used to calculate technical potential by replacement type are shown in the following sections.

3.1.1 Retrofit and Replace-on-Burnout Measures

RET measures, commonly referred to as advancement or early retirement measures, are replacements of existing equipment before the equipment fails. RET measures can also be efficient processes not currently in place and not required for operational purposes. RET measures incur the full cost of implementation, rather than incremental costs to some other baseline technology or process, because the

[92] John D. Sterman, *Business Dynamics: Systems Thinking and Modeling for a Complex World*, Irwin McGraw-Hill, 2000, for detail on System Dynamics modeling. See http://en.wikipedia.org/wiki/System_dynamics for a high-level overview.

[93] This study does not examine the impact of end-user electricity rates on consumption nor energy efficiency's impact on electricity rates.

customer could choose not to replace the measure and therefore incur no costs, as the decision to do so is discretionary.

In contrast, ROB measures, sometimes referred to as lost opportunity measures, are replacements of existing equipment that has failed and must be replaced or are existing processes that must be renewed. Because the failure of the existing measure requires a capital investment by the participant, the cost of implementing ROB measures is always incremental to the cost of a baseline (and less efficient) measure. The installation or labor for an ROB measure usually is not valued given the participant would have had to install the replacement equipment anyway.

RET and ROB measures have a different meaning for technical potential compared with new construction measures. In any given year, the model uses the existing building stock to calculate technical potential.[94] This method does not limit the calculated technical potential to a pre-assumed rate of adoption of RET measures. Existing building stock is reduced each year by the quantity of demolished building stock in that year and does not include new building stock that is added throughout the simulation. For RET and ROB measures, annual potential is equal to total potential, thus offering an instantaneous view of technical potential. The study team used Equation 3-1 to calculate technical potential for RET and ROB measures.

Equation 3-1. Retrofit and Replace-on-Burnout Measures, Technical Savings Potential

$$Total\ Potential = Existing\ Stock\ x\ Measure\ Density\ x\ Savings\ x\ Technical\ Suitability$$

Where:

- *Total Potential:* kWh or MJ
- *Existing Stock:*[95] Commercial floor space per year, residential households per year, or customer segment consumption per year
- *Measure Density:* Widgets per unit of stock, where widgets are defined as units of measure, such as a refrigerator or square meters of insulation
- *Savings:* kWh or MJ per widget per year
- *Technical Suitability:* Ratio between 0 and 1 to represent the percentage of situations the measure is technically suitable for the application

[94] In some cases, the team used customer-segment-level and end-use-level consumption as proxies for building stock. These consumption figures are treated like building stock and subject to demolition rates and stock tracking dynamics.

[95] Units for building stock and measure densities may vary by measure and customer segment (e.g., 1,000 m^2 of building space, number of residential households, customer-segment consumption/sales, etc.).

3.1.2 New Construction Measures

The cost to implement new construction measures is incremental to the cost of a baseline (and less efficient) measure. However, NEW technical potential is driven by equipment installations in new building stock rather than by equipment in existing building stock.[96] New building stock is added to keep up with forecast growth in total building stock and to replace existing stock that is demolished each year. Demolished (sometimes called replacement) stock is calculated as a percentage of existing stock in each year, and this study uses a demolition rate of 0.5% per year for residential and commercial stock, and 0% for industrial stock. New building stock (the sum of growth in building stock and replacement of demolished stock) determines the incremental annual addition to technical potential, which is then added to totals from previous years to calculate the total potential in any given year. Navigant used Equation 3-2 to calculate technical potential for new construction measures.

Equation 3-2. New Measures Technical Potential

$$AITP = New\ Stock\ x\ Measure\ Density\ x\ Savings\ x\ Technical\ Suitability$$

Where:

- *Annual Incremental NEW Technical Potential (AITP):* kWh or MJ
- *New Stock:*[97] Commercial floor space per year, residential households per year, or customer segment consumption per year
- *Measure Density:* Widgets per unit of stock
- *Savings:* kWh or MJ per widget per year
- *Technical Suitability:* Ratio between 0 and 1 to represent the percentage of situations the measure is technically suitable for the application

3.1.3 Competition Groups

Navigant's modeling approach recognizes some efficient technologies will compete against each other in the calculation of potential. The study defines competition as an efficient measure competing for the same installation as another efficient measure. For instance, a consumer has the choice to install a CFL or LED lamp, but not both. These efficient technologies compete for the same installation.

General characteristics of competing technologies Navigant used to define competition groups in this study include:

- Competing efficient technologies share the same baseline technology characteristics, including baseline technology densities, costs, and consumption
- The total (baseline plus efficient) measure densities of competing efficient technologies are the same

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[96] In some cases, customer-segment-level and end-use-level consumption are used as proxies for building stock. These consumption figures are treated like building stock in that these are subject to demolition rates and stock-tracking dynamics.

[97] Units for new building stock and measure densities may vary by measure and customer segment (e.g., 1,000 m^2 of building space, number of residential households, customer-segment consumption, etc.).

- Installation of competing technologies is mutually exclusive (i.e., installing one precludes installation of the others for that application)
- Competing technologies share the same replacement type (RET, ROB, or NEW)

To address the overlapping nature of measures within a competition group, the model analysis only selects one measure per competition group to include in the summation of technical potential across measures (e.g., at the end use, customer segment, sector, service territory, or total level). The study team uses the measure with the largest energy savings potential in each competition group to calculate the total technical potential for that competition group. This approach ensures the aggregated technical potential does not double count savings. However, the model still calculates the technical potential for each individual measure outside of the summations to communicate a per-measure technical potential.

4. ECONOMIC POTENTIAL FORECAST

This section describes the economic savings potential, which is potential that meets a prescribed level of cost-effectiveness. The section begins by explaining the approach to calculating economic potential and then presents the economic potential results.

4.1 Approach to Estimating Economic Potential

Economic potential is a subset of technical potential, using the same assumptions regarding immediate replacement as in technical potential but including only those measures passing the benefit-cost test chosen for measure screening. The current program framework for Alberta is based on GHG emissions reductions; it is not driven by utility-run programs and an integrated resource plan. Navigant ensured the proposed cost test and discount rates it used to determine cost-effectiveness reflect this goal.

For the economic potential analysis, Navigant used a dual test approach: the TRC test and the EMT. Because both tests have significance—one under the National Standard Practice Manual (NSPM) and other utility/regulatory practices (TRC) and the other to address EEA's objective to cost-effectively lower GHG emissions (EMT)—this approach allows Navigant to evaluate these concepts side by side for EEA.

In this case, Navigant used a modified TRC test as the chosen benefit-cost test for measure screening. The TRC test modifications included using a societal discount rate (rather than a weighted average cost of capital), and not including program administrative costs because the economic potential analysis identifies measures cost-effective on the margin and prior to program interventions.[98] The study team also considered results from the EMT test when selecting measures for economic potential, which calculates net costs per lifetime emissions abated. Navigant included measures with a GHG emissions reduction benefit less than or equal to a \$30 per tCO_2e threshold even if these did not pass the TRC threshold. If a measure's ratio met or exceeded the TRC threshold, or was lower than the EMT threshold, it was included in the economic potential. It should be noted that the analysis revealed there were no measures that passed the EMT and failed the TRC.

The modified TRC test is a benefit-cost metric that measures the net benefits of energy efficiency measures from the combined stakeholder viewpoint of the program administrator and program participants. Navigant calculated the TRC benefit-cost ratio in the model using Equation 4-1.

Equation 4-1. TRC Test Benefit-Cost Ratio for Economic Screening

$$TRC = \frac{PV(Avoided\ Costs + Externalties)}{PV(Technology\ Cost)}$$

Where:

- *PV( )* is the present value calculation that discounts cost streams over time. Typically, the discount rate from the perspective of society is included here.

[98] Navigant used a benefit-cost ratio of 1.0 as the primary cost-effectiveness test for measures in the study. A small number of measures with a benefit-cost ratio between 0.85 and 1.0 were also included because it is common for these measures to be included in programming to ensure program offerings reflect a well-rounded portfolio of measures attractive to participants while maintaining a portfolio benefit-cost ratio above 1.0.

- *Avoided Costs* are the monetary benefits resulting from electric energy and capacity savings, (e.g., avoided costs of infrastructure investments and avoided fuel (commodity costs) due to electric energy conserved by efficient measures).
- *Externalities* are the monetary or quantifiable benefits associated to GHG emissions reductions (i.e., the market cost of carbon). Navigant multiplied only the natural gas savings by the market cost of carbon.
- *Technology Cost* is the incremental equipment cost to the customer to purchase and install a measure.

Navigant calculated the TRC ratios for each measure based on the present value of benefits and costs (as defined above) over the lifetime of each measure. The study team did not include the effects of free ridership and spillover in the potential study results as these often cancel each other out. These effects may be considered as part of program design, and as further research is undertaken to determine their levels in Alberta.

Program administrator costs will be included when reporting sector-specific or portfolio-wide cost-effectiveness. However, the team did not include these at the measure level for economic potential screening. For that screening, it is important to identify cost-effective measures on the margin prior to assessing impacts for the achievable potential, where program administrator costs are considered depending on the amount and level of programmatic spend.

Navigant calculated the abatement cost ($/t$CO_2$e) using the measure cost divided by tonnes of emissions avoided by the measure over the measure's lifetime. The team calculated the cost for GHG abatement in the potential model using Equation 4-2.

Equation 4-2. Emissions Test

$$EMT\ [\$/tCO2e] = \frac{PV(Technology\ Costs - Avoided\ Costs)}{Lifetime\ Emissions\ Reductions}$$

Where:

- *PV( )* is the present value calculation that discounts cost streams over time.
- *Technology Cost* is the incremental equipment cost to the customer.
- *Avoided Costs* are the monetary benefits resulting from electric energy and capacity savings, (e.g., avoided costs of infrastructure investments and avoided fuel (commodity costs) due to electric energy conserved by efficient measures).
- *Lifetime Emissions Reductions* are the sum of the annual emissions reductions over the life of the installed measure.

Navigant calculates the $/$tCO_2$e for each measure based on the present value of benefits and costs (as defined above) over each measure's lifetime. As with the TRC test, program administrator costs are only included at the sector and portfolio level for reasons previously described. Table 4-1 summarizes the economic screening tests. Details of the source and value of each cost test parameter are provided in Appendix B.6.

Table 4-1. Screening Costs Tests

Indicator Type	Screening	
Cost test	EMT ($/$tCO_2$e)	TRC
Carbon price	Market rate*	Market rate*
Discount rate	Societal discount rate	
Uses	Assessing performance against EEA's mandate (GHG emissions reduction)	Assessing performance against total investment

*Market rate as defined by government plans
Source: Navigant

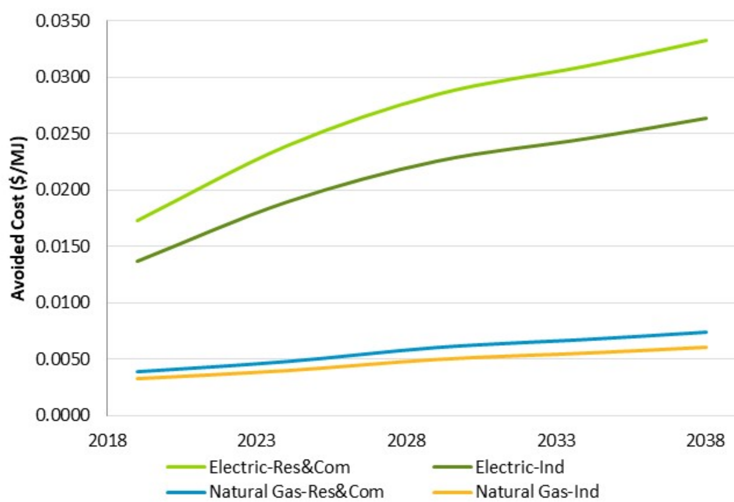
Similar to technical potential, the study team only included one economic measure from each competition group in the summation of economic potential across measures (e.g., at the end-use category, customer segment, sector, service territory, or total level). If a competition group is composed of more than one measure passing the TRC or EMT test, then the team included the economic measure providing the greatest electricity savings potential in the summation of economic potential. This approach ensures double counting is not present in the reported economic potential, though economic potential for each individual measure is still calculated and reported outside of the summation.

4.3 Fuel Switching Economic Potential

In this study, Navigant found there is currently no fuel switching economic potential. That is, the fuel switching measures do not pass the TRC or EMT cost-effectiveness tests. This result is driven by two key factors:

- **Avoided costs:** For fuel switching measures, the study team treated electricity avoided costs as a cost within the cost-effectiveness calculations since natural gas-to-electricity fuel switching results in an increase in electricity purchased from the grid.[99] The team treated natural gas avoided costs as a benefit since fuel switching decreases natural gas consumption. For Alberta, electricity avoided costs are higher than natural gas avoided costs, as shown in Figure 4-1.

Figure 4-1. Alberta Electric and Natural Gas Avoided Cost Comparison



Source: Navigant analysis

- **Cost and performance of heat pumps[100]:** Air source and ground source heat pumps are currently more expensive (per unit thermal output) than the natural gas counterparts they are replacing (boilers, furnaces, or RTUs). Furthermore, Alberta's cold climate results in a coefficient of performance (COP) for a heat pump which is lower when compared to a region with a more temperate climate.

[99] See Section 4.1 for the cost-effectiveness equations used within this study.

[100] This factor pertains to most (but not all) fuel switching measures—it does not pertain to the fuel switching measures where an electric storage water heater replaces a natural gas storage water heater.

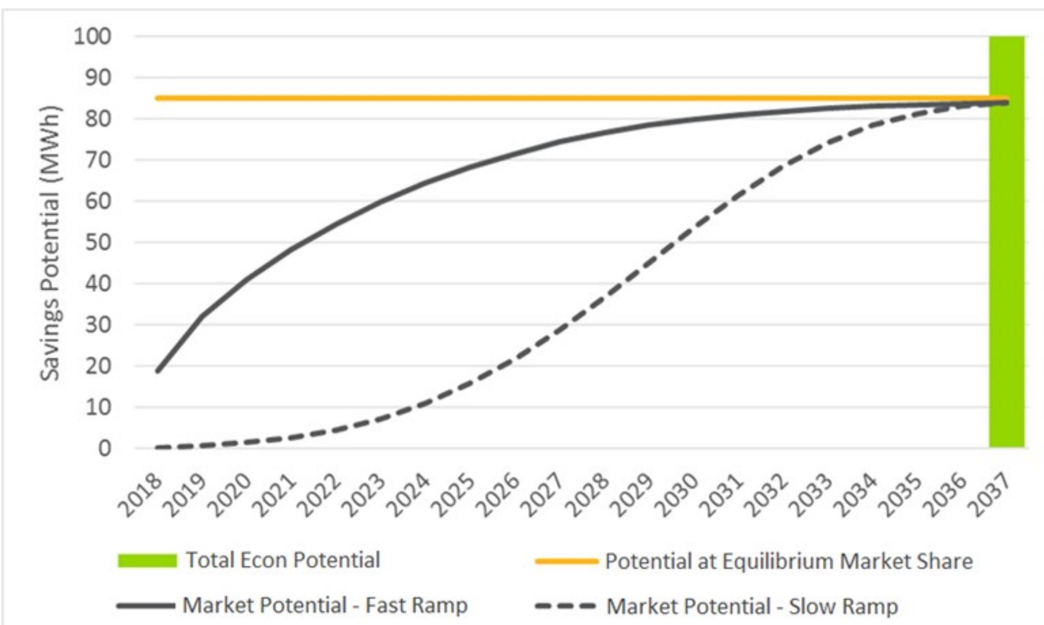
5. ACHIEVABLE POTENTIAL FORECAST

The achievable potential is the subset of economic potential considered achievable based on assumptions about the realistic market adoption of a given measure and is the product of technical potential with two measure-specific factors: (1) the calculated equilibrium market share of each measure, and (2) a time-dependent factor reflecting barriers to market adoption. Adoption barriers include consideration of likely implementation strategies, available market delivery channels, potential for adoption by building code or appliance standards, and experience of local program staff with similar measures, among other factors. Appendix F details the calculation and calibration methodology for this study.

Navigant modelled the effects of time-dependent barriers to market adoption by applying ramp rates to the maximum achievable potential. These ramp rates spread each measure's maximum achievable potential over the study horizon, accounting for assumptions about the timing of when the potential will be realized.

Figure 5-1 illustrates the relationship between total economic potential, maximum achievable potential, and final computed achievable potential in each year of the study as a function of ramp rate choice. The timing of achievable potential across the study horizon is driven by the choice of ramp rate. Values in the figure are for illustration purposes only.

Figure 5-1. Illustration of Achievable Potential Calculation



Source: Navigant

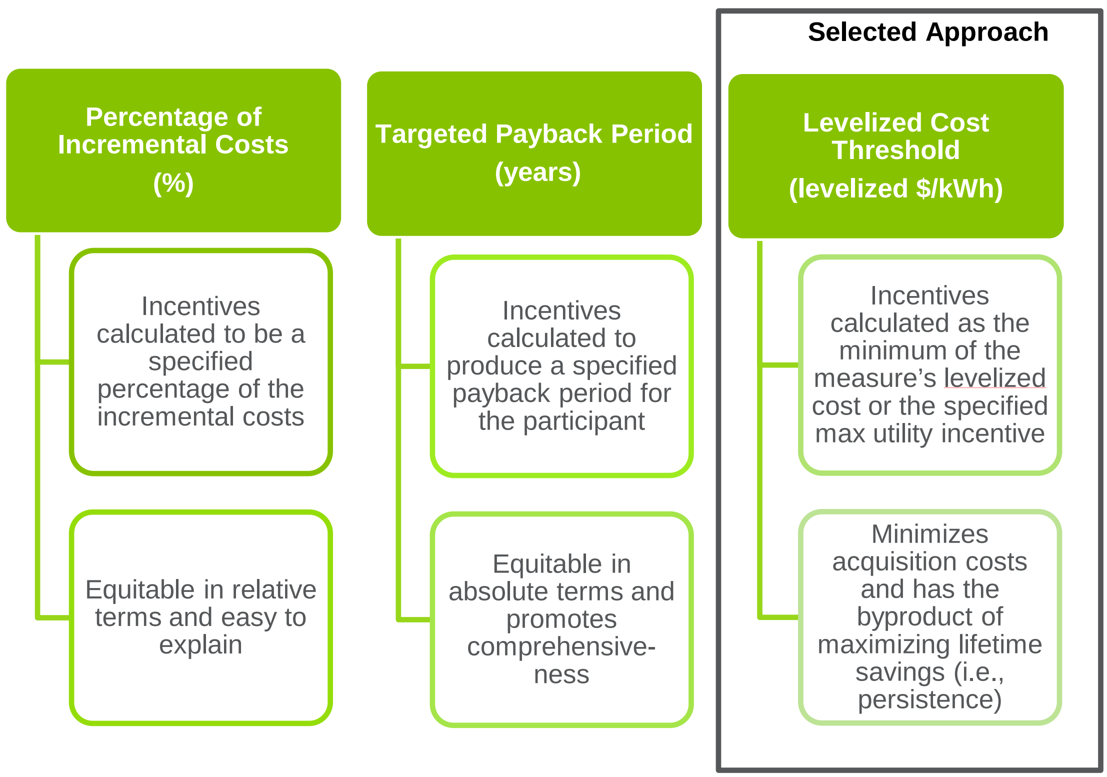
For measures involved in competition groups, an additional computational step is required to compute achievable potential. While the technical potential for a competition group reflects only the measure in that group with the greatest savings potential, all measures in a competition group may be allocated as achievable potential based on their relative attractiveness to one another.

For each competition group measure, Navigant computed the relative customer economics ratio to reflect all costs and savings a customer would experience because it implemented the measure. The study team then input this ratio into a logit discrete choice model[101] to allocate market share across the competing measures based on their relative customer economics. The team multiplied the resulting market share splits by the maximum achievable potential for the competition group to determine the achievable potential for each individual measure. This methodology ensured the final estimates of achievable potential reflect the relative economic attractiveness of measures in a competition group, and the sum of achievable potential from all measures in a competition group reflect the maximum achievable potential of the group.

5.1 Achievable Potential Scenarios

A key component of a potential study is determining the appropriate level to set measure incentives for each scenario. The analysis included several different strategies for setting incentive levels, as illustrated in Figure 5-2.

Figure 5-2. Incentive Approaches



Source: Navigant

[101] A logit formulation is based on documented consumer decision theory that accounts for consumer preferences in competing choices based on the relative and absolute differences between the choices.

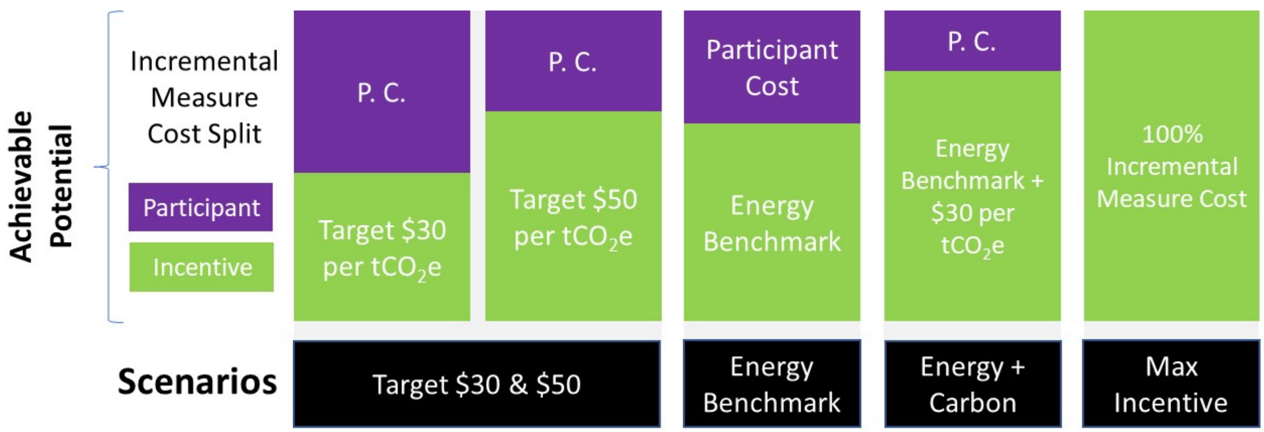
Daniel McFadden and Kenneth Train, "Mixed MNL Models for Discrete Response," *Journal of Applied Econometrics,* Vol. 15, No. 5, 447-470, 2000; and Kenneth Train, *Discrete Choice Methods with Simulation*, (Massachusetts: Cambridge University Press, 2003).

For EEA, the incentive-level strategy is the Levelized Cost Threshold Approach (shown in Figure 5-2.). In this approach, incentive levels are set to achieve a specified threshold spending level (on a $/levelized kWh or GJ saving basis). This threshold incentive level would be adjusted iteratively to a point where the overall portfolio investment meets the investment constraints identified by EEA, most specifically for scenarios with target carbon price floor shown in Figure 5-3. Appendix F describes the calibration approach in more detail. This approach is innovative because it results in higher savings at a lower cost than alternative approaches to specifying incentive levels.[102] This approach also has the benefit of maximizing the net benefits achieved.

5.1.1 Scenario Analysis

Navigant ran multiple scenarios for achievable potential, including multiple investment-constrained scenarios, and an unconstrained investment scenario representing maximum achievable potential as illustrated in Figure 5-3. To convert a portfolio's first year costs to a levelized cost (i.e., over the lifetime of savings), the study team identified a representative portfolio life. Using a U.S. DOE study that reviewed program and portfolio valuation of the life of the savings, a simple average across more than 1,600 program years of data resulted in 13 years.[103]

Figure 5-3. Achievable Potential Scenarios



Source: Energy Efficiency Alberta

It is important to note EEA decided not to include a budget (investment)-constrained scenario, thus the potential study outputs are a market achievable analysis, not a budget achievable analysis.

5.1.1.1 Maximum Incentives (Unconstrained Investment Scenario)

In the unconstrained incentive scenario, theoretical scenario, Navigant set incentives to 100% of the incremental cost of a measure. Setting incentives at 100% of incremental cost will result in the highest

[102] Cory Welch, Denise Richerson-Smith, "Incentive Scenarios in Potential Studies: A Smarter Approach." Presented at the ACEEE Summer Study on Energy Efficiency in Buildings, Monterey, California, August 2012, http://www.aceee.org/files/proceedings/2012/data/papers/0193-000050.pdf.

[103] Energy Savings Lifetimes and Persistence: Practices, Issues, and Data, May 2015, https://eta.lbl.gov/sites/all/files/publications/savings-lifetime-persistence-brief.pdf.

forecast savings levels (effectively a zero-payback time) but will also come with a higher level of investment forecasts. This is not considered a realistic scenario but can be used to compare others against.

5.1.1.2 Reference Case Scenario: Price of Abated Emissions (Carbon Price Ceiling)

In the reference case scenario, Navigant iterated incentives using the levelized cost threshold approach until an average portfolio cost of abated equivalent tCO_2e was less than or equal to $30/ tCO_2e. This threshold is achieved via the calibration process explained in Appendix F for energy efficiency measures, including oil & gas. Specifically, the study team calculated the average portfolio cost for each year in the study period in nominal terms, which were then calculated in real 2019 dollars. The team then averaged these values to obtain the average portfolio cost over the entire study period. Navigant selected the $30/$tCO_2e$ value as the target cost because this is the current market price of carbon, and it is advisable to support measures that can reduce emissions at a cost less than or equal to the market price.

The reference case scenario assumes only the GHG reduction value ($30/$tCO_2e$) of the programs is considered when funding. This approach contrasts with typical program funding, which includes the value of energy, and in some jurisdictions, the value of the avoided GHG emissions. Therefore, considering only the value of GHG reductions is a relatively stringent condition to place on budgets when funding programs.

5.1.1.3 Future Price of Abated Emissions (Carbon Price Ceiling)

In this scenario, Navigant used the same approach as the reference case, but with respect to a $50/$tCO_2e$ value. The purpose of this scenario is to determine what potential could result when providing incentives resulting in an average portfolio cost of equivalent tCO_2e of less than or equal to $50/$tCO_2e$. This value was selected because the market price of carbon is expected to rise to $50/$tCO_2e$ by 2022; thus, it is more representative of the long-term pricing of carbon.

5.1.1.4 Energy Benchmark

In this scenario, the study team based the incentives on values from benchmark studies of portfolio administration and incentive costs per unit of energy savings solely associated with energy savings. The purpose of this scenario is to model the potential savings achievable and compare results with regulated energy efficiency agencies in other jurisdictions.

5.1.1.5 Energy + Carbon

In this scenario, Navigant considered the incentive values mentioned in the energy benchmark, while also including a level of portfolio investment meeting the $30/$tCO_2e$ average portfolio cost target. The purpose of this scenario is to inform what savings might be possible assuming funding was obtained from both the carbon levy and the utility system (as opposed to just the utility system, as shown in the Energy Benchmark scenario).

5.2 Results Summary

Values shown for achievable potential are termed incremental annual potential and represent the new potential made available by new equipment installed in each year. The cumulative annual potential over the study period is the sum of each year's incremental annual achievable potential. In this study, economic potential can be considered a bucket of potential from which programs can draw over time. Achievable potential represents the draining of that bucket, the rate of which is governed by several factors, including the lifetime of measures (for ROB technologies), market effectiveness, incentive levels, and customer willingness to adopt, among others. If the cumulative annual achievable potential ultimately reaches the economic potential, it would signify all economic potential in the bucket had been drawn down or captured. However, achievable potential levels rarely reach the full economic potential level due to a variety of market and customer constraints inhibiting full economic adoption.[104]

The following figures (except in Section 5.2.1) present the potential savings for the reference case scenario solely based on the carbon price floor at \$30/tCO_2e.

5.2.1 Scenario-Level Results

As explained in Section 5.1.1, Navigant modelled the achievable potential analysis with five different scenarios. The scenarios are based on the cost per levelized kWh for electricity and per levelized GJ for natural gas.

Table 5-1 and Table 5-2 provides a summary of the five different incentive scenarios performed, detailed as follows:

- **Reference case:** Incentives are set in a manner to achieve a portfolio average of \$30/tCO_2e when considering all sectors and measures.
- **Future price of carbon:** Incentives are set in a manner to achieve a portfolio average of \$50/tCO_2e when considering all non-generation measures (i.e., excluding CHP and solar, but including the oil & gas customer segments).
- **Maximum Incentives:** 100% of the incremental measure cost is covered by incentives. This is a theoretical scenario.
- **Energy Benchmark:** Incentives based on typical energy benchmark studies. This scenario results in higher program budgets than the Reference case scenario.
- **Energy + Carbon:** Incentives based on benchmark studies, and adding to those values, incentives aimed specifically at abating emissions.

The Reference case is the lowest cost scenario, while serving as a starting point for increased savings in other scenarios. The marginal increases in achievable potential seen in the other scenarios come at a higher cost per unit, with the \$30/tCO_2e cost scenario being the most cost efficient.

[104] Constraints on achievable potential inhibiting realization of the full economic potential include the rate at which households and businesses will adopt efficient technologies and word of mouth and marketing effectiveness for the technology. If a technology already has high saturation at the beginning of the study, it may theoretically be possible to fully saturate the market and achieve 100% of the economic potential.

Table 5-1. Cumulative Annual Gross Savings (By Scenario, Including Solar, Excluding Oil & Gas Customer Segments), Over the Study Period (2019-2038) [105]

Value	Description	Reference: $30/ tCO2e Portfolio Average Cost	$50/ tCO2e Portfolio Average Cost	Incentives at 100% of Incremental Measure Cost	Energy Benchmark	Incentives Based on Energy and Carbon
Electricity Achievable Potential (GWh)	Annual GWh saved from measures installed over the study period	10,523	12,069	24,928	12,104	14,377
Electricity Achievable Potential (% of Consumption)	GWh savings in 2038 as a percent of the forecasted consumption for 2038	20.0%	22.9%	47.3%	23.0%	27.3%
Natural Gas Achievable Potential (TJ)	Annual TJ saved from measures installed over the study period	27,892	33,268	41,142	26,432	35,858
Natural Gas Achievable Potential (% of Consumption)	TJ savings in 2038 as a percent of the forecasted consumption for 2038	5.6%	6.6%	8.2%	5.3%	7.1%
Peak Winter Demand Savings, 2038 (MW)	Peak winter demand savings in 2038	919	959	1,048	959	992

Source: Navigant analysis

[105] The cumulative annual potential over the time period (2019-2038) is the sum of each year's annual incremental achievable potential.

Table 5-2 presents similar results while including the oil & gas customer segments.

Table 5-2. Cumulative Annual Gross Savings (All Scenarios Including Solar Including Oil & Gas Customer Segments), Over the Study Period (2019-2038)

Value	Description	Reference: $30/ tCO2e Portfolio Average Cost	$50/ tCO2e Portfolio Average Cost	Incentives at 100% of Incremental Measure Cost	Energy Benchmark	Incentives Based on Energy and Carbon
Electricity Achievable Potential (GWh)	Annual GWh saved from measures installed over the study period	13,652	15,584	28,842	15,656	18,205
Electricity Achievable Potential (% of Consumption)	GWh savings in 2038 as a percent of the forecasted consumption for 2038	13.3%	15.2%	28.1%	15.3%	17.7%
Natural Gas Achievable Potential (TJ)	Annual TJ saved from measures installed over the study period	132,036	150,504	171,632	130,126	162,468
Natural Gas Achievable Potential (% of Consumption)	TJ savings in 2038 as a percent of the forecasted consumption for 2038	6.3%	7.1%	8.1%	6.2%	7.7%
Peak Winter Demand Savings, 2038 (MW)	Peak winter demand savings in 2038	1,337	1,429	1,572	1,435	1,505

Source: Navigant analysis

In addition to the fuel savings cumulated over the study period, it is also important to consider the total costs and benefits over the lifetime of the measures installed during the study period. Table 5-3 provides such values for the reference scenario and the relevant equations used to arrive at the values (if applicable). Table 5-4 presents similar results while including the oil & gas customer segments.

Table 5-3. Cumulative Lifetime Gross Savings at Meter, Carbon Abatement at Generator, and Net Benefits (All Scenarios Including Solar, Excluding Oil & Gas Customer Segments), Over the Study Period

Value	Equation	Description	Reference: $30/ tCO2e Portfolio Average Cost	$50/ tCO2e Portfolio Average Cost	Incentives at 100% of Incremental Measure Cost	Energy Benchmark	Incentives Based on Energy and Carbon
[A] - Lifetime Electricity Potential (GWh)	A	Electric Lifetime Energy Saved by All Measures Installed During the Study Period	188,424	224,895	541,286	225,523	280,300
[B] - Lifetime Natural Gas Potential (TJ)	B	Natural Gas Lifetime Energy Saved by All Measures Installed During the Study Period	402,872	491,646	632,524	383,378	537,562
[C] - Lifetime Emissions Abated (Lifetime tCO2e)	C	Lifetime Emissions Reductions Provided by All Measures Installed During the Study Period	88,459,006	104,533,035	220,457,053	99,053,702	124,761,040
[E] - Incremental Measure Costs (2019 $ Millions)	E	Cost of the Efficient Measure Less the Cost of the Baseline Measure	$8,049	$10,180	$31,474	$9,741	$13,320
[F] - Incentives (2019 $ Millions)	F	Incentive Provided to the Participant	$2,307	$4,362	$31,474	$3,883	$7,400
[G] - Participant Cost (2019 $ Millions)	E - F	Incremental Measure Cost of the Measure Less the Incentives Provided	$5,742	$5,819	$0	$5,858	$5,920
[H] - Administrative Costs (2019 $ Millions)	H	Admin Costs Required to Support the Program	$ 788	$1,385	$6,388	$1,176	$2,093
[J] - Total Costs (2019 $ Millions)	E + H	Incremental Measure Costs + Admin Costs	$8,837	$11,565	$37,862	$10,917	$15,413
[K] - Total Benefits (2019 $ Millions)	K	Lifetime Benefits of the Measures Deployed Throughout the Study Period	$19,946	$23,548	$51,958	$16,112	$28,434
[L] - Net Benefits (2019 $ Millions)	K - J	Total Benefits Less Total Costs	$11,109	$11,982	$14,097	$5,195	$13,021
[M] - Societal Abatement Costs (2019 $ / Lifetime tCO2e)	(J - K) / C	Societal Net Costs per Lifetime tCO2e Abated	$(126)	$(115)	$(64)	$(52)	$(104)

Note: 2.0% inflation was used to convert values to real 2019 dollars.

Table 5-4. Cumulative Lifetime Gross Savings at Meter, Carbon Abatement at Generator, and Net Benefits (All Scenarios Including Solar, Including Oil & Gas Customer Segments), Over the Study Period

Value	Equation	Description	Reference: $30/t tCO2e Portfolio Average Cost	$50/tonne Portfolio Average Cost	Incentives at 100% of Incremental Measure Cost	Energy Benchmark	Incentives Based on Energy and Carbon
[A] - Lifetime Electricity Potential (GWh)	A	Electric Lifetime Energy Saved by All Measures Installed During the Study Period	221,351	263,575	586,374	264,764	323,861
[B] - Lifetime Natural Gas Potential (TJ)	B	Natural Gas Lifetime Energy Saved by All Measures Installed During the Study Period	1,889,686	2,204,506	2,586,221	1,892,211	2,423,500
[C] - Lifetime Emissions Abated (Lifetime tCO2e)	C	Lifetime Emissions Reductions Provided by All Measures Installed During the Study Period	178,185,799	207,124,622	337,373,254	191,716,306	237,811,209
[E] - Incremental Measure Costs (2019 $ Millions)	E	Cost of the Efficient Measure Less the Cost of the Baseline Measure	$11,560	$14,498	$36,904	$13,313	$18,457
[F] - Incentives (2019 $ Millions)	F	Incentive Provided to the Participant	$3,887	$7,675	$36,904	$6,472	$11,918
[G] - Participant Cost (2019 $ Millions)	E - F	Incremental Measure Cost of the Measure Less the Incentives Provided	$7,673	$6,824	$0	$6,841	$6,540
[H] - Administrative Costs (2019 $ Millions)	H	Admin Costs Required to Support the Program	$1,465	$2,805	$8,715	$2,285	$4,029
[J] - Total Costs (2019 $ Millions)	E + H	Incremental Measure Costs + Admin Costs	$13,025	$17,303	$45,619	$15,598	$22,486

[K] - Total Benefits (2019 $ Millions)	K	Lifetime Benefits of the Measures Deployed Throughout the Study Period	$32,980	$38,314	$68,605	$23,204	$44,626
[L] - Net Benefits (2019 $ Millions)	K - J	Total Benefits Less Total Costs	$19,956	$21,011	$22,986	$7,606	$22,140
[M] - Societal Abatement Costs (2019 $ / Lifetime tCO2e)	(J - K) / C	Societal Net Costs per Lifetime tCO2e Abated	$(112)	$(101)	$(68)	$(40)	$(93)

Note: 2.0% inflation was used to convert values to real 2019 dollars.
Source: Navigant analysis

To provide some insight in to near term costs required to drive energy savings, Table 5-5 shows the fuel-specific program spending associated with its energy savings through 2028. Table 5-6 presents similar results while including the oil & gas customer segments.

Table 5-5. Fuel-Specific Program Spending per Unit of Energy Saved, At Meter in 2028 (Including Solar, Excluding Oil & Gas Customer Segments)

Value	Description	Reference: $30/ tCO2e Portfolio Average Cost	$50/ tCO2e Portfolio Average Cost	Incentives at 100% of Incremental Measure Cost	Energy Benchmark	Incentives Based on Energy and Carbon
Program $/First Year kWh	(Incentives + Admin Costs Spent on Electricity-Saving Measures through 2028) / kWh Saved in 2028	$0.20	$0.31	$1.45	$0.31	$0.45
Program $/First Year GJ	(Incentives + Admin Costs Spent on Gas-Saving Measures through 2028) / GJ Saved in 2028	$31.21	$49.46	$86.52	$38.83	$60.65

Note: 2.0% inflation was used to convert values to real 2019 dollars.
Source: Navigant analysis

Table 5-6. Fuel-Specific Program Spending per Unit of Energy Saved, At Meter in 2028 (Including Solar, Including Oil & Gas Customer Segments)

Value	Description	Reference: $30/ tCO2e Portfolio Average Cost	$50/ tCO2e Portfolio Average Cost	Incentives at 100% of Incremental Measure Cost	Energy Benchmark	Incentives Based on Energy and Carbon
Program $/First Year kWh	(Incentives + Admin Costs Spent on Electricity-Saving Measures through 2028) / kWh Saved in 2028	$0.18	$0.28	$1.29	$0.28	$0.41
Program $/First Year GJ	(Incentives + Admin Costs Spent on Gas-Saving Measures through 2028) / GJ Saved in 2028	$19.57	$36.33	$56.15	$28.77	$44.42

Note: 2.0% inflation was used to convert values to real 2019 dollars.
Source: Navigant analysis

In addition, Table 5-7 shows the fuel-specific program spending over the course of the study period associated with the lifetime energy savings of all measures installed, excluding the oil & gas customer segments. Table 5-8 shows the same information while including the oil & gas customer segments.

Table 5-7. Fuel-Specific Program Spending Over Study Period per Lifetime Energy Savings, At Meter (Excluding Solar, Excluding Oil & Gas Customer Segments)

	Description	Reference: $30/ tCO2e Portfolio Average Cost	$50/ tCO2e Portfolio Average Cost	Incentives at 100% of Incremental Measure Cost	Energy Benchmark	Incentives Based on Energy and Carbon
Program ¢/Lifetime kWh	(Incentives + Admin Costs Spent on Electricity-Saving Measures through 2038) / Lifetime kWh Saved	¢1.35	¢1.92	¢4.37	¢1.92	¢2.52
Program $/Lifetime GJ	(Incentives + Admin Costs Spent on Gas-Saving Measures through 2038) / Lifetime GJ Saved	$2.25	$3.49	$5.76	$2.61	$4.16
Total ¢/Lifetime kWh	(Incremental Costs + Program Costs Spent on Electricity-Saving Measures through 2038) / Lifetime kWh Saved	¢2.43	¢2.66	¢4.28	¢2.65	¢2.92
Total $/Lifetime GJ	(Incremental Costs + Program Costs Spent on Gas-Saving Measures through 2038) / Lifetime GJ Saved	$3.88	$4.33	$5.55	$3.85	$4.66

Source: Navigant analysis; Note: 2.0% inflation was used to convert values to real 2019 dollars.

Table 5-8. Fuel-Specific Program Spending Over Study Period per Lifetime Energy Savings, At Meter (Excluding Solar, Including Oil & Gas Customer Segments)

	Description	Reference: $30/ tCO2e Portfolio Average Cost	$50/ tCO2e Portfolio Average Cost	Incentives at 100% of Incremental Measure Cost	Energy Benchmark	Incentives Based on Energy and Carbon
Program ¢/Lifetime kWh	(Incentives + Admin Costs Spent on Electricity-Saving Measures through 2038) / Lifetime kWh Saved	¢1.35	¢1.95	¢4.14	¢1.98	¢2.61
Program $/Lifetime GJ	(Incentives + Admin Costs Spent on Gas-Saving Measures through 2038) / Lifetime GJ Saved	$1.45	$2.56	$3.79	$2.04	$3.07
Total ¢/Lifetime kWh	(Incremental Costs + Program Costs Spent on Electricity-Saving Measures through 2038) / Lifetime kWh Saved	¢2.43	¢2.72	¢4.08	¢2.73	¢3.02
Total $/Lifetime GJ	(Incremental Costs + Program Costs Spent on Gas-Saving Measures through 2038) / Lifetime GJ Saved	$2.61	$3.06	$3.74	$2.64	$3.36

Note: 2.0% inflation was used to convert values to real 2019 dollars.
Source: Navigant analysis

The following sections discuss the results with respect to the reference case ($30/t$CO_2$e portfolio cost scenario).

5.2.2 Summary of Potential Results

This section provides a summary of the achievable potential results. As shown in Figure 5-3, this study considers the reference case at the current carbon price floor of \$30/tCO_2e. As the amount of available funding increases (such as funding programs from both the carbon levy) and the value of avoided energy costs benefits increases, there are higher energy savings and carbon reductions are cost-effective. All results are presented as gross energy savings at the meter, with carbon emissions abated presented at the generator.

Table 5-9 provides a summary of the study results for the reference scenario as cumulated through 2038.

Table 5-9. Cumulative Annual Gross Savings, Over the Study Period (2019-2038)

Value	Description	EE (Excluding Oil & Gas)	EE (Including Oil & Gas)	PV Solar	PV Solar + EE (Including Oil & Gas)
Electricity Achievable Potential (GWh)	Annual GWh saved from measures installed over the study period	7,008	10,137	3,515	13,652
Electricity Achievable Potential (% of Consumption)	GWh savings in 2038 as a percent of the forecasted consumption for 2038	13.3%	9.9%	10.5%	13.3%
Natural Gas Achievable Potential (TJ)	Annual TJ saved from measures installed over the study period	27,892	132,036	N/A	132,036
Natural Gas Achievable Potential (% of Consumption)	TJ savings in 2038 as a percent of the forecasted consumption for 2038	5.6%	6.3%	N/A	6.3%
Peak Winter Demand Savings, 2038 (MW)	Peak winter demand savings in 2038	919	1,337	N/A	1,337

Source: Navigant analysis

In addition to the energy savings cumulated over the study period, it is also important to consider the total costs and benefits over the lifetime of the measures installed during the study period. Table 5-10 provides such values for the reference scenario and the relevant equations used to arrive at the values (if applicable).

Table 5-10. Cumulative Lifetime Gross Savings at Meter, Carbon Abatement at Generator, and Net Benefits, Over the Study Period

Value	Equation	Description	EE (Excluding Oil & Gas)	EE (Including Oil & Gas)	PV Solar	PV Solar + EE (Including Oil & Gas)
[A] - Lifetime Electricity Potential (GWh)	A	Electric Lifetime Energy Saved by All Measures Installed During the Study Period	100,551	133,479	87,873	221,351
[B] - Lifetime Natural Gas Potential (TJ)	B	Natural Gas Lifetime Energy Saved by All Measures Installed During the Study Period	402,872	1,889,686	N/A	1,889,686
[C] - Lifetime Emissions Abated (Lifetime tCO2e)	C	Lifetime Emissions Reductions Provided by All Measures Installed During the Study Period	61,192,660	150,919,453	27,266,346	178,185,799
[E] - Incremental Measure Costs (2019 $ Millions)	E	Cost of the Efficient Measure Less the Cost of the Baseline Measure	$3,324	$6,834	$4,726	$11,560
[F] - Incentives (2019 $ Millions)	F	Incentive Provided to the Participant	$1,587	$3,167	$720	$3,887
[G] - Participant Cost (2019 $ Millions)	E - F	Incremental Measure Cost of the Measure Less the Incentives Provided	$1,737	$3,668	$4,005	$7,673
[H] - Administrative Costs (2019 $ Millions)	H	Admin Costs Required to Support the Program	$680	$1,357	$108	$1,465
[J] - Total Costs (2019 $ Millions)	E + H	Incremental Measure Costs + Admin Costs	$4,004	$8,192	$4,833	$13,025
[K] - Total Benefits (2019 $ Millions)	K	Lifetime Benefits of the Measures Deployed Throughout the Study Period	$12,706	$25,740	$7,240	$32,980
[L] - Net Benefits (2019 $ Millions)	K - J	Total Benefits Less Total Costs	$8,702	$17,549	$2,407	$19,956
[M] - Societal Abatement Costs (2019 $ / Lifetime tCO2e)	(J - K) / C	Societal Net Costs per Lifetime tCO2e Abated	$(142)	$(116)	$(88)	$(112)

Note: 2.0% inflation was used to convert values to real 2019 dollars.
Source: Navigant analysis

To provide insight in to annual costs required to drive energy savings, Table 5-11 shows the fuel-specific program spending associated with its energy savings through 2028[106].

Table 5-11. Fuel-Specific Program Spending per Unit of Energy Saved, At Meter in 2028

	Description	EE (Excluding Oil & Gas)	EE (Including Oil & Gas)	PV Solar	PV Solar + EE (Including Oil & Gas)
Program $/First Year kWh	(Incentives + Admin Costs Spent on Electricity-Saving Measures through 2028) / kWh Saved in 2028	19.0¢	16.9¢	27.2¢	18.2¢
Total $/First Year kWh	(Incremental Measure Costs + Admin Costs Spent on Electricity-Saving Measures through 2028) / kWh Saved in 2028	34.7¢	30.8¢	$1.61	47.5¢
Program $/First Year GJ	(Incentives + Admin Costs Spent on Gas-Saving Measures through 2028) / GJ Saved in 2028	$31.21	$19.57	N/A	$19.57
Total $/First Year GJ	(Incremental Measure Costs + Admin Costs Spent on Gas-Saving Measures through 2028) / GJ Saved in 2028	$52.68	$34.80	NA	$34.80

Note: 2.0% inflation was used to convert values to real 2019 dollars.
Source: Navigant analysis

Navigant provides several specific observations of the modelled potential:

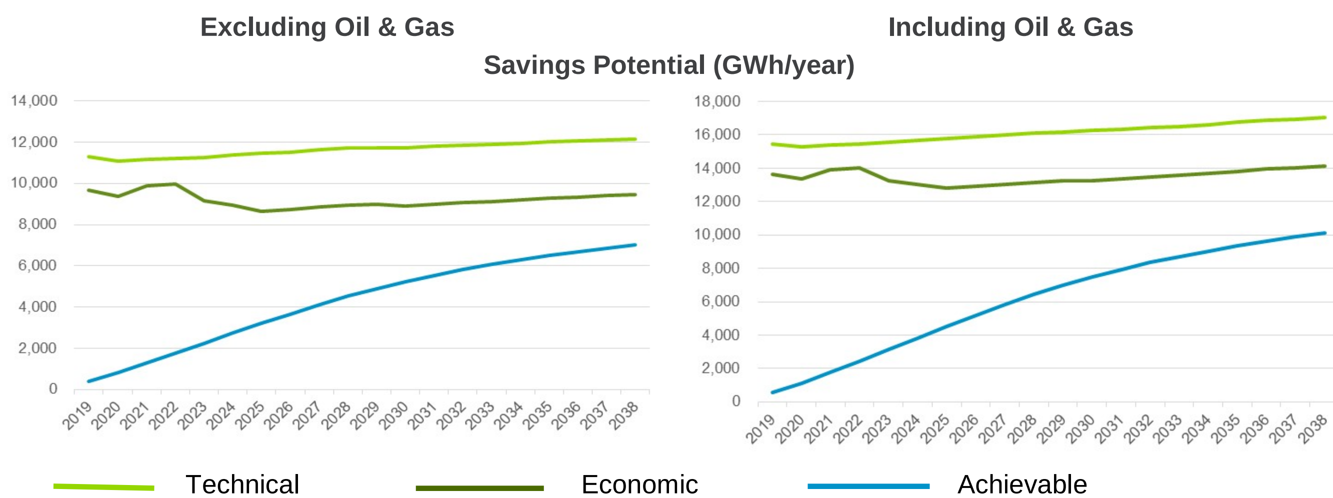
- The study team expects the portfolio level of investment to increase annually through 2027 (achievable savings peaks in 2027, excluding oil & gas), with an average increase of 7% per year, and then decrease close to the 2021 value in real dollars. The team expects decreases due to minimal building stock growth and because only currently known technologies were modelled.
- Avoided electricity and natural gas costs increase over the 20-year horizon based on fuel costs forecasts and inflation.
- Over the 20-year study period, the average energy efficiency (including oil & gas sector) is $30/lifetime t$CO_2$e (2019 real dollars).

[106] Navigant chose to report at year 2028 since it is halfway through the study period and represents typical program costs.

Note: Unless otherwise stated, the following results DO NOT include the oil & gas customer segment, solar generation, and financing potential (and thus address only energy efficiency).

As shown in Figure 5-4, the electricity achievable energy efficiency potential, which accounts for the rate of DSM acquisition, increases steadily throughout the study period. Excluding the oil & gas sector, energy efficiency potential reaches 7,008 GWh (10,137 including oil & gas) in 2038. By 2038, achievable energy efficiency potential reaches just over 74% (72% including oil & gas) of the economic energy efficiency potential, both including and excluding oil & gas. Incremental annual achievable energy efficiency potential averages 350 GWh (507 GWh annually, including oil & gas) over the study period (2019-2038).

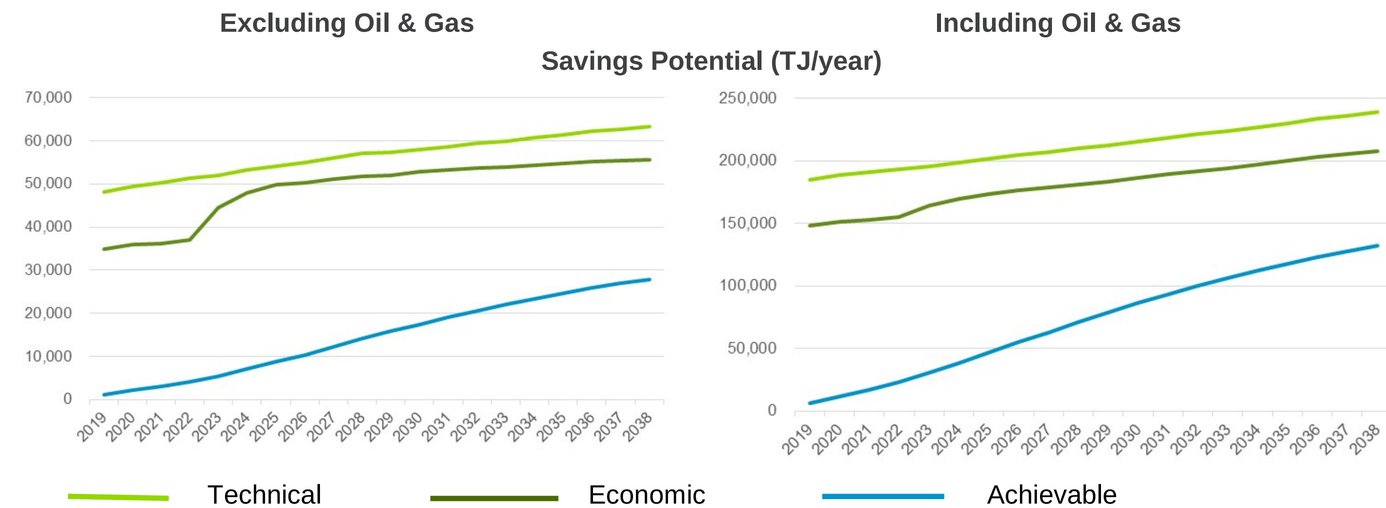
Figure 5-4. Electricity Energy Efficiency Potential by Potential Type, Cumulative Annual Gross Savings at Meter, GWh



Source: Navigant analysis

As shown in Figure 5-5, the natural gas achievable energy efficiency potential increases steadily throughout the study period, annually reaching 27,900 TJ (132,000 TJ annually, including oil & gas) in 2038. By 2038, achievable energy efficiency potential reaches just over 50% (63% including oil & gas) of the economic energy efficiency potential. Incremental annual achievable energy efficiency potential averages 1,395 TJ (6,602 TJ annually, including oil & gas) over the study period.

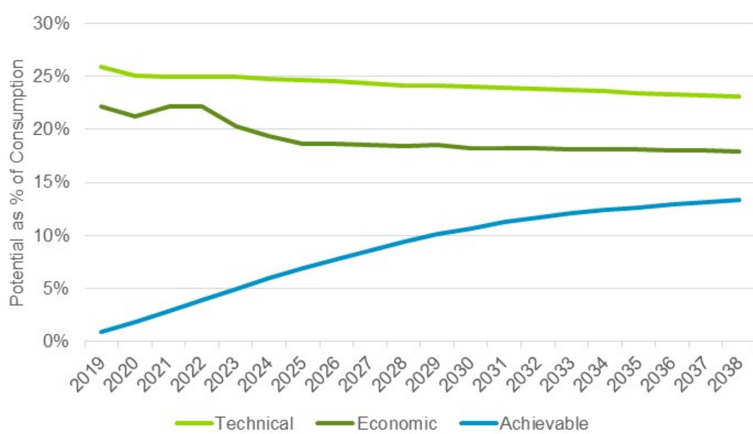
Figure 5-5. Natural Gas Energy Efficiency Potential by Potential Type, Cumulative Annual Gross Savings at Meter, TJ*



Source: Navigant analysis

As shown in Figure 5-6, electricity achievable energy efficiency potential grows from 0.9% in 2019 to 13.3% of forecast electricity consumption by 2038. The incremental annual achievable energy efficiency potential is approximately 0.7% on average over the study period.

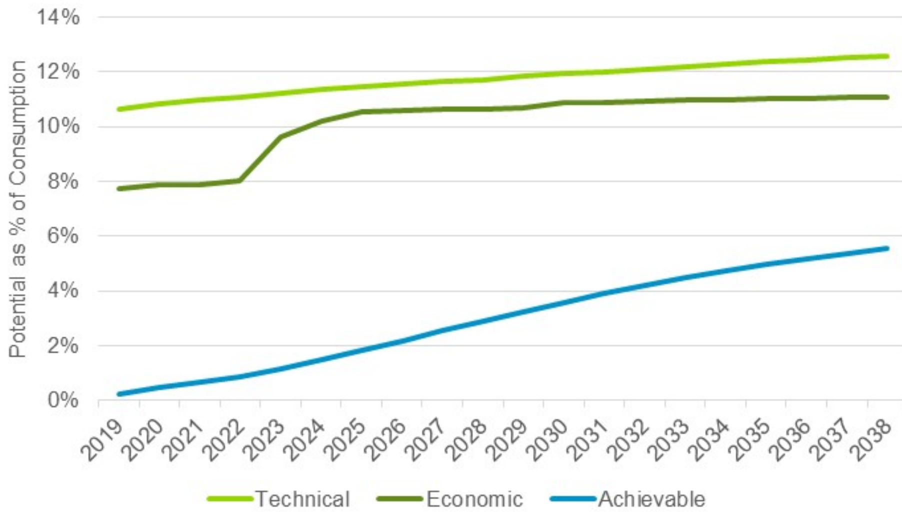
Figure 5-6. Electricity Energy Efficiency Potential by Potential Type, Cumulative Annual Gross Savings at Meter, Percentage of Consumption



Source: Navigant analysis

As shown in Figure 5-7, natural gas achievable energy efficiency potential grows from 0.2% in 2019 to 5.6% of forecast natural gas consumption by 2038. The incremental annual achievable energy efficiency potential is approximately 0.3% per year on average over the study period.

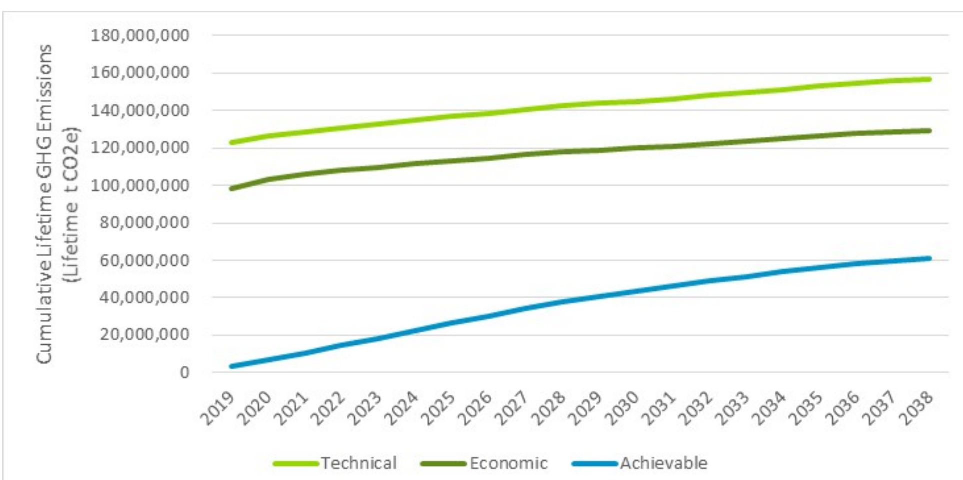
Figure 5-7. Natural Gas Energy Efficiency Potential by Potential Type, Cumulative Annual Gross Savings at Meter, Percentage of Consumption



Source: Navigant analysis

As shown in Figure 5-8, the achievable lifetime emissions abatement potential for electricity and natural gas increases steadily throughout the study period, reaching 61 million lifetime tCO_2e/year in 2038. By 2038, achievable energy efficiency potential reaches more than 47% of the economic energy efficiency potential. Incremental annual achievable energy efficiency potential averages to 3.1 million lifetime tCO_2e over the study period.

Figure 5-8. Cumulative Lifetime GHG Emissions Reduction by Potential for Electricity and Natural Gas, Lifetime tCO_2e



Source: Navigant analysis

5.3 Sector-Level Results

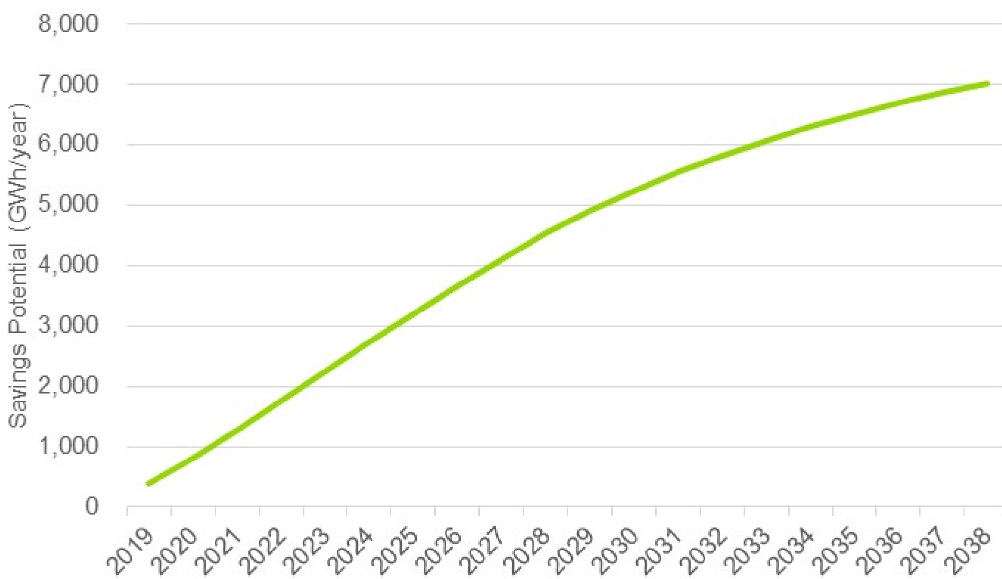
Note: Unless otherwise stated, the following figures exclude the oil & gas customer segment.

5.3.1 Electricity Potential Results

Figure 5-9 and Figure 5-10 presents the cumulative annual gross electricity savings potential at the meter, and the cumulative potential as a percentage of sector consumption (excluding the industrial oil & gas subsector), respectively:

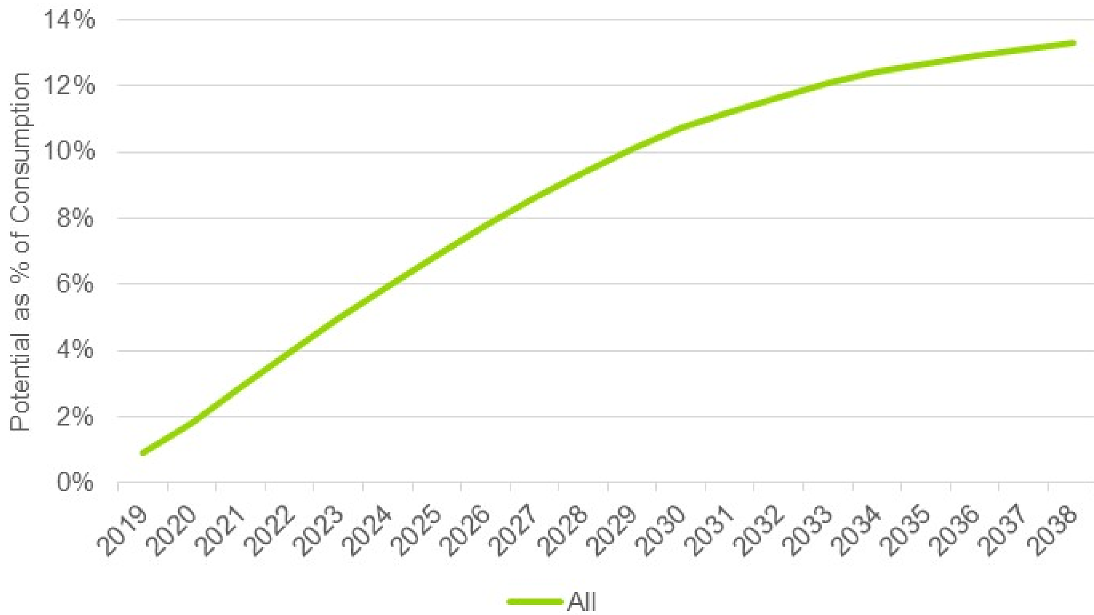
- In 2038, cumulative annual achievable potential as a percentage of total sector consumption reaches 13.3% (7,008 GWh and 919 MW), with an annual average of 0.7% (350 GWh and 46 MW) over the 20-year period (2019-2038).
- Commercial savings potential as a percentage of sector consumption grows faster than the residential or industrial sectors, reaching 19.1% by 2038, with an average annual savings of 1% over 20 years.
- Residential savings potential as a percentage of sector consumption reaches 9.0% by 2038, achieving an average annual savings of 0.45% over 20 years. The residential sector's lower percentage reflects the lower cost-effectiveness and longer payback times of the residential sector, on average.
- Industrial sector (excluding oil & gas) savings potential as a percentage of sector consumption reaches 9.8% by 2038, achieving an average annual savings of 0.49% over 20 years.

Figure 5-9. Electricity Achievable Potential, Cumulative Annual Gross Savings at Meter (Excluding Oil & Gas)



Source: Navigant analysis

Figure 5-10. Electricity Achievable Potential, Cumulative Annual Gross Savings at Meter as Percentage of Consumption (Excluding Oil & Gas)



Source: Navigant analysis

Table 5-12 presents the incremental annual gross electricity savings potential at the meter for all sectors. The annual incremental potential increases for all sectors in the early years of the study period (until around 2025) and subsequently declines in the second half of the study period. This reflects how market adoption increases over time and eventually reaches an inflection point where higher levels of market saturation decrease the annual incremental potential. It is important to note this study only quantifies impacts of known, market-ready technologies. Based on historical precedence, new technologies are introduced over time, thus it is recommended to update the potential study every three to five years.

Table 5-12. Electricity Achievable Potential, Incremental Annual Gross Savings at Meter, GWh

Year	Total (excludes Oil & Gas)	Total (includes Oil & Gas)
2019	393	539
2020	423	588
2021	464	640
2022	489	676
2023	477	682
2024	490	696
2025	464	673
2026	451	665
2027	461	657
2028	425	606
2029	364	557
2030	325	498
2031	308	454
2032	279	412
2033	243	362
2034	231	342
2035	210	313
2036	192	288
2037	164	252
2038	153	236
Total	7,008	10,137

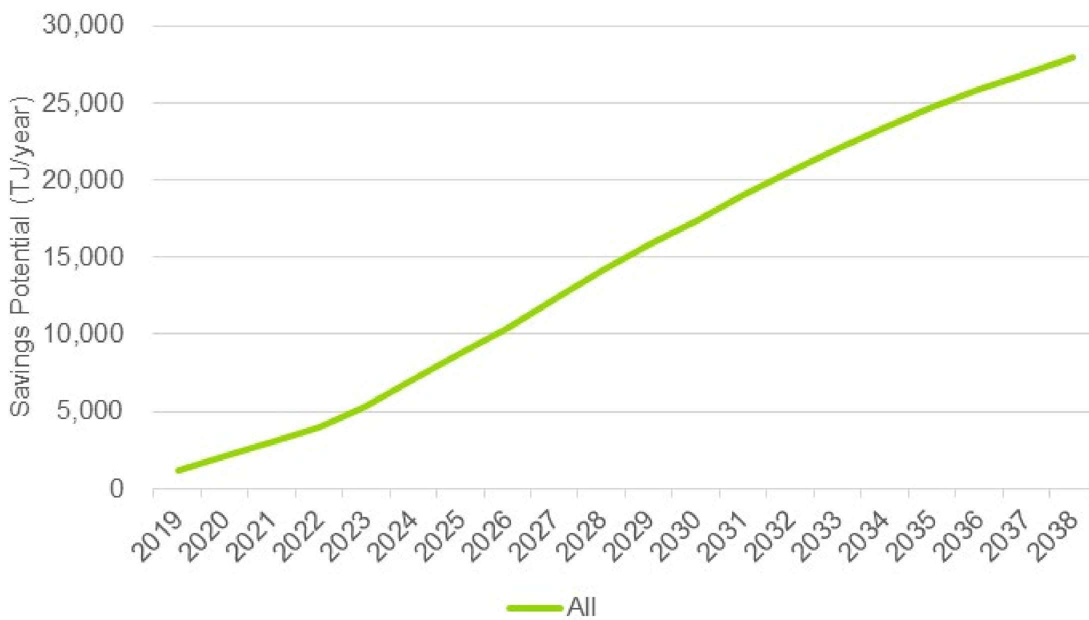
Source: Navigant analysis

Natural Gas Potential

Figure 5-11 presents the cumulative annual gross natural gas savings potential. Figure 5-12 shows the cumulative potential as a percentage of sector consumption (excluding the industrial oil & gas subsector).

- Total achievable potential as a percentage of total sector consumption reaches 5.6% with respect to an average annual BAU forecast by 2038, with average annual savings of 0.28% over the 20-year period (2019-2038). This percentage results in 29,930 TJ by 2038, an annual average of 1,497 TJ over the 20-year period.[107]
- Industrial savings potential as a percentage of sector consumption by 2038 is 6.1%, achieving an average annual savings of 0.31% over 20 years.
- Residential savings potential as a percentage of sector consumption reaches 5.6% by 2038, achieving an average annual savings of 0.28% over 20 years.
- Commercial savings potential as a percentage of sector consumption by 2038 is 5.6%, achieving an average annual savings of 0.22% over 20 years.

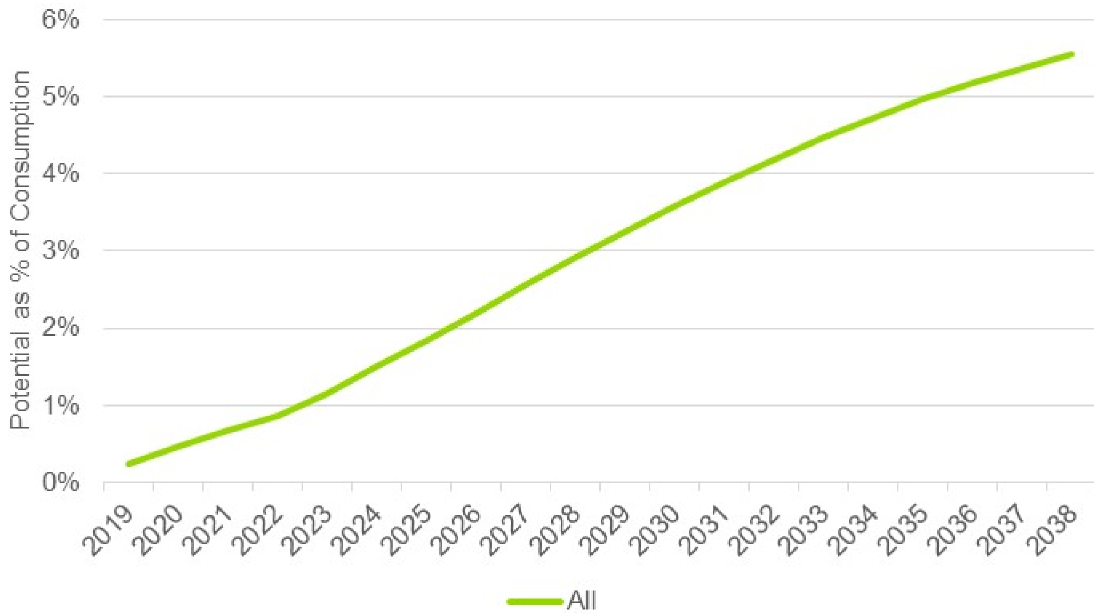
Figure 5-11. Natural Gas Achievable Potential, Cumulative Annual Gross Savings, TJ (Excluding Oil & Gas)



Source: Navigant analysis

[107] With the oil & gas segments included, the cumulative achievable potential as a percentage of total sector consumption is 6.3% (132,036 TJ) by 2038. This is higher compared to the case when oil & gas segments are excluded, because including the oil & gas segments increases the industrial savings potential as a percentage of industrial consumption.

Figure 5-12. Natural Gas Achievable Potential, Cumulative Annual Gross Savings as a Percentage of Consumption (Excluding Oil & Gas)



Source: Navigant analysis

Table 5-13 presents the incremental annual gross natural gas savings potential at the meter for all sectors. The industrial (excluding the oil & gas sector) composes the highest proportion of natural gas savings potential until 2029. From 2030 onwards, the study forecasts the residential sector to provide the greatest savings potential.

For the residential and commercial sectors, the annual incremental potential increases in the first half of the study period, and subsequently decreases in the second half of the study period. Similar to the electricity fuel type, this reflects how market adoption increases over time and eventually reaches an inflection point where higher levels of market saturation decrease the annual incremental potential. The industrial sector is also affected by these factors; however, there are some fluctuations in the industrial annual potential because of forecasted changes in the industrial natural gas BAU forecast.

Table 5-13. Natural Gas Achievable Potential by Sector, Incremental Annual Gross Savings, TJ

Year	Total (excludes Oil & Gas)	Total (includes Oil & Gas)
2019	1,121	5,987
2020	998	5,733
2021	940	5,574
2022	964	5,972
2023	1,336	7,228
2024	1,708	7,783
2025	1,654	8,139
2026	1,662	8,521
2027	1,931	8,154
2028	1,849	7,779
2029	1,602	8,165
2030	1,593	7,441
2031	1,629	7,123
2032	1,588	6,786
2033	1,412	6,107
2034	1,388	5,863
2035	1,300	5,517
2036	1,228	5,225
2037	1,029	4,605
2038	961	4,334
Total	**27,892**	**132,036**

Source: Navigant analysis

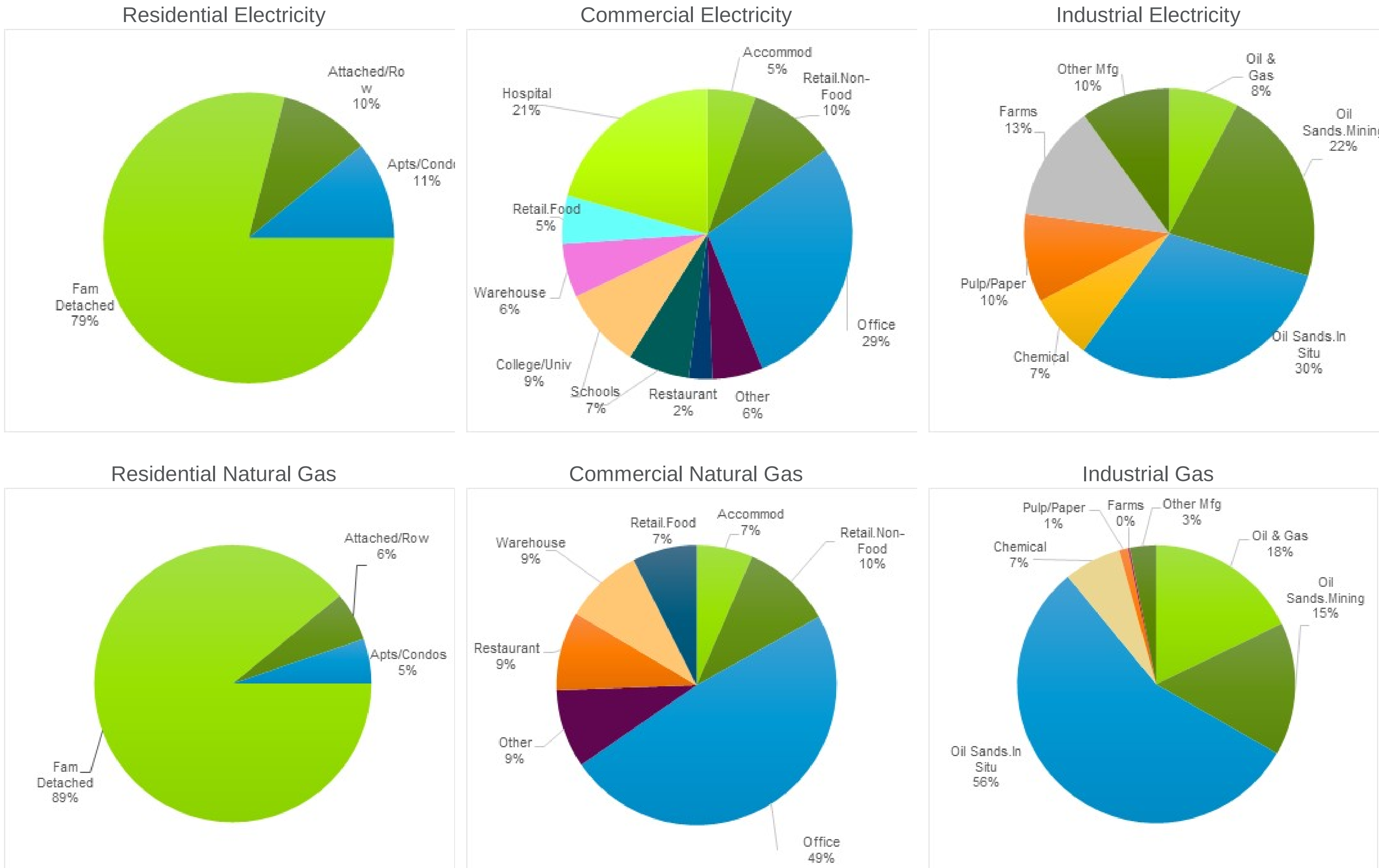
5.4 Segment-Level Results

Figure 5-13 shows the electricity and natural gas achievable savings potential in 2028 for each sector by customer segment. Navigant chose to present results for 2028 as the midpoint of the forecast period. Potential studies forecast long-term savings. Given minimal historical data for calibration, any near-term savings potential estimates will not reflect actual, immediate results. The distant 20-year future forecasts have more uncertainty. Thus, the midpoint of the study period is reflective of the full study estimate allocation by segment.

In general, the distribution of savings among customer segments aligns well with the distribution of electricity consumption among segments. Navigant found several segment-specific findings:

- For the residential sector, detached single-family homes represents the largest savings electricity and natural gas potential of any other residential customer segment, accounting for 79% and 89% of the total savings potential, respectively.
- Offices and non-food retail provide nearly half of the electricity savings in the commercial sector, while offices provide nearly half of the natural gas savings in the commercial sector.
- In the industrial sector, the farms customer segment accounts for the largest share of electric energy savings at 32%. Other manufacturing and pulp and paper also provide greater than 20% savings among industrial segments.
- In the industrial sector, the chemical segment accounts for the largest share of natural gas energy savings at 61%. Other manufacturing also provides significant savings (28%).

Figure 5-13. 2028 Achievable Potential, Cumulative Gross Savings at Meter, by Segment



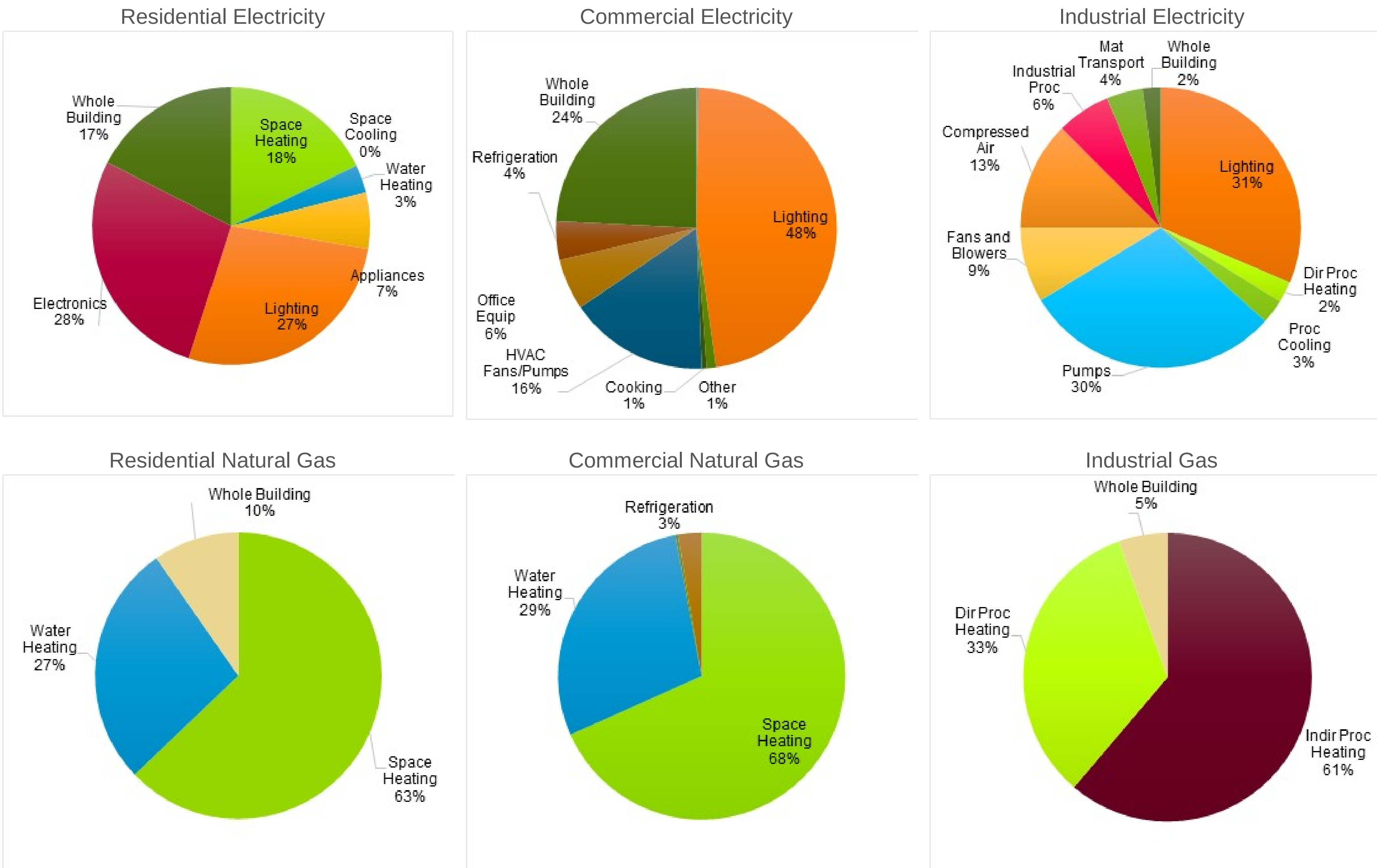
Source: Navigant analysis

5.5 End-Use-Level Results

Figure 5-14 provides the end-use savings achievable potential in 2028 by sector (excluding the industrial oil & gas segment) and fuel type. Navigant presents the following end-use-specific findings:

- Lighting and electronics end uses account for 55% of the residential sector's total savings potential.
  - Lighting provides the most electricity savings potential in all sectors.
  - Electronics, including plug loads in residential, make up an almost equal proportion in energy savings as lighting.
- The whole building end use in both the residential and commercial sectors accounts for energy savings attributed to combined heating and cooling savings and envelope measures. Both sectors have high savings for this end use, at 17% and 24%, respectively. There is no overlap of savings for this end use with other end uses.
- Savings in commercial lighting come largely from interior LED tubes. The whole building end use's savings are driven by building controls and automation systems.
- Pumps and compressed air also have high potential savings; combined, these comprise more savings than lighting in the industrial sector.
- Natural gas savings potential is highest for space heating in the residential and commercial sectors, while process heating is greatest for the industrial sector.
- Residential natural gas savings are largely driven by furnace early retirement.
- Similar to electricity savings, the natural gas whole building end use is comprised of measures affecting a wide range of another end uses, such as building envelope.
- The industrial sector indirect process heating end use includes measures such as heat exchanging.

Figure 5-14. 2028 Achievable Potential, Cumulative Gross Savings at Meter, by End Use

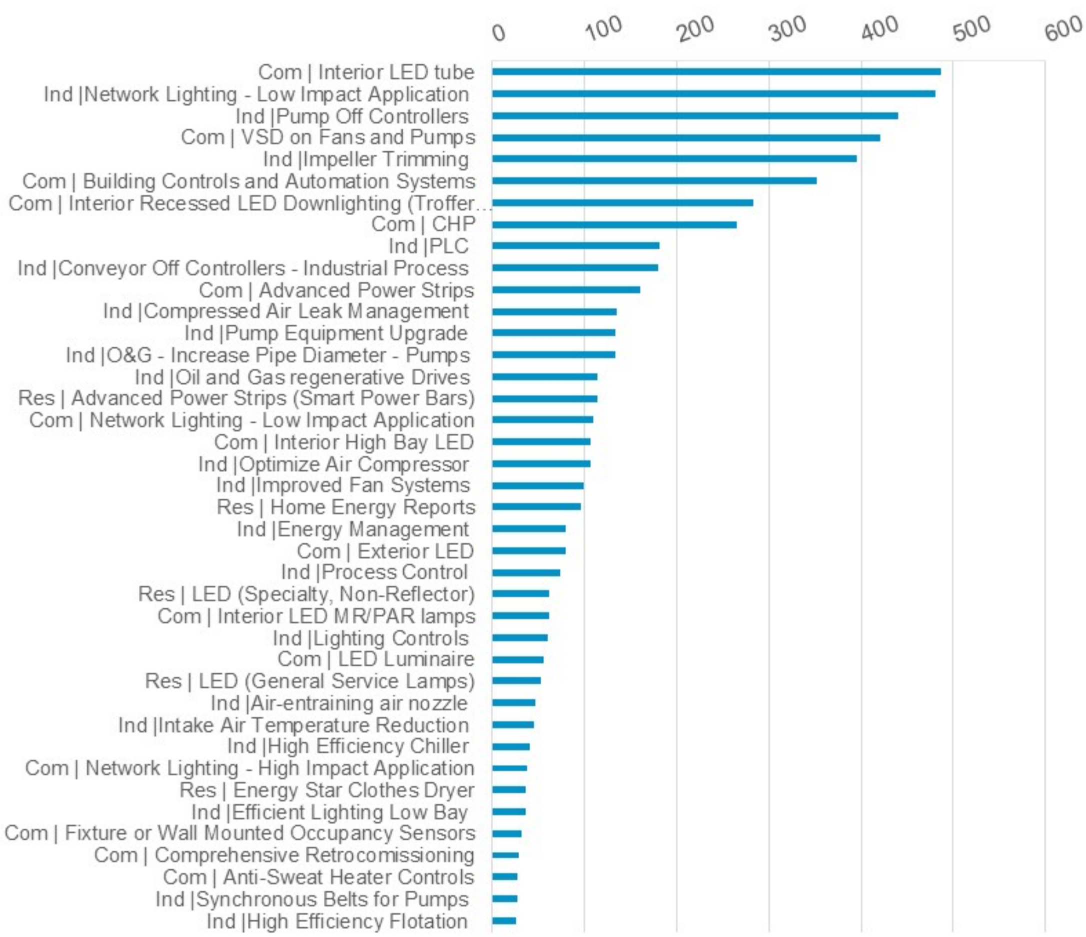


Source: Navigant analysis

5.6 Measure-Level Results

Figure 5-15 presents the top 40 electricity measures in 2028 (cumulative annual savings at the meter) ranked by achievable potential. The top 10 measures come from the lighting, whole building, HVAC fans and pumps, electronics, and pumps end uses, with three of the top 10 measures associated with the lighting end use. Interior LED tubes ranks as the highest impact economic potential measure and remains first in achievable potential.

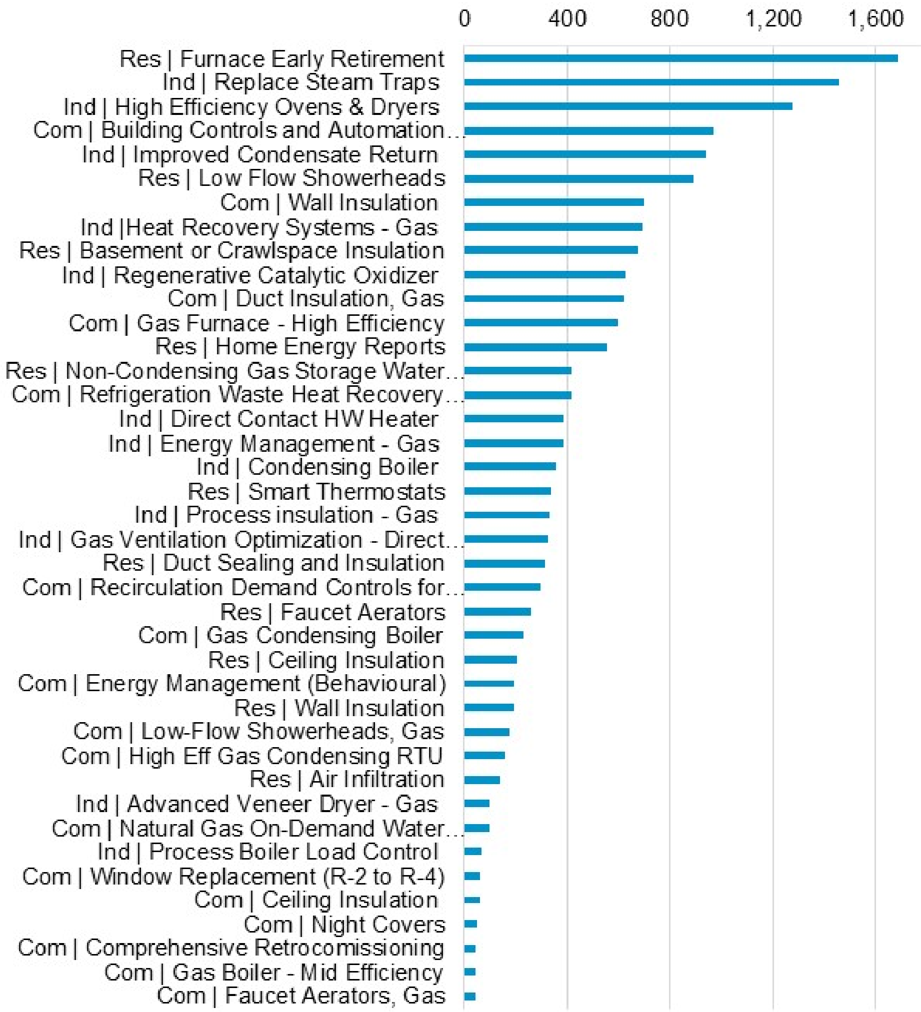
Figure 5-15. 2028 Top 40 Electricity Measures, Achievable Potential, Cumulative Annual Gross Savings at Meter, GWh



Source: Navigant analysis

Figure 5-16 presents the top 40 measures in 2028 ranked by natural gas energy achievable savings potential. The top 10 measures come from the indirect process heating, space heating, direct process heating, water heating, and whole building end-uses, with six of the top 10 measures associated with the indirect process heating and mostly residential space heating end uses.

Figure 5-16. 2028 Top 40 Natural Gas Measures, Achievable Potential, Cumulative Annual Gross Savings at Meter, TJ



Source: Navigant analysis

Table 5-14 ranks the top 20 measures by their potential to reduce GHG emissions over their lifetimes. Three out of the top 10 measures come from the lighting end use, totaling more than 14% of the total lifetime emissions reductions of measures installed during the study period. Cost-effective savings are achieved in every sector and for a broad range of measures.

- Like other jurisdictions, lighting is the highest savings potential and emissions potential reduction representing five of the measures in the top 20.
- Residential savings are dominated by the natural gas consumption of both furnaces and basement insulation.
- Residential lighting savings would have been higher; however, general service lamps are impacted by a change in baseline due to 2020 federal regulations requiring a minimum lamp efficacy (lumens per watt). Networked lighting controls have slower adoption in this sector than in commercial and industrial.
- Industrial (non-oil & gas) natural gas measures' GHG emissions reductions potential are lower than the residential measures but are still potentially strong contributors to avoiding emissions. However, in including oil & gas, the industrial sector has the largest emissions reductions potential.

Table 5-14. 2019-2038 Top 20 Measures for Reducing GHG Avoided Emissions, Total Lifetime tCO_2e, at Generator

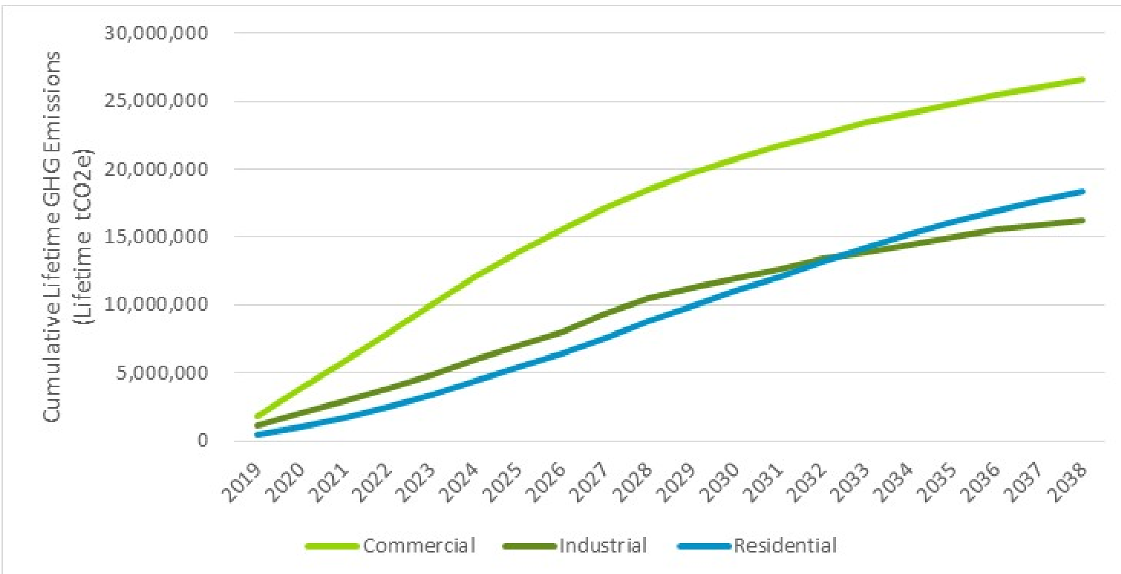
Measure	End Use	2019-2038 GHG Avoided Emissions in Million Lifetime tCO2e	2019-2038 Percentage of Total Emissions Savings
Com | Interior LED tube	Lighting	3.81	6.2%
Res | Furnace Early Retirement Only	Space Heating	3.73	6.1%
Com | Building Controls and Automation Systems - Electric	Whole Building	3.20	5.2%
Com | VSD on Fans and Pumps	HVAC Fans/Pumps	2.77	4.5%
Ind | Network Lighting - Low Impact Application	Lighting	2.49	4.1%
Com | Interior Recessed LED Downlighting (Troffer LEDs)	Lighting	2.30	.3.8%
Res | Basement or Crawlspace Insulation - G	Space Heating	1.83	3.0%
Ind | High Efficiency Ovens & Dryers	Direct Process Heating	1.37	2.2%
Com | Wall Insulation	Space Heating	1.35	2.2%
Com | Building Controls and Automation Systems - Gas	Whole Building	1.34	2.2%
Com | Interior LED MR/PAR lamps	Lighting	1.22	2.0%
Ind | Improved Condensate Return	Indirect Process Heating	1.21	2.0%
Ind | Regenerative Catalytic Oxidizer	Direct Process Heating	1.01	1.7%
Res | Low Flow Showerheads Gas Only	Water Heating	0.97	1.6%
Ind | Improved Fan Systems	Fans and Blowers	0.92	1.5%
Com | Gas Furnace - High Efficiency	Space Heating	0.91	1.5%
Ind | Heat Recovery Systems - Gas	Indirect Process Heating	0.90	1.5%
Com | Duct Insulation, Gas	Space Heating	0.89	1.5%
Res | LED (General Service Lamps) <= 10 Watt LED	Lighting	0.88	1.4%
Res | Home Energy Reports - Electric	Whole Building	0.84	1.4%

Source: Navigant analysis

5.8 Greenhouse Gas Emission Reduction Results

Figure 5-17 details the cumulative lifetime emissions abatement potential throughout the study period (excluding oil & gas). Starting with 2019, this represents the emissions reductions of all measures installed in a year, summed over their useful lifetimes. Each preceding year includes the addition of the prior year(s) savings. As shown in Table 5-14. , the emissions reductions are largely led by the lighting end use.

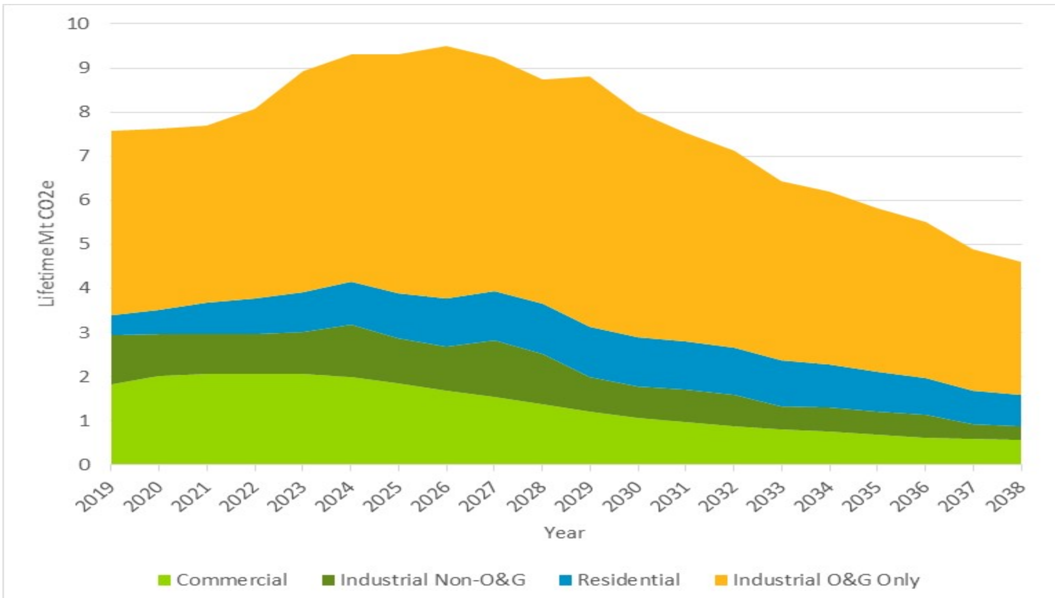
Figure 5-17. 2019-2038 Lifetime GHG Emissions Reduction Achievable Potential at Generator by Sector, Lifetime tCO_2e (excluding Oil & Gas)



Source: Navigant analysis

Figure 5-18 shows the incremental avoided lifetime emissions by sector without oil & gas. When considering industrial oil & gas, oil & gas measures contribute slightly more than half the emissions reductions of the entire portfolio. The initial general upward trend of incremental emissions abated is due to the ramping up of market adoption of the efficient measures. As the market becomes saturated (and the study does not include adoption of yet-to-be market-ready technologies), less units are installed on an annual basis; thus, the incremental lifetime emissions of years following the peak decrease over time.

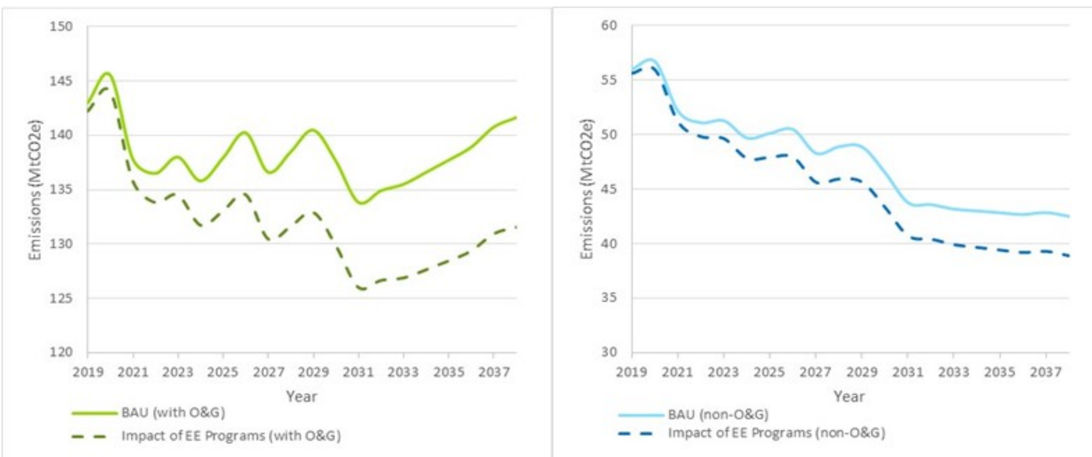
Figure 5-18. Annual Incremental Avoided Lifetime Emissions Potential by Year and Sector, at Generator



Source: Navigant analysis

Figure 5-19 presents the emissions reductions resulting from the reference case achievable potential. These reductions as compared to the BAU case are 7.1% when including the O&G customer segments and 8.6% when excluding O&G. The reference case scenario models the achievable potential most plausible (and reflects current budgetary consideration), which is the program cost of the current Alberta carbon levy of $30 per tCO_2e.[108] This scenario assumes program funding is allocated solely to reduce emissions. While this is not necessarily the approach that is or will be taken for allocating funding, it is considered a somewhat conservative approach to funding energy efficiency programs. It should also be noted that these estimates only account for emission reductions that result from program delivery. Further emission reductions are possible from energy efficiency through the advancement of codes and standards, and other market transformation activities, which can be supported through incentive programs.

Figure 5-19. BAU Emissions Produced vs. Energy Efficiency Program Impact, $MtCO_2e$[109]



Source: Navigant analysis

5.9 Cost-Effectiveness Results

Table 5-15 shows the benefit-cost test ratios for each benefit-cost test in the portfolio. Generally, the benefit-cost test ratios are greater than 1.0 for all benefit-cost test types at the sector and portfolio levels. The TRC is explained in section 4.1. 6.2B.6 provides additional descriptions of the tests:

- **TRC:**[110] *TRC = (avoided costs + market price of carbon)/ (administrator costs + incremental technology costs)*
- **Societal Cost Test (SCT):** *SCT = (avoided costs + other utility benefits + other participant benefits)/ (administrator costs + incremental technology costs)*

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[109] The variable nature of the BAU emissions forecast is due to the expected transition from coal-fired power plants to more natural gas and renewable energy-based power generation. This forecast estimates the year in which coal-fired power plants will either close or be converted to natural gas. Given these are very large facilities, the impact on the BAU forecast is very noticeable and results in an overall emission forecast that reflects several year-over-year step-changes in emissions intensity of the electric grid.

[110] This study does modify the TRC by using the social discount rate, rather than the standard WACC used typically for TRC.

- **Program Administrator Cost Test (PAC[111]):** *PAC = (avoided costs + other utility benefits) / (administrator costs + incentives)*
- **Participant Cost Test (PCT):** *PCT = (incentives + bill reductions) / incremental technology costs*

Table 5-15. Achievable Potential, Portfolio Benefit-Cost Ratios Excluding Oil & Gas and Solar Potential

Year	TRC Test	Societal Cost Test (SCT)	Utility Cost Test (UCT)	Participant Cost Test (PCT)
2019	2.2	3.2	2.5	3.9
2020	2.2	3.2	2.7	4.0
2021	2.2	3.1	2.7	4.1
2022	2.2	3.1	2.6	4.1
2023	2.4	3.4	2.5	4.3
2024	2.5	3.5	2.4	4.4
2025	2.5	3.4	2.4	4.4
2026	2.5	3.4	2.4	4.3
2027	2.5	3.3	2.3	4.2
2028	2.4	3.3	2.2	4.1
2029	2.3	3.1	2.1	4.1
2030	2.3	3.1	2.1	4.0
2031	2.3	3.0	2.0	3.9
2032	2.2	3.0	2.0	3.8
2033	2.2	2.9	1.9	3.8
2034	2.2	3.0	1.9	3.8
2035	2.2	3.0	1.9	3.8
2036	2.2	3.0	1.9	3.8
2037	2.1	2.9	1.8	3.8
2038	2.1	2.9	1.8	3.8
2019-2038	2.3	3.2	2.3	4.1

Source: Navigant analysis

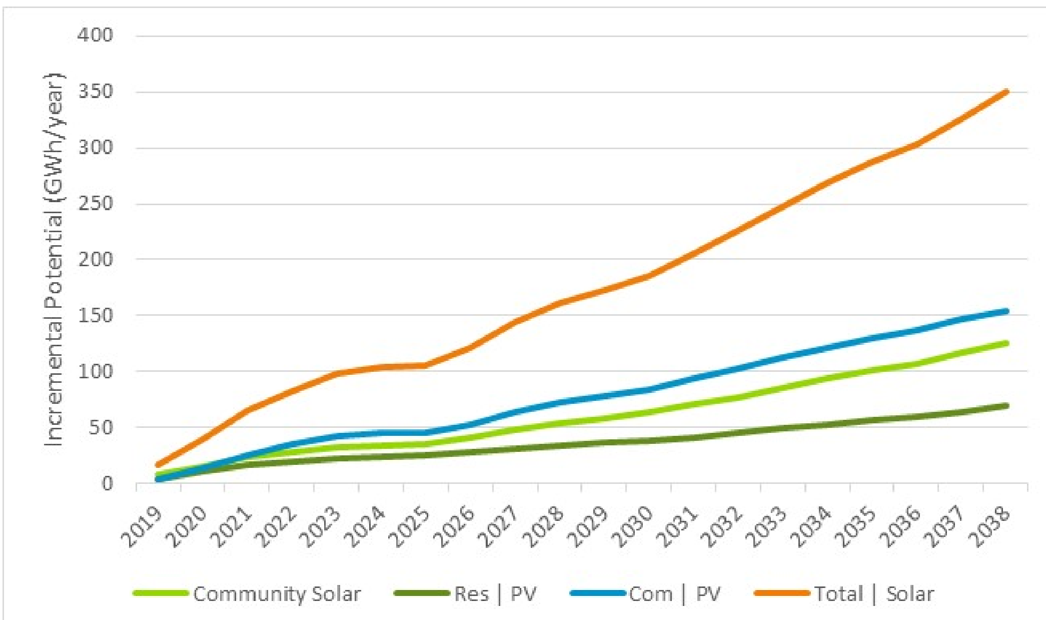
[111] Often called the Utility Cost Test (UCT) when a utility administers the services.

5.11 Generation Results

Figure 5-20 provides the incremental annual gross generation achievable potential at meter for small-scale renewables. The study team did not model generation measures within the industrial oil & gas subsector. The team only included solar PV in the residential and commercial sectors. Other generation—CHP and solar water heating—is captured under the energy efficiency savings estimates.

Community solar shows high potential over the 20 years. However, Navigant recognizes the community solar industry is yet to be developed in Alberta. The financial and market adoption dynamics of this study reveal a strong potential as the solar industry develops to meet this demand. Residential and commercial solar PV is expected to grow over the 20-year timeframe, with most savings from the commercial sector.

Figure 5-20. Electricity Generation Achievable Potential, Incremental Annual Gross Savings at Meter, GWh/year



Source: Navigant analysis

5.12 Sensitivity Analysis

Sensitivity analysis was performed with respect to what were considered to be the highest impact/profile variables. This was carried out by first calculating the "baseline" achievable potential that resulted from running the model using unaltered variables. Next, a single variable was selected adjusted by both increasing and decreasing its values by 25%, holding all other variables constant. The potential was then calculated based on the increase/decrease of the variable to provide bounds on the impact varying this single variable had on the achievable potential. This process was then repeated for each of the selected variables.

Figure 5-21 and Figure 5-22 (including the oil & gas customer segments) detail the results of the sensitivity analysis. Figure 5-21 shows the sensitivity of electric energy achievable potential to the variables shown in the figure, while Figure 5-22 shows the same, but with respect to natural gas achievable potential.

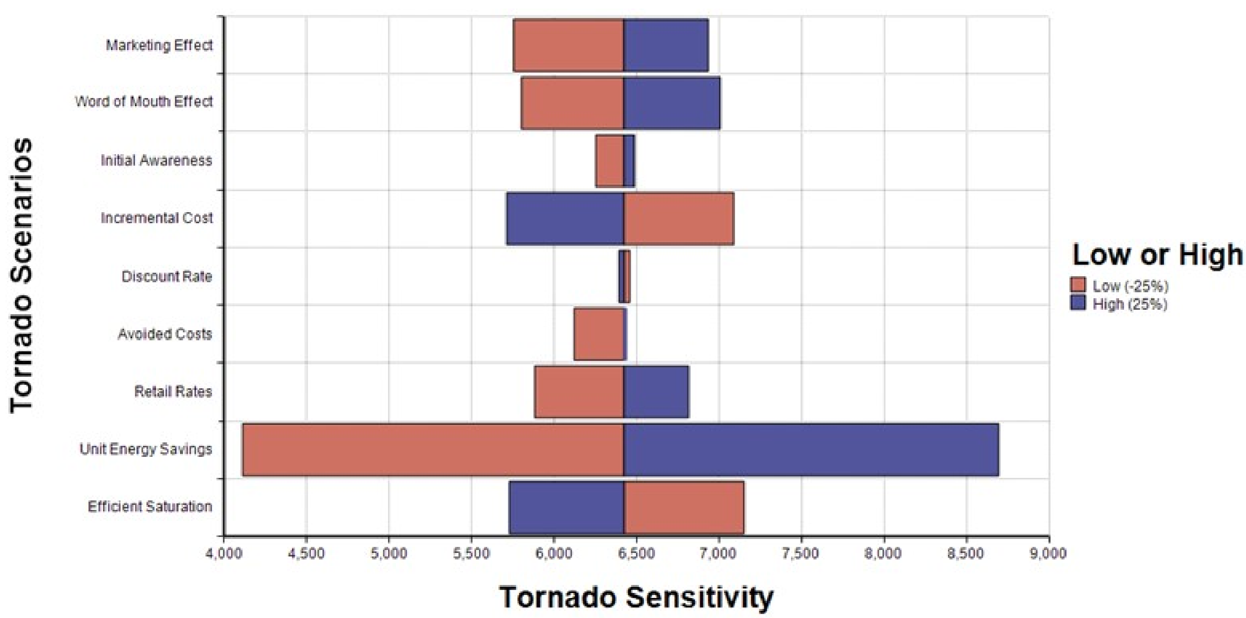
The diffusion parameters, which include marketing effect, word of mouth effect, and initial awareness (see Appendix F), are each evenly distributed about the origin, while initial awareness has a relatively lower impact. This figure shows the results in 2028, halfway through the study period, where diffusion is dictated by word of mouth and marketing. Initial awareness typically has a much larger impact near the beginning of a study, with marketing and word of mouth having smaller impacts, and vice versa as time goes on.

Varying the discount rate by +/-25% has little effect on the achievable potential as varying by this amount is not enough to cause many measures to switch from being economic or changing from non-economic to the opposite. In addition, after measures pass the economic screen, market share for non-competing measures is determined using a simple payback calculation which does not consider discount rates. For competing measures, the discount rate is used only to inform the split of market share amongst the competing measures which has a minimal impact on the overall potential.

Varying avoided costs has minimal effect on potential. The sensitivity of avoided costs is tied to the supply curve of benefit-cost ratios, meaning because there are few measures with benefit-cost ratios close to the economic threshold, the change in potential will be minimal. For a greater sensitivity to avoided costs, more measures would need to be just under or above the threshold where varying the avoided costs would cause these measures to tip one way or the other.

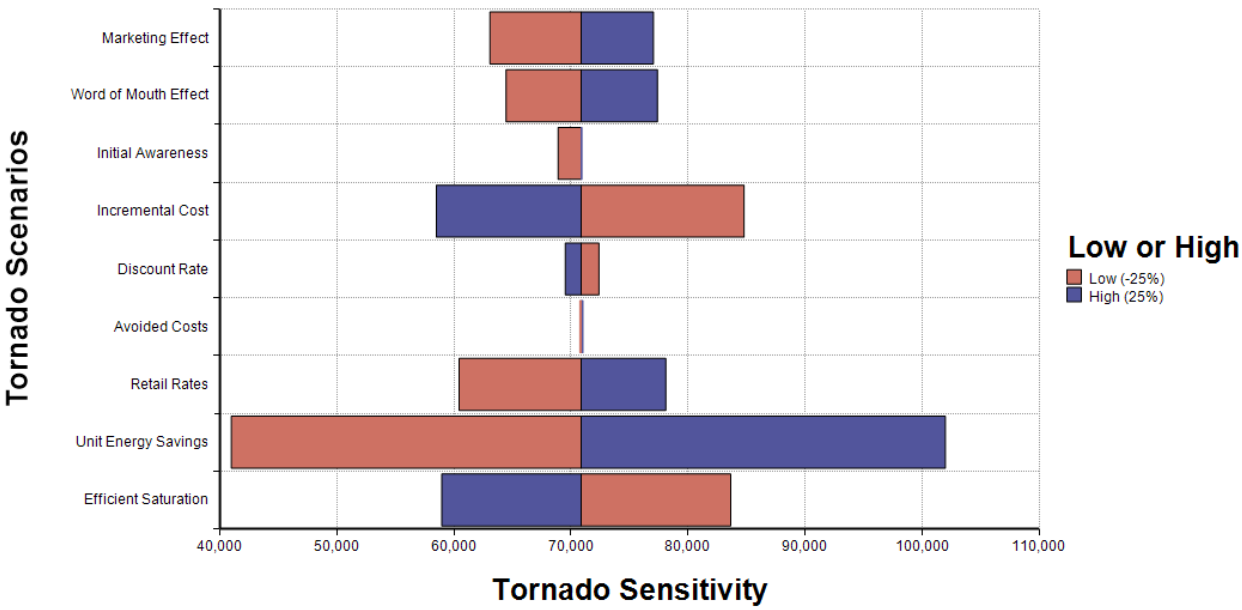
The unit energy savings has a tremendous effect on potential, as it is essentially potential (the difference between baseline and efficient measure energy savings). Thus, if unit energy savings are decreased by 25%, the potential will decrease by at least 25% assuming all the same measures pass the economic screen. However, many measures no longer would pass screening, and, therefore, the market share will be reduced; the same is true when increasing unit energy savings. This also affects all avoided costs of the measure (avoided energy costs and avoided costs of carbon) as these scale with energy savings, so the impact on a measure's cost-effectiveness is much more significant than any other variable.

Figure 5-21. 2028 Cumulative Achievable Electric Potential, Tornado Sensitivity (GWh/year)



Source: Navigant analysis

Figure 5-22. 2028 Cumulative Achievable Natural Gas Potential, Tornado Sensitivity (TJ/year)



Source: Navigant analysis

6. OBSERVATIONS AND INSIGHTS

The results of this potential study are intended to further EEA's ability to develop and target energy efficiency services for Albertans leading to significant GHG emission reductions and bill savings by energy users (excluding transportation). The potential study planning horizon provides directional information for 20 years, from 2019 through 2038. The near-term data will support portfolio and program planning over the next several years.

6.1 Program Planning

Through this potential study, Navigant has provided EEA with a wealth of data to support its energy efficiency and small-scale generation program planning efforts. This data ranges from measure characterization to load shape profiles for peak demand savings calculations, each providing building blocks to defining data inputs for program planning.

The study team derived projected savings goals and the corresponding level of investment in tandem with the potential study results. EEA's portfolio consists of programs, which are comprised of measures. The buildup of the measures into programs and into a portfolio results in a plan to achieve a defined goal at a certain level of investment. The potential study does not provide program-level potential; thus, programmatic design, such as delivery method and marketing strategies, will have implications to the overall savings goals and level of investment. Additionally, near-term savings potential or actual achievable goals at the measure level will vary. The overall mix of measures is directionally considered with the review of historical program participation and an understanding of current Alberta market conditions (with the team members with boots on the ground) to inform the potential study.

Navigant provides the following observations on the potential study's results as input to program planning:

- **Lighting:** Typically, lighting is a high percentage of electricity efficiency portfolios. This study has similar findings; however, there is a move toward LED lighting with advanced lighting controls in all sectors. The remaining potential in residential LED lamps is limited due to projected updates in federal standards. Commercial and industrial lighting provides a large savings potential.
- **Community Solar:** The potential study indicates a significant potential starting in 2019. However, the study team recognizes a pipeline of projects does not yet readily exist in Alberta. Achievable potential is modelled based on known technical and economic conditions in the study period's early years, but does not account for other market barriers to implementation.
- **Financing:** Incorporating financing for energy efficiency measures amounts to electricity savings of 1.7% of total consumption (116 GWh) and natural gas savings of 5.4% (1,629 TJ) across all sectors except oil and gas. Actual acceptance and adoption of financing within Alberta may differ, and the study team's estimates are based on customer acceptance rates to increase adoption from other studies.

6.2 Additional Measures

It is important to note this study was limited in scope since it did not include agricultural and transportation measures. Additionally, this study had limited Alberta-based data regarding specific measure inputs and measures. There are also measures Navigant did not include, but that should be considered for future studies, such as additional financing opportunities, exploring deeper the opportunities for advanced lighting options, benchmarking programs, competition programs, pay for performance programs (such as new home construction exceeding a target or deep retrofits in commercial buildings), waste heat recovery, advanced HVAC retrofits, and industrial process improvements. Future studies can either include specific measures or more broad-based measures to cover holistic savings reductions, such as advanced lighting controls disaggregated to networked/connected lighting controls, and luminaire light level controls. Note the study team did not qualify advanced lighting controls because these were not included in the selected referenced potential studies. Nonetheless, this study limitation should not limit EEA programs from including such emerging technology measures.

APPENDIX A. ADDITIONAL MODEL RESULTS AND INPUT ASSUMPTIONS

Navigant provided the model results and assumptions separately in a set of workbooks. Table A-1 identifies the supplementary workbooks provided to Energy Efficiency Alberta (EEA).

Table A-1. List of Supplementary Workbooks

Name	Description
Base Year Data	Base year 2016 sales and stock data disaggregated to sector, segment, and end use
FlatFile_Output	Full model output for each scenario
FiguresAndTables	Figures and tables for reference scenario
Methodology for Peak Savings	Peak load shape factor calculations
Carbon Intensities and Costs	Analysis supporting use of both a market and social cost of carbon and emissions intensities for electricity and natural gas
Avoided Costs and Billing Rates	Analysis for avoided energy and capacity costs for electricity and natural gas; billing rates for energy users
Measure Details	Measure characterization details
MeasureList	Full and selected measure list by sector; includes descriptions of why a measure was not included in this study

Source: Navigant

Detailed Market Characterization Methodology

A.1.1 End-Use Definitions

Table A-2 provides descriptions of end uses.

Table A-2. Description of End Uses

Segment	End Use	Definition
Residential	Appliances	Large/small appliances including ovens, refrigerators, freezers, clothes washers, etc.
	Electronics	Televisions, computers and related peripherals, and other electronic systems
	Water Heating	Heating of water for domestic hot water use
	Lighting	Interior, exterior, and holiday/seasonal lighting
	Other	Miscellaneous loads
	Space Cooling	All space cooling, including both central air conditioning and room or portable air conditioning
	Space Heating	All space heating, including both primary heating and supplementary heating

Segment	End Use	Definition
Commercial	Cooking	Food preparation equipment including ranges, broilers, ovens, and griddles
	HVAC Fans/Pumps	HVAC auxiliaries including fans, pumps, and cooling towers
	Water Heating	Hot water boilers, tank heaters, and others
	Lighting	Interior, exterior, and holiday/seasonal lighting for main building areas and secondary areas
	Office Equipment	Computers, monitors, servers, printers, copiers, and related peripherals
	Other	Miscellaneous loads including elevators, gym equipment, and other plug loads
	Refrigeration	Refrigeration equipment including fridges, coolers, and display cases
	Space Cooling	All space cooling equipment, including chillers and direct expansion (DX) cooling
	Space Heating	All space heating equipment, including boilers, furnaces, unit heaters, and baseboard units
Industrial	Compressed Air	Air compressors and related equipment
	Fans and Blowers	Fans and blowers for ventilation, combustion, and pneumatic conveyance
	Industrial Process	Industrial processes for various applications not addressed by processing cooling or heating such as mechanical processes like grinding, drilling, or injection molding
	Lighting	Interior, exterior, and seasonal lighting loads
	Material Transport	Feedstock and product movement by conveyance or stackers
	Direct Process Heating	Direct heating systems do not have an intermediate heat transfer medium and the end use includes ovens, dryers, furnaces, and kilns
	Indirect Process Heating	Systems where an intermediate heat transfer medium is used, such as steam or hot water
	Process Compressors	Natural gas (non-air) process compressors
	Pumps	Process pump systems
	Other	Includes all end uses that do not fit under the above-mentioned industrial end uses. Comfort heating and cooling systems are included in the end use together with ventilation systems.

Source: Navigant

A.1.2 Residential Sector

The following sections describe the approach Navigant used to determine electricity and natural gas consumption by segment, the approach used to estimate end-use intensities (EUIs), and the resulting residential household stock.

Base Year EUIs

To develop base year residential EUIs, Navigant took the following steps:

1. Collected Alberta-specific electricity and natural gas consumption by segment and end use for the latest year of available data (2014) from NRCan CEUD[112]
2. Calculated electricity EUIs in kWh/household (HH) and natural gas EUIs (in GJ/HH) using the following formula Equation A-1.

Equation A-1. Residential Base Year End-Use Electric and Natural Gas EUIs

$$EUI = \frac{End\ use\ consumption\ by\ segment}{households\ by\ segment}$$

End-Use Mapping

For most of the end uses the study team modelled in the study, there is a corresponding NRCan end use. For example, Navigant models residential space heating and NRCan captures residential space heating consumption data. However, certain Navigant end uses provide more granularity than NRCan end uses. That is, Navigant chose to model Appliances, Electronics, and Other as residential end uses, while NRCan captures these under the umbrella of Appliances.

To keep the granularity of Navigant end uses, the study team mapped the NRCan Appliances end uses to the corresponding Navigant end uses. This was done by using the relative split in electricity consumption between Appliances, Electronics, and Other from another Canadian utility's service territory as a proxy for Alberta.[113] The team only did this for the electricity fuel type, as it assumes there is no natural gas consumption for the Electronics or Other end use in Alberta.

A sample calculation of the applied methodology for single-family detached homes is shown below. Navigant applied relative end-use consumption factors from Table A-3 to the NRCan Appliances end-use consumption estimate (shown in Appendix A.1.4) to arrive at Alberta-specific consumption estimates for Appliances, Electronics, and Other as in Table A-4.

Table A-3. Single-Family Detached Homes Relative End-Use Consumption for Appliances, Electronics, and Other

End Use	Canadian Utility (FBC) EUI (kWh/HH)	Relative End-Use Consumption per HH
Appliances	3,355	57%
Electronics	1,952	26%
Other	1,510	17%
Total	6,817	100%

Source: Navigant analysis

[112] In the NRCan CEUD, the latest year of available data is 2014, although the base year in this study is 2016. However, this is not an issue as Navigant calibrated the end-use consumption at the segment level to a 2016 sector-level consumption value from the AESO load forecast (electric) and CESAR model (natural gas). The calibration methodology is explained in more detail in Appendix A.1.5.

[113] This breakdown is from another Conservation Potential Review that Navigant conducted for FortisBC Electric in British Columbia. The public report can be found here: https://www.fortisbc.com/About/RegulatoryAffairs/GasUtility/NatGasBCUCSubmissions/Documents/170915_FBC_2016_LTERP_LT_DSM_Plan_Errata_FF.pdf

Table A-4. Single-Family Detached Homes Alberta-specific EUIs for Appliances, Electronics, and Other

NRCan End Use	NRCan EUI (kWh/HH)	Navigant End Uses	Relative End-Use Consumption per HH	Alberta EUI (kWh/HH)
Appliances	3,744	Appliances	57%	2,140
		Electronics	26%	963
		Other	17%	642
Total	3,744	-	100%	3,745

Source: Navigant analysis

A.1.3 Commercial Sector

Segment Mapping

Navigant mapped the CESAR model stock data and consumption data from NRCan to the measure characterization analysis segments from Navigant's prior potential studies. Table A-5 shows how the study team conducted the mapping.

In some instances, multiple CESAR model/NRCan segments corresponded to a singular Navigant segment. For these cases, the study team aggregated stock and consumption data across the segments as needed. For other cases, a single NRCan/CESAR model segment corresponded to multiple Navigant segments. This meant stock and electric/natural gas consumption at the segment/end-use level had to be disaggregated into the corresponding Navigant segments in an appropriate fashion.

Table A-5. Commercial Segment Mapping

CESAR/NRCan Segment[114]	Corresponding Navigant Segment
Wholesale	Warehouse/Wholesale
Retail	Food Retail, Non-food Retail
Warehouse	Warehouse/Wholesale
Cultural	Other
Office	Office
Educational	School, University/College
Health	Hospital
Recreation	Other
Accommodation	Accommodation, Restaurant
Other	Other

Source: Navigant

For the Retail Trade, Educational, and Accommodation CESAR/NRCan segments, the study team disaggregated the data using another Canadian utility's potential study results as a proxy.

[114] While there are slight differences in naming conventions between CESAR and NRCan commercial segments, the segment classification is essentially identical between the two sources. Thus, only CESAR model segment names are shown in the table.

The team used the same approach outlined in Section 0, except the input data from FBC was either stock or consumption at the segment/end-use level. Since FBC is an electricity utility, Navigant relied on internal assumptions based on prior potential studies to arrive at the same disaggregation of consumption for natural gas.

Because the proxy utility data corresponds to British Columbia (BC), Navigant took an additional step to disaggregate the stock for the CESAR/NRCan Accommodation segment. Tourism is a relatively higher economic driver in BC than in Alberta, thus the study team did not want to underestimate commercial floor space attributed to the Restaurant segment in Alberta. To approximate differences in tourism between BC and Alberta, Navigant compared the floor space of the Arts, Entertainment, Recreation NRCan segment between BC and Alberta. This demonstrated that in Alberta, Arts, Entertainment, Recreation composed 2.46% of total Alberta floor space, while in BC the segment composed 2.72% of total BC floor space, a difference of 10% between the provinces (i.e., 2.72% is approximately 10% larger than 2.46%). Navigant used this 10% factor to discount the proportion of floor space attributed to the Navigant Accommodation segment.[115] This methodology is summarized in Table A-6.

Table A-6. Disaggregating Accommodation CESAR/NRCan Segment

CESAR/NRCan Segment	Navigant Segment	FBC Split in Stock (%)	Alberta Split in Stock (%)[116]
Accommodation	Accommodation	81%	73%
	Restaurant	19%	27%

Source: Navigant

Base Year EUI

To develop base year commercial EUIs, Navigant took the following steps:

1. Collected Alberta-specific electricity and natural gas consumption by segment and end use for the latest year of available data (2014) from the NRCan CEUD[117]
2. Calculated electricity EUIs (in kWh/m^2) and natural gas EUIs (in GJ/m^2) using Equation A-2.

Equation A-2. Commercial Base Year End-Use Electric and Natural Gas EUIs

$$EUI = \frac{end\ use\ consumption}{floor\ space\ by\ segment}$$

[115] While the methodology described is only a simple approximation for estimating the difference in tourism between BC and Alberta, is important to note the Accommodation and Restaurant segments combined represent only 5% of total commercial floor space in Alberta. Therefore, using a larger adjustment factor or a different approach to disaggregate the CESAR/NRCan Accommodation segment would have a minimal impact on results.

[116] This column shows the final split in stock after applying the adjustment factor using the Arts, Entertainment, Recreation segment.

[117] In the NRCan CEUD, the latest year of available data is 2014, although the base year in this study is 2016. However, this is not an issue as the study team calibrated the end-use consumption at the segment level to a 2016 sector-level consumption value from the AESO load forecast (electric) and CESAR model (gas). The calibration methodology is explained in more detail in Appendix A.1.5.

End-Use Mapping

For most of the end uses modelled in this study, there is a corresponding NRCan end use. For example, Navigant models commercial water heating and NRCan captures commercial water heating consumption data. However, certain Navigant end uses provide more granularity than NRCan end uses. Navigant chose to model Cooking, Office Equipment, Refrigeration, and Other as commercial end uses while NRCan captures all these end uses under the umbrella of Auxiliary Equipment.

To disaggregate NRCan's Auxiliary Equipment end use into the corresponding Navigant end uses, the study team used FBC CPR results using the same methodology described in Section A.1.2. The team only did this for the electricity fuel type, and Navigant attributed all the natural gas consumption from NRCan's Auxiliary Equipment end use to Navigant's Cooking end use. Natural gas consumption for any of the other end uses (Office Equipment, Refrigeration, and Other) would either be highly unlikely or negligible.

A.1.4 Industrial Sector

Base Year Consumption

The first step in characterizing the industrial sector is developing an estimate of the base year electricity and natural gas consumption by industrial segment.

Oil & Gas Industrial Segments

Navigant downloaded the oil sands, mining, and in-situ and conventional oil & gas production data from the Canadian Association of Petroleum Producers' online Publications and Statistics, including the Statistical Handbook with historical production summaries.[118] The study team extracted historical production summaries from CAPP production summaries and broke them down by mining oil sands, in-situ oil sands, conventional gas, and crude oil.

[118] Canadian Association of Petroleum Producers, *2017 CAPP Crude Oil Forecast, Markets & Transportation*, CAPP, http://www.capp.ca/publications-and-statistics/publications/303440.

The team collected energy intensities corresponding to the input energy required to produce each resource from various sources and assessed them based on their reputation and variance to the average. These energy intensities are shown in Table A-7.

Sources of production energy intensities include:

- *Energy Return on Investment of Canadian Oil Sands Extraction from 2009 to 2015*[119]
- *Alberta Oil Sands Energy Efficiency and GHG Mitigation Roadmap*[120]
- *Trottier Energy Futures Project: Greenhouse Gas Emissions from the Canadian Oil and Gas Sector*[121]

The study team multiplied energy intensities by production data to obtain total end-use energy in terms of electricity and natural gas consumption per resource. The team compared calculated total energy consumption for natural gas and electricity to that reported by Statistics Canada in CANSIM, Table 128-0016. The calculated end-use energy was then scaled to match the CANSIM total reported for each calendar year.

Navigant calculated energy intensities from units provided in sources by converting to GJ per common base units of production. In certain cases, energy intensity was reported as an energy return on energy invested. In this case, the team converted the base unit of production from energy into volume using the following conversion factors:

- Natural gas: 0.0373 GJ per m^3
- Synthetic crude oil: 39.4 GJ per m^3
- Heavy: 40.9 GJ per m^3
- Light: 38.5 GJ per m^3

Table A-7. Oil & Gas Production Energy Intensity (GJ/m^3)

Resource	Energy Intensity (GJ/m^3) per Study		
	Wang	*Suncor*	*Trottier*
Conventional Gas	0.0019	-	0.00112
Conventional Oil	2.05	-	-
Oil Sands (mining, upgraded)	5.63	4.68	-
Oil Sands (mining, raw)	-	1.86	-
Oil Sands (in-situ, upgraded)	8.56	11.41	-
Oil Sands (in-situ, raw)	-	8.6	-

Source: Navigant

[119] Ke Wang, *Energy Return on Investment of Canadian Oil Sands Extraction from 2009 to 2015*, energies, http://www.mdpi.com/1996-1073/10/5/614.

[120] *Alberta Oil Sands Energy Efficiency and GHG Mitigation Roadmap*, Suncor, 2012.

[121] R.L. Evans and Tyler Bryant, *Trottier Energy Futures Project: Greenhouse Gas Emissions from the Canadian Oil and Gas Sector*, Trottier Energy Futures, 2014.

Navigant used findings from the Suncor study to split total energy intensity into electricity and natural gas quantities as in Table A-8 and Table A-9. Because CAPP's production data was split into raw bitumen and upgraded (synthetic crude), the conversion factors for oil sands upgrading were split out from mining and in-situ production.

Table A-8. Oil Sands (In-Situ) Energy Intensity by Fuel, Raw Bitumen (GJ/m^3)

Type	Intensity (GJ/m^3)	Percentage
Electricity	0.5	6%
Fuel Gas	8.1	94%
Total	8.6	100%

Source: Navigant

Table A-9. Oil Sands (Mining) Energy Intensity by Fuel, Raw Bitumen (GJ/m^3)[122]

Production Process	Intensity (GJ/m^3)
Electricity	0.05
Diesel	0.60
Mining (Total)	0.65
Hot Process water	0.50
Electricity	0.40
Steam	0.20
Extraction (Total)	1.10

Source: Navigant

Upgraded (synthetic crude) oil sands from mining and in-situ operations requires an additional process with associated energy end uses documented in Table A-10.

Table A-10. Oil Sands (Upgraded) Energy Intensity by Fuel[123]

Production Process	Intensity (GJ/m^3)
Natural Gas	1.8
Electricity	0.3
Steam	0.6
Total (Upgrading)	2.7

Source: Navigant

The study team assumed steam generation and hot process water to be produced from natural gas combustion. The team assumed a common boiler efficiency of 85% to determine natural gas usage in both processes, and no heat recovery occurs for hot process water production. Using data in Table A-8 through Table A-10, EEA estimated the electricity and natural gas shares of oil sands production.

[122] Suncor, 2012.

[123] Suncor, 2012.

As public data was not available to split conventional oil & gas production into its appropriate electricity and natural gas components, EEA assumed 90% of the production input energy is consumed as natural gas based on internal analysis. Electricity and natural gas shares of energy intensity for the oil & gas segments are shown in Table A-11.

Table A-11. Calculated Electricity and Natural Gas Shares of Energy Intensity

Share (%)	Conventional Oil & Gas	Mining (bitumen)	Mining (upgrading)	In-Situ (bitumen)	In-Situ (upgrading)
Electricity	10%	45%	16%	6%	7%
Natural Gas	90%	44%	71%	94%	93%

Source: Navigant

The study team used energy intensities from Table A-7 and natural gas and electricity shares from Table A-11 to calculate total energy consumption from CAPP historical production, and subsequently as percent shares of the total. Electricity and natural gas percent shares are shown in Table A-12 and Table A-13. The team then used these shares to break down total production consumption reported in CANSIM, Table 128-0016.

Table A-12. Electricity Use Share by Oil Sands Segment

Year	Conventional Oil	Conventional Gas	Oil Sands (Mining)	Oil Sands (In-Situ)
2005	17%	26%	35%	23%
2006	15%	23%	39%	23%
2007	14%	23%	39%	24%
2008	15%	22%	37%	27%
2009	13%	19%	39%	29%
2010	13%	17%	39%	31%
2011	13%	15%	38%	34%
2012	13%	14%	37%	36%
2013	13%	13%	36%	38%
2014	13%	12%	36%	40%
2015	11%	11%	37%	40%
2016	11%	11%	37%	41%

Source: Navigant analysis

Table A-13. Natural Gas Use Share by Oil Sands Segment

Year	Conventional Oil	Conventional Gas	Oil Sands (Mining)	Oil Sands (In-Situ)
2005	18%	28%	17%	37%
2006	17%	26%	19%	38%
2007	16%	25%	19%	40%
2008	16%	24%	17%	43%
2009	14%	21%	18%	47%
2010	13%	19%	18%	50%
2011	13%	16%	18%	53%
2012	14%	14%	17%	55%
2013	14%	13%	16%	57%
2014	13%	12%	16%	59%
2015	12%	12%	17%	60%
2016	11%	12%	17%	61%

Source: Navigant analysis

Non-Oil & Gas Industrial Segments

For the non-oil & gas industrial segments, the study team used StatsCan's CANSim Table 128-0016 as the primary data source to estimate base year (2016) electricity and natural gas consumption.[124] Table A-14 shows how the StatsCan industrial segments were grouped to form this study's industrial segments.

Table A-14. Mapping StatsCan Segments to Navigant's Segments

Navigant Segment	StatsCan (CANSim Table 128-0016) Segment
Chemical	Chemicals and Fertilizer Manufacturing
Pulp and Paper	Pulp & Paper Manufacturing
Other Manufacturing	Refined Petroleum Products Manufacturing
	Iron and Steel Manufacturing
	All Other Manufacturing
Farms	Agriculture

Source: Navigant analysis

End-Use Allocation Factors – Percentage

Unlike the residential and commercial sectors, the industrial sector did not require the estimation of industrial stock. Navigant and EEA developed industrial end-use allocation factors to estimate electricity and natural gas consumption by industrial segment and end use. Table A-15 and Table A-16 show the electricity and natural gas industrial end-use allocation factors, respectively.

[124] CANSim Table 128-0016 provides distinct consumption estimates for natural gas, natural gas liquids (NGLs) and still gas. As this study only focuses on natural gas, the energy consumption associated with NGLs or still gas was not considered.

Navigant used data from different sources in addition to internal data sources to develop end-use allocation factors. The sources are listed as follows (and provided in Section 2.1), along with a description of how these were used to develop allocation factors:

- Canadian Manufacturers & Exporters (CME) 2010 Report: *Improving Energy Efficiency for Alberta's Industrial and Manufacturing Sectors*[125]
    - Contained electricity and natural gas end-use allocation factors for chemical, pulp and paper, and other manufacturing segments.
- FBC CPR Report[126]
    - Provided applicable electricity end-use allocation factors for the conventional oil & gas and oil sands (mining) segments.
    - Informed the development of electricity allocation factors for the farms segment.
- *Alberta Oil Sands Energy Efficiency and GHG Mitigation Roadmap* (Suncor, 2012)[127]
    - Indicated 95% of all energy consumed is to produce hot water or steam for the oil sands (in-situ) segment. This data indicates hot water/steam (i.e., indirect process heating) is the most important end use for this segment. The remaining 5% is from electricity consumption.
    - Similarly, 55% of all energy consumed is to produce hot water or steam for the oil sands (mining) segment, indicating hot water/steam (i.e., indirect process heating) is the most important end use. The remaining 45% is from electricity and diesel consumption.
    - As natural gas is the primary source used to produce hot water/steam, it is assumed indirect process heating will require approximately 80% of the total natural gas consumption for oil sands (mining) and 95% for oil sands (in-situ) segments.
    - The remaining natural gas allocation factors for both oil sands segments are proportional to the allocation factors from the conventional oil & gas end use after accounting for indirect process heating.
    - Oil sands (in-situ) operations require significantly more pumping power than conventional oil & gas. Thus, Navigant assumed the electric power requirement for the pumps end use was twice as much for oil sands (in-situ) compared to conventional oil & gas.
    - The remaining electricity allocation factors (from the referenced FBC CPR report) for oil sands (in-situ) are proportional to the allocation factors from the conventional oil & gas end use after accounting for the pumps end use.
- *Descriptive Analysis of On-Farm Energy Analysis in Canada* (Canadian Agricultural Energy End-Use Data and Analysis Centre, 2000)[128]
    - Informed the development of lighting and space heating (included under the Other end use) electricity allocation factors for the farms segment.
- Navigant's internal data sources
    - Informed development of natural gas allocation factors for conventional oil & gas and farms.

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125 Canadian Manufacturers & Exporters, Improving Energy Efficiency for Alberta's Industrial and Manufacturing Sectors, Canadian Manufacturers & Exporters, 2010, http://ab.cme-mec.ca/download.php?file=geebgbcx.pdf

126 FortisBC, FortisBC Conservation Potential Review, 2017, https://www.fortisbc.com/About/RegulatoryAffairs/GasUtility/NatGasBCUCSubmissions/Documents/170915_FBC_2016_LTERP_LT_DSM_Plan_Errata_FF.pdf.

127 Suncor, "Alberta Oil Sands Energy Efficiency and GHG Mitigation Roadmap," 2012.

128 Canadian Agricultural Energy End Use Data and Analysis Centre, Descriptive Analysis of On-Farm Energy Analysis in Canada, 2000, http://www.usask.ca/agriculture/caedac/pubs/Energy.PDF

Table A-15. Industrial Electric End-Use Allocation Factors

Segment	Indirect Process Heating	Direct Process Heating	Process Cooling	Pumps	Fans & Blowers	Compressed Air	Industrial Process	Lighting	Material Transport	Process Compressors	Other	Total
Conventional Oil & Gas	0%	0%	8%	14%	19%	8%	17%	1%	0%	33%	0%	100%
Oil Sands (Mining)	0%	0%	0%	13%	6%	1%	69%	4%	8%	0%	0%	100%
Oil Sands (In-Situ)	0%	0%	7%	30%	15%	7%	14%	1%	0%	27%	0%	100%
Chemical	0%	0%	3%	16%	11%	2%	63%	1%	4%	0%	1%	100%
Pulp and Paper	2%	2%	1%	31%	13%	19%	1%	2%	24%	0%	5%	100%
Other Manufacturing	1%	17%	7%	13%	8%	14%	13%	3%	15%	0%	10%	100%
Farms	0%	0%	12%	17%	13%	8%	2%	45%	2%	0%	1%	100%

Source: Navigant

Table A-16. Industrial Natural Gas End-Use Allocation Factors

Segment	Indirect Process Heating	Direct Process Heating	Process Cooling	Pumps	Fans & Blowers	Compressed Air	Industrial Process	Lighting	Material Transport	Process Compressors	Other	Total
Conventional Oil & Gas	5%	10%	0%	0%	0%	0%	75%	0%	0%	0%	10%	100%
Oil Sands (Mining)	80%	2%	0%	0%	0%	0%	16%	0%	0%	0%	2%	100%
Oil Sands (In-Situ)	95%	1%	0%	0%	0%	0%	4%	0%	0%	0%	1%	100%
Chemical	36%	63%	0%	0%	0%	0%	0%	0%	0%	0%	2%	100%
Pulp and Paper	65%	19%	0%	0%	0%	0%	2%	0%	0%	0%	14%	100%
Other Manufacturing	27%	48%	0%	0%	0%	0%	1%	0%	0%	0%	24%	100%
Farms	50%	0%	0%	0%	0%	0%	0%	0%	0%	50%	0%	100%

Source: Navigant

The team's final step of the industrial analysis applied the end-use allocation factors to the industrial sales calculated in the previous section. Table A-17 shows the breakdown of electricity sales by end use and industrial segment.

Table A-17. Alberta Industrial Base Year Sales by Segment and End Use – GWh

Segment	Compressed Air	Fans and Blowers	Industrial Process	Lighting	Material Transport	Process Heating	Product Drying	Pumps	Process Cooling	Space Heating	Total
Potash Mines	286	182	727	104	390	26	-	805	-	78	2,598
Northern Mines	37	27	316	16	27	52	-	77	-	6	558
Steel	56	104	129	18	-	257	-	41	1	3	610
Oil & Gas	1,638	989	2,260	63	-	-	-	1,292	411	11	6,664
Pulp and Paper	257	33	246	12	23	32	206	103	4	21	938
Manufacturing	214	209	584	191	38	31	-	125	63	175	1,630
Farms	49	90	45	271	14	-	-	170	53	118	810

Source: Navigant

A.1.5 Base Year and BAU forecast Calibration

Base Year Calibration

After developing an initial set of base year EUIs and consumption estimates on a segment/end-use level (as described in Appendices A.1.2 to A.1.4), it is important to calibrate the results to a source providing representative values of electricity and natural gas consumption within Alberta. For this study, the study team calibrated electricity results to sector-level base year consumption from the AESO, and natural gas results to sector-level base year consumption from the CESAR model. The CESAR model was used because it is a reputable source and provided the residential and commercial stock estimates used within this study. In general, it is valuable to minimize the number of sources used for this type of calibration exercise so the underlying assumptions are consistent across the sectors analyzed within this study.[129] To ensure that the CESAR model's estimates are representative of Alberta, Navigant compared it to Alberta Energy Regulator's (AER's) marketable natural gas demand values for the base year (2016) and determined there is alignment between the two sources.[130]

Table A-18 shows the difference in sector-level consumption between Navigant's initial estimates using NRCan consumption data and the sector-level estimates from AESO and the CESAR model. The team used this difference as an adjustment factor to calibrate base year sales on a segment level, and to calibrate base year EUIs for the residential and commercial sectors. The calibration ensured the energy profile (i.e., EUIs and consumption estimates) at the most granular segment/end-use level reconciled with the sector-level energy consumption estimated by AESO and the CESAR model. The bottom-up method used for this study resulted in calibration factors close to 1.0, indicating the various data sources and analysis used for granular modeling were sufficient.

Table A-18. Base Year (2016) Calibration Factors

Sector	Initial Electric Use Estimate (GWh)	Target Electric Use (GWh)	Electric Calibration Factor	Initial Natural Gas Use Estimate (PJ)	Target Natural Gas Use (PJ)	Natural Gas Calibration Factor
Residential	10,848	9,925	0.91	187	165	0.88
Commercial	15,315	14,900	0.97	111	103	0.92
Industrial	49,357	51,653	1.05	1,183	1,183	1.00

Source: Navigant

BAU forecast Calibration

To ensure the BAU forecast is representative of Alberta, it is important to calibrate the results to relevant sector-level load forecasts from reliable sources. For the electricity fuel type, Navigant calibrated the residential and commercial BAU forecast to a modified AESO 2017 Long-Term Outlook (LTO) load

[129] Base year calibration was not done for industrial natural gas consumption. The CESAR model did not provide estimates for industrial natural gas consumption, and Navigant determined it was not essential to calibrate to an alternative source.

[130] The AER marketable natural gas demand for 2016 and subsequent years (up till 2027) can be found here: https://www.aer.ca/data-and-publications/statistical-reports/natural-gas-demand

forecast.[131] For the natural gas fuel type, the team calibrated the residential and commercial BAU forecast to the CESAR model's sector-level natural gas forecast. The CESAR model was used because it is a reputable source and provided the residential and commercial stock forecast used within this study. In general, it is valuable to minimize the number of sources used for this type of calibration exercise, so the underlying assumptions are consistent across the sectors analyzed within this study. To ensure the CESAR model's natural gas forecast is representative of Alberta, Navigant compared it to AER's marketable natural gas demand forecast, which is available till 2027, and found that is alignment between the two sources.[132]

To calibrate the residential and commercial BAU forecasts with their respective load forecasts, Navigant split the BAU forecast into four separate blocks of time and applied a calibration factor to the EUI trends for each block.[133] The magnitude of the calibration factor depended on the difference between the BAU forecast and load forecast pre-calibration, and was calculated using Excel's goal-seek function to minimize the difference between the BAU forecast and load forecast at the end of the forecast horizon. There calibration factors resulted in five sets of EUI trends:[134]

- Residential electricity end uses
- Residential natural gas end uses
- Commercial electricity non-lighting end uses
- Commercial electricity lighting end use[135]
- Commercial natural gas end uses

Table A-19 provides the calibrated electricity and natural gas EUI trends for the residential and commercial sectors. The EUI trends are reflective of the overall change in the sector-level AESO electric load forecast and the CESAR model's natural gas consumption forecast.

Table A-19. EUI trends for the Residential and Commercial Sectors

Sector	Fuel Type	EUI Trend (% Change in End-Use Consumption Year over Year)			
		2019-2022	2023-2027	2028-2032	2033-2038
Residential	Electric	-0.092%	-0.064%	-0.045%	-0.032%
Residential	Natural Gas	-0.069%	-0.014%	-0.003%	-0.001%
Commercial	Electric – Non-Lighting End Uses	0.724%	1.051%	1.526%	2.215%
Commercial	Electric – Lighting End Uses	-1.000%	-1.000%	-1.000%	-1.000%
Commercial	Natural Gas	-1.523%	-1.555%	-1.588%	-1.621%

[131] See Section A.1.1 for a description of how a modified AESO 2017 LTO load forecast was developed.

[132] The AER marketable natural gas demand forecast (up till 2027) can be found here: https://www.aer.ca/data-and-publications/statistical-reports/natural-gas-demand

[133] See Sections 2.2.1 and 2.2.2 for a description of how EUI trends were developed.

[134] BAU case calibration was not needed for industrial electricity and natural gas consumption because the segment-level BAU case projections are derived directly from the industrial electric load forecast.

[135] The report includes an explanation of the different EUI trends for lighting and non-lighting.

Table A-20 demonstrates that there is alignment between the sector-level BAU forecasts post-calibration and the sector-level load forecasts.

Table A-20. Comparison of Post-Calibration BAU forecast to Load Forecast

Sector	2038 Natural Gas Sales (TJ)			2038 Electric Sales (GWh)		
	Ref Case	Load Forecast	Diff. (%)	Ref Case	Load Forecast	Diff. (%)
Residential	209,073	209,279	0%	12,514	12,517	0%
Commercial	91,648	91,650	0%	21,869	21,882	0%
All Industrial	1,797,392	1,797,392	0%	69,123	69,123	0%
Total	2,098,113	2,098,321	0%	103,505	103,523	0%

Source: Navigant-modified AESO 2017 LTO Load Forecast

The AESO 2017 LTO load forecast was modified for several reasons:

- The AESO 2017 LTO only provides a provincial-level forecast, while a sector-level forecast was necessary.
- The AESO 2017 load forecast contains embedded assumptions on energy efficiency, as the BAU forecast was designed to represent consumption prior to assumptions on energy efficiency, and Navigant needed a load forecast without assumptions on energy efficiency. Through discussions between Navigant, EEA, and AESO, the team took steps to factor out the 2017 LTO's embedded assumptions on energy efficiency.

The following steps were taken to develop a sector-level electric load forecast from the 2017 LTO's provincial load forecast.

Step 1: Apply a suitable multiplying factor to estimate the provincial load forecast without any embedded assumptions on energy efficiency. These multiplying factors (shown in Table A-21) were developed by Navigant and EEA, supplemented with input from the AESO.

Table A-21. Alberta Provincial Load Forecast (GWh)

Year	AESO 2017 LTO Provincial Load Forecast (with energy efficiency assumptions)	Multiplying Factor	AESO 2017 LTO Provincial Load Forecast (without energy efficiency assumptions)
	[A]	[B]	[C] = [A] * [B]
2019	85,467	1.003	85,723
2020	86,536	1.003	86,796
2021	87,295	1.003	87,557
2022	87,872	1.003	88,136
2023	88,253	1.003	88,518
2024	89,223	1.008	89,937
2025	89,939	1.013	91,108
2026	90,677	1.018	92,309
2027	91,682	1.023	93,791
2028	92,708	1.028	95,304
2029	93,389	1.033	96,471
2030	94,304	1.038	97,888
2031	95,287	1.043	99,384
2032	96,350	1.048	100,975
2033	96,809	1.053	101,940
2034	97,586	1.061	103,539
2035	98,216	1.069	104,993
2036	98,967	1.077	106,587
2037	99,209	1.085	107,642
2038	99,791	1.090	108,772

Source: Navigant

Step 2: Calculate the percentage difference between the AESO's 2014 LTO oil sands production forecast and CAPP's 2017 oil sands production forecast. Apply this percentage difference to the 2014 LTO's oil sands load forecast to calculate an updated oil sands load forecast. The updated oil sands forecast is shown in column E of Table A-22.

Table A-22. Updated AESO 2014 LTO Oil Sands Forecast[136]

Year	All Oil Sands 2014 LTO Outlook (kbbl/day)	All Oil Sands June 2017 CAPP Forecast (kbbl/day)	Percentage difference between [A] and [B]	2014 LTO Oil Sands Load Forecast (GWh)	Updated 2014 LTO Oil Sands Load Forecast (GWh)
	[A]	[B]	[C] = ([B] / [A]) - 1	[D]	[E] = [D] * (1 + [C])
2019	4,528	3,060	-32%	27,334	18,469
2020	4,750	3,122	-34%	29,631	19,473
2021	4,917	3,164	-36%	31,117	20,021
2022	5,068	3,199	-37%	32,009	20,201
2023	5,240	3,254	-38%	32,711	20,313
2024	5,411	3,296	-39%	33,386	20,338
2025	5,566	3,353	-40%	33,734	20,321
2026	5,718	3,420	-40%	34,260	20,493
2027	5,849	3,433	-41%	34,637	20,332
2028	5,971	3,469	-42%	35,008	20,338
2029	6,084	3,575	-41%	35,183	20,675
2030	6,197	3,669	-41%	35,428	20,977
2031	6,303	3,737	-41%	35,611	21,113
2032	6,398	3,806	-41%	35,807	21,300
2033	6,477	3,876	-40%	35,913	21,493
2034	6,546	3,948	-40%	36,040	21,737

Source: Navigant

Step 3: Calculate an updated Alberta Internal Load (AIL) forecast, after updating the 2014 LTO's forecast of grid losses. The AIL is defined as the total energy flowing through Alberta's electric grid, including behind-the-fence energy generation and grid losses.

[136] The 2014 LTO does not forecast data beyond 2034. For 2035-2038, the percentage difference in the year 2034 was used.

Step 4: Calculate the percentage of residential, commercial, and industrial load using the updated 2014 LTO's sector-level load forecast. These percentages are shown in Table A-23.

Table A-23. Sector-Level Breakdown of the Alberta Internal Load

Year	Residential	Commercial	Industrial	Losses
	[A]	[B]	[C]	[D]
2019	13%	20%	63%	5%
2020	12%	19%	64%	5%
2021	12%	19%	65%	5%
2022	12%	19%	65%	5%
2023	12%	19%	65%	5%
2024	12%	19%	65%	5%
2025	12%	19%	65%	5%
2026	12%	19%	65%	5%
2027	12%	19%	64%	5%
2028	12%	19%	64%	5%
2029	12%	19%	64%	5%
2030	12%	19%	64%	5%
2031	12%	19%	64%	5%
2032	12%	20%	64%	5%
2033	12%	20%	64%	5%
2034	12%	20%	64%	5%
2035	12%	20%	64%	5%
2036	12%	20%	64%	5%
2037	12%	20%	64%	5%
2038	12%	20%	64%	5%

Source: Navigant

Step 5: Disaggregate the modified provincial 2017 LTO forecast from Step 1 (i.e., forecast without embedded assumptions on energy efficiency) using the percentage split from Step 4. This produces a sector-level load forecast based on the 2017 LTO's load forecast, shown in Table A-24.

Table A-24. Alberta Sector-Level Load Forecast

Year	Residential (GWh)	Commercial (GWh)	Industrial (GWh)	Losses (GWh)
	[A]	[B]	[C]	[D]
2019	10,465	16,129	52,107	3,907
2020	10,231	15,868	53,805	3,981
2021	10,280	16,040	55,323	4,079
2022	10,255	16,132	56,268	4,141
2023	10,297	16,300	56,777	4,183
2024	10,361	16,512	57,047	4,215
2025	10,372	16,660	57,247	4,239
2026	10,514	17,024	58,088	4,311
2027	10,637	17,353	58,747	4,371
2028	10,738	17,644	59,494	4,433
2029	10,916	18,076	60,292	4,507
2030	11,083	18,499	61,138	4,584
2031	11,182	18,807	61,839	4,643
2032	11,301	19,162	62,710	4,714
2033	11,458	19,585	63,552	4,790
2034	11,622	20,021	64,463	4,869
2035	11,738	20,370	64,915	4,917
2036	11,915	20,829	65,797	4,997
2037	12,082	21,122	66,721	5,067
2038	12,266	21,443	67,735	5,144

Source: Navigant

APPENDIX B. INPUT ASSUMPTIONS

B.1 Measure List and Characterization Assumptions

See the *EEA_MeasureList* and *EEA Measure Details* Excel workbook for granular measure inputs to the model. This workbook provides the following items:

- Data dictionary for the variables provided per measure (Section 2.3.1.1 provides descriptions of key variables)
- Example calculations that define the calculations for technical potential estimates
- Tabs of all the energy efficiency measures characterized for the study by sector
- Load shape factors description is provided in Appendix D
- Baseline and efficiency consumption multipliers are provided for measures that have a change in efficiency due to codes and standards
- Baseline and efficiency cost multipliers are provided for measures that have a change in costs over time

B.2 Alberta Economic Indicators

Table B-1 summarizes the Alberta economic indicators from the Alberta Energy Regulator (AER) and Statistics Canada (CANSIM Table 326-0020).

Table B-1. Major Alberta Economic Indicators

Parameter	2016	2017	2018	2019-2026
Real GDP growth (%)	-2.80	1.80	1.90	2.50
Inflation Rate (%)	1.20	1.80	2.00	2.00
Exchange Rate (US$/CAD$)	0.75	0.73	0.75	0.8

Source: AER ST98-2017 (AER's ST98): Alberta's Energy Reserves & Supply/Demand Outlook (ISSN 1910-4235), *http://aer.ca/data-and-publications/statistical-reports/st98*

Exchange Rate
For any measure costs translated from sources in the U.S., the study used AER's ST98 forecast of 1.25 CAD = 1 USD.[137]

Inflation Rate
The inflation rate used for this study is 2%, sourced from AER's ST98 forecast.

[137] Bank of Canada - https://www.bankofcanada.ca/rates/exchange/legacy-noon-and-closing-rates/; the 2017 exchange rate averaged at $0.77. Over the forecast period, the exchange rate is expected to stabilize at $0.85. Therefore, a value of $0.80 was selected for this study.

B.3 Avoided Costs and Billing Rates

B.3.1 Summary

This analysis is the first energy efficiency potential study of its kind for EEA. With this consideration, the study team chose a simple approach to the estimation of avoided costs. EEA will explore using more sophisticated methodologies for future studies. The different components of utility system benefits included in the avoided costs estimate are summarized in Table B-2.

Table B-2. Summary of EEA 2017 Avoided Costs, Utility System Benefits of Energy Efficiency

Avoided Cost Component	Description	Electricity	Natural Gas
Energy	Energy charge to the consumer	✓	✓
Capacity	Avoided cost of generating capacity	✓[2]	✘
Transmission & Distribution (T&D)	Value of avoiding or deferring the construction of additional transmission and distribution assets	✘	✘
Ancillary Services	Value of avoided ancillary services[138] required to operate	✘	✘
Environmental Compliance	Avoided cost of compliance with existing and future environmental regulations	✓[2]	✓[3]
Demand Reduction Induced Price Effects (DRIPE)	Value of energy or capacity market price mitigation or suppression resulting from reduced customer demand	✘	✘
Utility Non-Energy Benefits (NEBs)	Value of cost savings to a utility stemming directly from energy efficiency programs[139]	✘	✘
Avoided Cost of Renewable Portfolio Standards (RPS)	Value of a reduced cost of compliance with renewable portfolio standards as electricity sales decrease	✘	✘

1. After losses
2. Included in energy price
3. Carbon levy applied separately

Source: ACEEE, "Everyone Benefits: Practices and Recommendations for Utility System Benefits of Energy Efficiency", June 2015

[138] Include reactive power and voltage support, spinning reserves, supplemental reserves, generator imbalance, energy imbalance, regulation and frequency response, and schedule, system control, and dispatch. "FERC: Guide to Market Oversight - Glossary." 15 Mar. 2016, https://www.ferc.gov/market-oversight/guide/glossary.asp. Accessed 6 Sep. 2018.

[139] Could include reduced arrearages, bad debt write-offs, terminations and reconnections, customer calls, collection notices, safety-related emergency calls, rate discounts, and insurance savings. "Utility System Benefits of Energy Efficiency - International Energy Agency." http://www.iea.org/topics/energyefficiency/multiplebenefits/UtilitySystemBenefitsofEnergyEfficiencyCurrentExperienceintheUS.pdf. Accessed 6 Sep. 2018.

The sources Navigant used to estimate avoided costs are listed in Table B-3.

Table B-3. Sources for 2017 Avoided and Billing Costs[140]

Component	Source
Natural Gas Price	AER[2] AER ST98-2017
Electricity Price	AESO 2017 Tariff Application
Energy Charges	AUC, MSA
Transmission Rates	AESO, 2017 Tariff Application
Distribution Rates	AUC, MSA
Pipeline Rates	NEB

Source: Navigant

The gas price used in this analysis was the annual average price of the AECO-C hub, in nominal Canadian dollars. Prices from Henry Hub were initially considered for the calculation, including a forecast by the Government of Alberta in their “March 2017 Economic Outlook”, as the Henry Hub price is used as the price standard across North America; however, the AECO-C hub price is a better representation of natural gas prices in Alberta. The first half of the forecasted AECO-C price data is taken directly from the forecast released by Alberta Energy Regulator (AER). This forecast is published on-line as “ST-98: Alberta’s Energy Reserves and Supply/Demand Outlook”.

The forecast released by the Alberta Energy Regulator only extends through 2026, so gas prices were needed for 2027 through 2037. Navigant used the Henry Hub nominal spot price from 2027 through 2037 to calculate the annual growth rate of the Henry Hub price for each year. The price data used to calculate the growth rate is from the U.S. Energy Information Administration (EIA) Annual Energy Outlook 2017. As the representative price for North America, Navigant found it appropriate to use the change in Henry Hub price as an estimate for the change in the AECO-C hub price. For the calculation, the final gas price for each year after 2026 is the gas price from the previous year multiplied by the Henry Hub growth rate.

140

- Alberta Electric System Operator, 2017 Tariff Application (AUC Proceeding 22093)
- Alberta Energy Regulator, ST-98-2017: Alberta’s Energy Reserves & Supply/Demand Outlook (ISSN 1910-4235)
- Alberta Utilities Commission, "Current rates electricity - Alberta Utilities Commission." http://www.auc.ab.ca/Pages/current-rates-electric.aspx. Accessed 10 Nov. 2017
- Alberta Market Surveillance Administrator, Retail Billing Tool 2016 Public.xls
- Alberta Market Surveillance Administrator, 2017-11-03 Retail Statistics.xls
- Nova Gas Transmission Ltd., L 2018 Interim Rates, Effective January 1, 2018 (http://www.tccustomerexpress.com/854.html)

The potential study used the avoided costs and billing rates provided in Table B-4.

Table B-4. Summary of Avoided and Billing Costs

Year	Avoided Costs for Distribution-connected Customers		Avoided Costs for Transmission-connected Customers		Billing Rates for Distribution-connected Customers		Billing Rates for Transmissions-connected Customers	
	Electric ($/kWh)	Natural Gas ($/MJ)	Electric ($/kWh)	Natural Gas ($/MJ)	Electric ($/kWh)	Natural Gas ($/MJ)	Electric ($/kWh)	Natural Gas ($/MJ)
2017	0.028	0.004	0.022	0.003	0.088	0.006	0.027	0.003
2018	0.054	0.004	0.043	0.003	0.115	0.006	0.047	0.003
2019	0.062	0.004	0.049	0.003	0.129	0.007	0.054	0.003
2020	0.079	0.004	0.062	0.003	0.151	0.007	0.068	0.004
2021	0.089	0.004	0.070	0.003	0.165	0.007	0.076	0.004
2022	0.091	0.004	0.072	0.004	0.169	0.008	0.078	0.004
2023	0.093	0.005	0.073	0.004	0.173	0.008	0.079	0.004
2024	0.086	0.005	0.068	0.004	0.167	0.008	0.074	0.004
2025	0.087	0.005	0.069	0.004	0.170	0.009	0.075	0.004
2026	0.097	0.005	0.077	0.004	0.185	0.009	0.083	0.005
2027	0.099	0.006	0.079	0.005	0.190	0.009	0.085	0.005
2028	0.102	0.006	0.080	0.005	0.194	0.010	0.087	0.005
2029	0.103	0.006	0.081	0.005	0.198	0.010	0.088	0.005
2030	0.104	0.006	0.082	0.005	0.201	0.011	0.090	0.005
2031	0.107	0.006	0.085	0.005	0.207	0.011	0.092	0.006
2032	0.108	0.007	0.085	0.005	0.209	0.011	0.093	0.006
2033	0.110	0.007	0.087	0.006	0.213	0.011	0.095	0.006
2034	0.112	0.007	0.088	0.006	0.217	0.011	0.096	0.006
2035	0.114	0.007	0.090	0.006	0.222	0.012	0.098	0.006
2036	0.116	0.007	0.091	0.006	0.226	0.012	0.100	0.006
2037	0.117	0.007	0.093	0.006	0.230	0.012	0.101	0.006
2038	0.120	0.007	0.095	0.006	0.235	0.012	0.103	0.007

Source: Navigant

B.3.2 Background

Avoided Costs Definition

The total avoided cost is the marginal cost avoided by society (participants and nonparticipants) through a reduction in energy usage. Cost-effectiveness from this perspective is evaluated using the total resource cost (TRC) test, which includes the avoided cost as the societal benefit of conservation. Costs included in the TRC are costs to purchase and install the energy efficiency measure (incremental to base measure costs) and costs of administering the energy efficiency program.

Utility System Benefits

Avoided cost is traditionally thought of as energy and capacity,[141] but other benefits can be substantial and extend to all ratepayers in a utility system through reduced rates in later years—not just to participants in energy efficiency programs. Considering all utility system benefits while screening programs will improve the attractiveness of energy efficiency as an investment and a low-cost resource. While avoided energy and capacity costs are a critical component, utility system benefits are more than just these avoided costs.

Other potential utility system benefits could include increased reliability, reduced utility risk, and reduced exposure to commodity price fluctuations (i.e. price-hedging). Exclusion of one or more of these benefits will adversely affect the screening process and narrow the range of potential programming.

Billing Savings

It is important to note avoided costs are not billing savings, which are the energy bill savings realized to the participant through reduced energy consumption and incentives received. Bill savings are used to assess cost-effectiveness from the perspective of the participant (the participant cost test or PCT). The PCT functions similarly to a simple payback calculation, which determines how many years it takes to recover the costs of purchasing and installing a device through bill savings.

[141] Defined in FERC Rulemaking (1980) as "incremental costs of electric energy, capacity, or both."

B.3.4 Quantification

Methodologies

There is no standard or generally accepted methodological approach to calculating utility system benefits. In U.S. states lacking specific methodological approaches, significant differences can even exist between utilities. These differences in assumptions, methodologies, and benefits greatly affect the net present value of the benefits in cost-effectiveness testing.[142] Methodologies used for quantifying utility system benefit component are summarized in Table B-5.

Table B-5. Utility System Benefit Methodologies

Avoided Cost	Methodology	Range of Values*
Energy	-Forward wholesale price forecast -Integrated Resource Planning (IRP)	$0.024 – 0.19/kWh
Capacity	-Construction cost of new marginal generation -Forward capacity market	$22 – 433/kW/year
T&D	-System modeling	$0 – 200/kW/year
Ancillary Services	-Typically included in other components	NA
Environmental Compliance	-Included in energy cost -Forecasted emission prices	Depends on regulation
DRIPE	-Statistical analysis -Market simulation modeling	Energy: $0 – 0.024/kWh/year Capacity: $0.62 - $34/kW/year
NEBs	-Fixed percentage of total benefits -Utility or measure specific estimation	$3.70 – 64/participant/year**
Avoided Cost of RPS	-Forecasted prices for Renewable Energy Credits (RECs)	$0.50 – 9.82/MWh

*From ACEEE, 2015. Nominal values in USD.
**Low-income residential customers
Source: Navigant

In general, time- and area-varying avoided costs estimates can provide more accurate signals to guide investment in energy efficiency than average avoided costs.

Challenges

While it is generally agreed there are significant utility system benefits associated with energy efficiency, some components of avoided cost are difficult to quantify (i.e. NEBs, T&D). Obstacles include data transparency, information availability, and complexity of the analysis or modeling.

[142] For example, energy and capacity DRIPE could reasonably represent 14% of total program cost. (ACEEE, 2015)

B.4 GHG Emissions Intensity

This section includes the GHG emissions intensity values for electricity and natural gas. Ideally, theses value would vary by time of year and over time. Future studies (or program planning analysis) can consider providing more granular analysis.

Natural Gas Emissions Intensity

Navigant used the value for tCO_2e/GJ, as documented in the *Government of Alberta's Carbon Offset Emissions Handbook,* for this study.[143] Using from the handbook Table 1 (global warming potentials) and Table B-6 (emissions factors for combustion of natural gas) "Residential, Construction, Commercial/ Institutional, Agriculture" emission factors, the team calculated the emissions intensity for natural gas according to the following table.

Table B-6. Natural Gas Emissions Factor

Specified Gas	100-year Global Warming Potential[144]		Emissions Factor (g/m^3)		Conversion Factor	Natural Gas Emissions Intensity
CO_2	1	X	1,918	X	26.853 m^3 = 1 GJ of natural gas[145] and 1,000,000 g = 1 tonne	0.0518 tCO_2e / GJ of natural gas
Methane	25		0.037			
Nitrous Oxide	298		0.035			

Source: Navigant

Electric Emissions Intensity

The emissions intensity associated with generating energy is directly related to the composition of a region's energy generation types and the capacity at which each type is utilized. The intensity of electricity changes over time and is influenced by what is operating on the margin, future builds and historical builds, capacity factors, etc.

Ideally, the research team should consider the marginal energy providers, not the baseload. This data is not currently available. However, to calculate emissions intensity calculations, EEA developed a calculator used in conjunction with capacity supply mix projections. The calculator functions as follows:

1. Identify historical generation capacities by type
2. Forecast load growth by generation type
    a. **Coal:** Consider coal plant phaseout timeline
    b. **Renewables:** Forecasted based on multiple Alberta-based sources including AUC, CANWEA, and AESO's Renewable Energy Program procurement.

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143 Alberta Government, *Carbon Offset Emission Factors Handbook*, http://aep.alberta.ca/climate-change/guidelines-legislation/specified-gas-emitters-regulation/documents/CarbonEmissionHandbook-Mar11-2015.pdf.

144 http://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=CA taken from the IPCC's Fourth Assessment Report – Errata 2012, http://www.ipcc.ch/report/ar4/wg1/.

145 Natural Resources Canada, "Natural Gas: A Primer," http://www.nrcan.gc.ca/energy/natural-gas/5641.

3. **Forecast generation by type:** Calculated by multiplying installed capacities by their respective capacity factors
4. **Grid average emissions intensity (tCO_2e/MWh):**
    a. Multiplied each type of energy generated by its associated emissions factors to obtain annual emissions
    b. Divided the sum of annual emissions by the total energy produced

The resulting analysis is presented in Table B-7.

Table B-7. CO_2e Emissions Intensity Projections

Year	EEA's Intensity (tCO_2e/MWh)
2017	0.76
2018	0.72
2019	0.72
2020	0.72
2021	0.61
2022	0.58
2023	0.58
2024	0.53
2025	0.53
2026	0.53
2027	0.47
2028	0.47
2029	0.47
2030	0.42
2031	0.36
2032	0.35
2033	0.34
2034	0.33
2035	0.32
2036	0.31
2037	0.31
2038	0.30

Sources: EEA analysis of supply mix and emissions intensities, Historical Capacities: http://www.auc.ab.ca/pages/annual-electricity-data.aspx, CanWEA provided historical wind farm installations, Coal Phase-Out: http://www.pembina.org/reports/out-with-the-coal-in-with-the-new.pdf

For projections of emissions intensities beyond 2031, the study team calculated average rates of change in the intensities and reduced these at a declining rate for the following 15 years; the team then reduced these at a constant rate for the remainder of the study (-0.01tCO_2e/MWh, then -0.005tCO_2e/MWh, and then -0.002tCO_2e/MWh, through 2063.

B.5 Cost of Carbon[146]

There are two pricing structures for carbon: the social price or the market price. This study uses the market price of carbon because Navigant believes it best reflects the market and policy environment in which this potential study is conducted. As mentioned in the Social Cost of Carbon section, the awareness and acceptance of the use of a social cost of carbon are low as the social cost of carbon estimates how society should value GHG emissions and not how the market values emissions. For this reason, the market price of carbon was used when generating all results *except* for those which reference the societal cost test. Figure B-1 is a comparison, adjusted for inflation, of Environment Canada's estimate of a social cost of carbon to the market price of carbon as stated by provincial and federal policy.

[146] US Environmental Protection Agency, "The Social Cost of Carbon," Climate Change, https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html.

Government of Alberta, *Climate Leadership Report to Minister*, https://www.alberta.ca/documents/climate/climate-leadership-report-to-minister.pdf.

EnviroEconomics, "The Cost and GHG Implications of WCI Cap and Trade in Ontario," https://www.enviroeconomics.org/single-post/2015/04/13/The-Cost-and-GHG-Implications-of-WCI-Cap-and-Trade-in-Ontario.

ICF Consulting Canada, *Long-Term Carbon Price Forecast Report*, Ontario Energy Board, https://www.oeb.ca/sites/default/files/uploads/OEB-LTCPF-Report-20170531.pdf.

Government of Canada, "Government of Canada Announces Pan-Canadian Pricing on Carbon Pollution," https://www.canada.ca/en/environment-climate-change/news/2016/10/government-canada-announces-canadian-pricing-carbon-pollution.html.

International Energy Agency, *World Energy Outlook 2015*, https://www.iea.org/publications/freepublications/publication/WEO2015.pdf

US Environmental Protection Agency, "Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis – Under Executive Order 12866" https://www.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf.

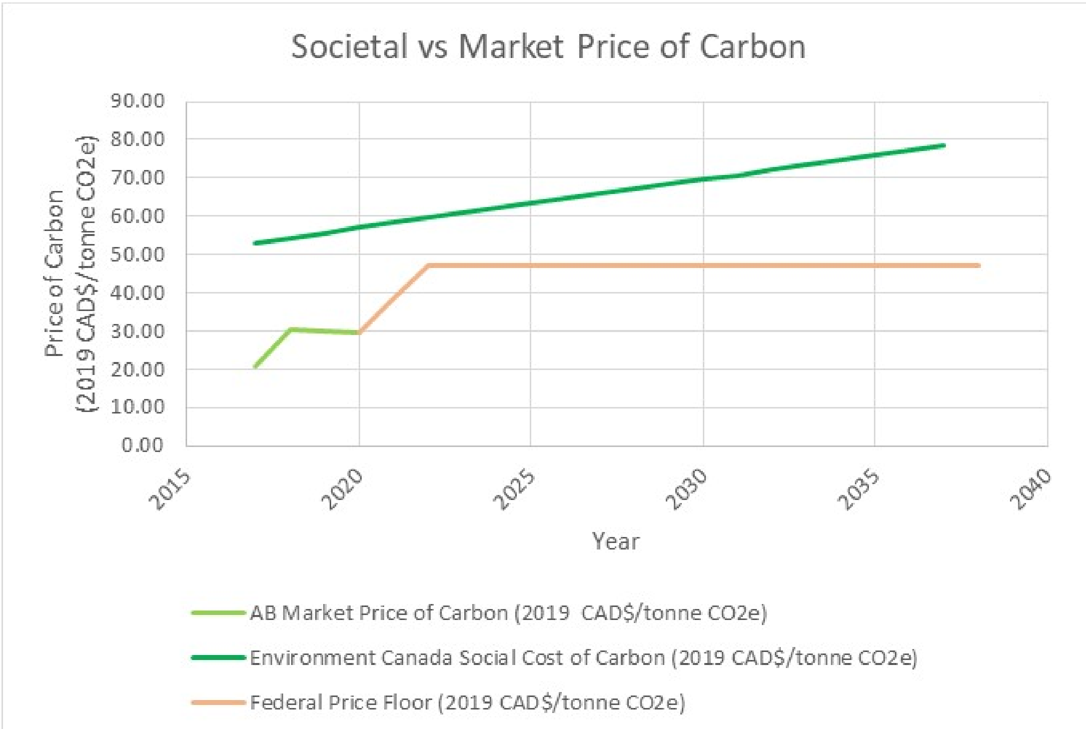
Government of Canada, "Technical Update to Environment Canada's Social Cost of Greenhouse Gas Estimates," Environment and Climate Change Canada, http://ec.gc.ca/cc/default.asp?lang=En&n=BE705779-1.

OANDA, "Average Exchange Rates," https://www.oanda.com/currency/average.

Morgan Friedman, "Inflation Calculator sourced from annual *Statistical Abstracts of the US,"* https://westegg.com/inflation/.

Government of Canada, "Consumer Price Index, by province (Canada)," Statistics Canada, http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/econ09a-eng.htm.

Figure B-1. Comparative, Societal vs. Market, Price of Carbon in 2019 (Real) Canadian Dollars



http://www.ec.gc.ca/cc/default.asp?lang=En&n=BE705779-1, AB Market Price of Carbon: https://www.alberta.ca/climate-carbon-pricing.aspx, https://www.canada.ca/en/services/environment/weather/climatechange/technical-paper-federal-carbon-pricing-backstop.html
Source: Environment Canada Social Cost of Carbon:

The market price of carbon is used when evaluating the economics of investing in energy savings strategies. The modified TRC test incorporates a market price of carbon for all natural gas consumption, but not electricity, as there is a different mechanism for carbon pricing in the electricity sector, and the way in which carbon prices flow through to consumers will depend on market conditions going forward.

Market Cost of Carbon

The market prices of carbon shown in Figure B-1 are also provided in Table B-8.

Table B-8. Market Price of Carbon Projections

Year	AB Market Price of Carbon (2019 CAD$/tCO$_2$e)
2017	20.81
2018	30.60
2019	30.00
2020	29.41
2021	38.45
2022	47.12
2023	47.12
2024	47.12
2025	47.12
2026	47.12
2027	47.12
2028	47.12
2029	47.12
2030	47.12
2031	47.12
2032	47.12
2033	47.12
2034	47.12
2035	47.12
2036	47.12
2037	47.12

Sources: https://www.alberta.ca/climate-carbon-pricing.aspx, https://www.canada.ca/en/services/environment/weather/climatechange/technical-paper-federal-carbon-pricing-backstop.html

B.6 Cost-Effectiveness Calculations

The National Standard Practice Manual (NSPM)[147] provides guidelines on how to select the appropriate cost test for a jurisdiction's policies and goals for reducing energy loads.

[147] National Efficiency Screening, *National Standard Practice Manual for Assessing Cost-Effectiveness of Energy Efficiency Resources*, https://nationalefficiencyscreening.org/wp-content/uploads/2017/05/NSPM_May-2017_final.pdf.

Cost-Effectiveness Tests

The NSPM refers to the generic test as the resource value test (RVT). The RVT serves as the test to assess cost-effectiveness of efficiency resources relative to a jurisdiction's applicable policy goals. However, there can be value in assessing cost-effectiveness of efficiency resources from perspectives represented by other tests. Each value stream quantified in the potential model is assigned as either a benefit, cost, transfer (not included in the cost test calculation), or not applicable for each cost test. The following cost tests, typically resulting in a ratio of benefit to cost, are considered in the DSMSim potential model and reported in this study:

- **TRC:**[148] Measures the net benefits and costs of a program including both the participants' and the program administrator's (combined stakeholder) benefits and costs. The benefits are meant to be the sum of the avoided costs of the supply-side resources avoided or deferred including the market price of carbon. The costs encompass the cost of the measures/equipment installed, and the costs incurred by the program administrator (or utility if administrating the program). The TRC informs public debate regarding efficiency resource acquisition and transmission infrastructure planning.

  TRC = (avoided costs + market price of carbon)/ (administrator costs + incremental technology costs)

- **Societal Cost Test (SCT):** Measures the net benefits and costs of a program including both the participants' and the program administrator's benefits and costs, and externalities such as emissions which are addressed by using the social cost of carbon.

  SCT = (avoided costs + other utility benefits + other participant benefits)/ (administrator costs + incremental technology costs)

- **Program Administrator Cost Test (PAC[149]):** Measures the net costs of a program as a resource option based on the costs incurred by the program administrator (including incentive costs), excluding any net costs incurred by the participant. The PAC informs decisions regarding which efficiency programs to prioritize if all cost-effective resources will not be acquired.

  PAC = (avoided costs + other utility benefits) / (administrator costs + incentives)

- **Participant Cost Test (PCT):** The measure of the quantifiable benefits and costs to participants due to participation in a program. PCT informs decisions regarding how much funding could or should be invested to acquire cost-effective savings.

  PCT = bill reductions / (incremental technology costs -incentives)

- **Rate Impact Measure (RIM):** Measures what happens to utility customer bills or rates due to changes in utility revenues and operating costs caused by the program.

  RIM = avoided costs / (administrator costs + incentives + bill reductions)

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[148] This study does modify the TRC by using the social discount rate, rather than the standard WACC used typically for TRC.

[149] Often called the Utility Cost Test (UCT) when a utility administers the services.

Table B-9 summarizes the cost test definitions and the inputs used in the model.

Table B-9. Cost-Effectiveness Framework

Value Stream	TRC	SCT	PAC	PCT	RIM
Avoided Costs	Benefit	Benefit	Benefit	N/A	Benefit
Incentives	Transfer	Transfer	Cost	Benefit	Cost
Lost Revenue	Transfer	Transfer	N/A	Benefit	Cost
Administrative Costs	Cost	Cost	Cost	N/A	Cost
Technology Incremental Costs	Cost	Cost	N/A	Cost	N/A
Externalities[150]	Benefit[151]	Benefit	N/A	N/A	N/A

Source: Navigant

Table B-10 presents the simplified formula for each of the five benefit/cost tests.

Table B-10. Benefit-Cost Test Formulas

Cost Test	Formula	Key of Terms	
Program Administrator Cost Test (PAC)	*PAC = (A + B) / (D + E)*	A = PV Avoided Costs	E = PV Incentive Costs
Participant Cost Test (PCT)	*PCT = G) / (F-E)*	B = PV Other Utility Benefits	F = PV Technology Costs
Rate Impact Measure Cost Test (RIM)	*RIM = A / (D + E + G)*	C = PV Other Participant Benefits	G = PV Bill Reductions
Total Resource Cost Test (TRC)	*TRC = (A + B + C + H) / (D + F)*	D = PV Administrator Costs	H = Externalities
Societal Cost Test (SCT)	*SCT = (A + B + C + H) / (D + F)*	PV = Present Value	

Source: Navigant

[150] Externalities include: Avoided Emissions Value [$/year] = Gas Savings [therms/year] * (CO_2 Price [$/ton] * CO_2 Intensity [ton/therm] + SOx Price [$/ton] * SOx Intensity [ton/therm] + NOx Price [$/ton] * NOx Intensity [ton/therm])

[151] May include emissions if there is a market price; in the case of Alberta, this is the carbon levy.

B.6.2 Reporting Cost-Effectiveness Summary

Table B-11 provides the values Navigant used for each cost-effectiveness test and the description of its use. The following section describes the selected discount rate described in more detail in the following section.

The selected screening and reporting metrics are based on EEA's strategic objectives. EEA's perspective is based on societal benefits and cost-effective based on the carbon levy. All other metrics are also reported for reference.

Table B-11. Cost-Effectiveness Screening and Reporting Values

Indicator Type	Screening			Reporting	
Description	GHG emissions	Cost	Social responsibility	EEA perspective	Customer perspective
Metric	Measure cost per tCO_2e	Modified TRC[152]	SC	PAC	PC
Carbon price	Market Rate*	Market Rate*	Social Cost of Carbon	Market Rate*	Market Rate*
Discount rate	Societal discount rate (3%)**			7%**	5.39%**
Uses	Assessing performance against EEA's mandate (GHG emissions reduction)	Assessing performance against EEA's level of investment	Assessing performance against global damages and managing climate change risk	Assessing performance against corporation; Communications	Assessing performance against customers; Communications

* Market rate, as defined by Government plans (e.g., carbon levy)
** All discount rates are real discount rates
Source: Navigant

[152] The modification to the TRC was using the societal discount rate, rather than the market rate.

B.8 Discount Rates[153]

This section describes the alternatives, assumptions, and calculations for the choice of discount rate for EEA.

For utility/regulatory analysis the same discount rate typically is used for all tests, the weighted average cost of capital (WACC) of the utility (utility discount rate). However, as suggested in the NSPM, Navigant proposed that different discount rates be used:

- **Societal discount rate:** Typically, the lowest since the value of future benefit is high
- **Utility WACC:** Set closer to the interest rate of government bonds or the utility cost of capital which results in energy efficiency resources that reflect the time value to utility shareholders
- **Customer discount rate:** Based on the cost of borrowing

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[153] Alberta Electric System Operator, "ID #2011-005T, Discount Rates for the ISO Tariff, https://www.aeso.ca/rules-standards-and-tariff/tariff/id-2011-005t-discount-rates/.

Alberta Utilities Commission, Decision 20371-D01-2015, 2016 Generic Cost of Capital: Application for Finalization of 2016 Approved Return on Equity and Capital Structures, July 8, 2015. Available at http://www.auc.ab.ca/applications/decisions/Decisions/2015/20371-D01-2015%202016.pdf

Bank of Canada, "Government of Canada LT Benchmark Bond Yield (V122544), Canadian Bond Yields: 10 Year Lookup," November 2017, https://www.bankofcanada.ca/rates/interest-rates/canadian-bonds/.

California Energy Commission, *Time Dependent Valuation of Energy for Developing Building Efficiency Standards*, http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cedocuments/Title24_2013_TDV_Methodology_Report_23Feb2011.pdf.

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US Environmental Protection Agency, *Guide to Resource Planning with Energy Efficiency*, https://www.epa.gov/sites/production/files/2015-08/documents/resource_planning.pdf.

Government of Alberta, *Economic Outlook, 2017-20 Fiscal Plan, 2017 Budget*, available at https://open.alberta.ca/dataset/e46d1308-612d-4f47-8801-507ae3f8a88d/resource/d6dc3745-f9d2-46da-901f-861a88c2f3a0/download/fiscal-plan-economic-outlook-1.xlsx.

RAP, *Hidden Barriers to Efficiency: The Treatment of Discount Rates and Energy Efficiency Costs in EU Policy Scenarios,* http://www.raponline.org/wp-content/uploads/2016/05/rap-discountratesee-2015-may.pdf.

Peter Spiro, *The Social Discount Rate for Provincial Government Investment Projects*, https://ssrn.com/abstract=2259707, http://www.peterspiro.com/Social_Discount_Rate.pdf.

David Burgess G.P. Jenkins, *Discount Rates for the Evaluation of Public Private Partnerships*, McGill-Queen's University Press, 2010.

Statistics Canada, Table 187-8002, Historical (Real-Time) Releases of Quarterly Statement of Changes in Financial Position, by North American Industry Classification System (NAICS), Selected Financial Ratios and Selected Seasonally Adjusted Components.

White House. *Circular No. A-94, Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs.* https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/circulars/A94/a094.pdf. Also referenced in Circular A-4. https://www.whitehouse.gov/omb/circulars_a004_a-4.

For this study, EEA used three rates: (1) societal discount rate, (2) WACC for the program administrator (de-facto utility), and (3) customer discount rate that is the average of the discount rates used in the other Canadian province potential studies and the Independent Electric System Operator's (IESO's) discount rate.

Choosing the Appropriate Discount Rate

The discount rate essentially reflects a time preference, which is the relative importance of short-term versus long-term costs and benefits. The choice of discount rates is critical for long-term cost-effectiveness analysis, especially when calculating benefits for long-lived efficiency resources such as energy efficiency. To choose the discount rate, it is important to answer the following questions:

1. What are the policy goals?
2. How relevant is the customer discount rate?
3. How relevant is the societal discount rate?
4. How relevant is the utility's WACC?
5. Is there another rate to consider?
6. What are the risk implications based on the selected rate?

The choice of discount rate for efficiency analysis should reflect the perspective represented by the cost-effectiveness test in use. The U.S. Department of Energy's and EPA's National Action Plan on Energy Efficiency (NAPEE, 2007, 5-4)[154] states that, for:

- **SCT:** Use societal discount rate
- **UCT, TRC, and RIM:** Use utility WACC[155]
- **PCT:** Use customer discount rate

For risk management, it is recommended the resource-specific risks are addressed separately for each resource type, rather than embedded in a discount rate. Discount rates are applied to all resources in a cost-effectiveness analysis. There may be situations where the costs or benefits do not properly reflect resource-specific risks. For example, the full set of risks associated with valuing the avoided costs may not be forecast accurately. Therefore, choosing to apply a low risk discount rate to reflect the net-risk benefits of energy efficiency resources may result in compensating for those benefits, which otherwise would not be accounted for in the inputs to the analysis.

Social Discount Rate

The study team uses 3% (real) for the social discount rate[156] which reflects typical choices made by jurisdictions in Canada and the United States. The central federal rate uses this social discount rate to

[154] US Environmental Protection Agency, "National Action Plan for Energy Efficiency," https://www.epa.gov/energy/national-action-plan-energy-efficiency.

[155] Except EEA is using the societal discount rate for TRC, hence this is considered a modified TRC. EEA is a public entity and not beholden to utility investor return expectations.

[156] Note the values provided here are in real terms, unless specifically stated.

discount damages resulting from GHG emissions (see the social portion of Appendix B.5). Any future studies should examine implications to EEA's future program designs.

Customer Discount Rate

The customer discount rate is the nominal value of 7.39%, and applied to the PCT. This value was derived by averaging the discount rates used in the other potential studies Navigant performs for Canadian clients, along with the IESO nominal discount rate of 6.00%.[157] One discount rate is used for all sectors, residential, commercial, and industrial. This is consistent with the approach most of other jurisdictions use for cost tests and potential studies.

WACC

The Alberta Utilities Commission (AUC) uses WACC methodology in its financial regulation. From the AUC regulatory filing and the benchmark data, the cost of equity can vary from 5.8% to 8.75%. EEA chose to use 7% (real) as the WACC for the program administrator discount rates.

Table B-12 provides the use of discount rates by screening and reporting metrics.

Table B-12. Use of Discount Rates by Screening and Reporting Metrics

Indicator Type	Screening		Reporting		
Description	GHG emissions	Cost	Social responsibility	EEA perspective	Customer perspective
Metric	TRC (per tCO_2e)	TRC	SC	PAC*	PC
Discount rate (real)	Societal discount rate (3%)			WACC (7%)	Customer discount rate (5.39%)

*PAC is uniquely defined by EEA as a system-wide energy efficiency programs administrator
Source: Navigant

[157] Independent Electricity System Operator, *Conservation & Demand Management Energy Efficiency Cost Effectiveness Guide*, http://www.ieso.ca/-/media/files/ieso/document-library/conservation/ldc-toolkit/cdm-ee-cost-effectiveness-test-guide-v2-20150326.pdf?la=en.

APPENDIX C. INTERACTIVE EFFECTS OF EFFICIENCY STACKING

The report's results assume that all measures are implemented in isolation from one another and that the measures do not include adjustments for interactive effects from efficiency stacking. Interactive effects from efficiency stacking are different from cross end-use interactive effects (e.g., efficient lighting affects heating/cooling loads), which are present regardless of stacking assumptions and are included in the reported savings estimates. This appendix describes the challenges related to accurately determining the effects of efficiency stacking, and why Navigant has modelled savings as though measures are implemented independently from one another.

C.1 Background on Efficiency Stacking

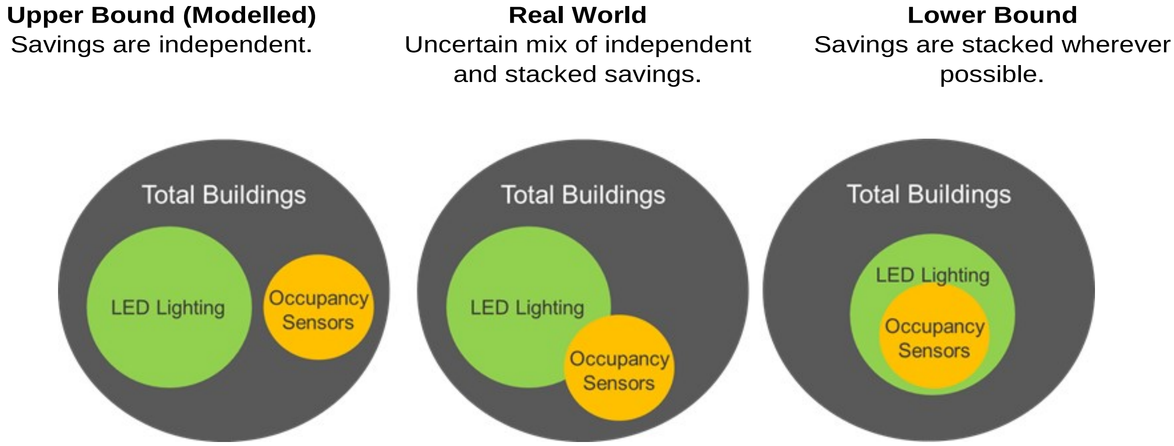
When a home or business installs two or more measures that impact the same end-use energy consumption in the same building, the total achievable savings is less than the sum of the savings from those measures independently. For example, in isolation, the installation of LED lighting might save 40% of electricity consumption relative to baseline linear fluorescent fixtures, while occupancy sensors might save 25% of electricity consumption relative to fixtures without occupancy sensors. However, if both LED fixtures and occupancy sensors are installed in the same facility, the savings from the LED lighting decrease due to the reduced lighting operating hours caused by the occupancy sensors.

Navigant generalizes this concept by referring to measures that convert energy as engines (boilers, light bulbs, motors, etc.), and by referring to measures that affect the amount of energy an engine must convert as drivers (insulation, thermostats, lighting controls, etc.). Anytime an engine and driver are implemented in the same building, the expectation is savings from the engine measure will decrease.[158]

[158] In practice, it does not matter whether one assumes the engine's savings decrease or the driver's savings decrease, as the final savings result is the same. In this discussion, Navigant chose to always reduce the savings from the engine measures, while holding the savings from the driver measures fixed.

Figure C-1 provides an illustration of three different efficiency stacking approaches. The modelled approach assumes no overlap in measure implementation and no efficiency stacking, which leads to an upper bound on savings potential. The opposite of the modelled approach is to assume all measures are stacked wherever possible, which provides a lower bound on savings. Lastly, there is the real-world approach where some measures are implemented in isolation and others are stacked. However, the data is simply not available to accurately estimate the savings from the real-world approach.

Figure C-1. Venn Diagrams for Various Efficiency Stacking Situations



Source: Navigant

The area of the colored circle represents the number of buildings with a given savings opportunity. Overlapping circles indicate a building has implemented both measures.

C.2 Illustrative Calculation of Savings after Efficiency Stacking

For a simplistic scenario looking at only two measures it is possible to determine the stacked savings from the lower bound approach, which assumes efficiencies are stacked wherever possible. To find the LED lighting savings relative to the baseline after stacking:

1. Find the complement of the occupancy sensor savings percentage.

   Occupancy Sensor Savings Complement = 100% - Occupancy Sensor Savings

   Occupancy Sensor Savings Complement = 100% - 25% = 75%

2. Reduce the LED lighting unstacked savings by the complement of the occupancy sensor savings.

   Stacked LED Lighting Savings = Unstacked LED Lighting Savings X Occupancy Sensor

   Savings Complement Stacked LED Lighting Savings = 40% x 75% = 30%

3. Find the greatest percentage of buildings where LED lighting and occupancy sensor stacking is possible.

   % of Buildings with Stacking = Buildings with Occupancy Sensors / Buildings with LED lighting x 100%

   % of Buildings with Stacking = 145,300 / 720,200 x 100% = 20.2%

4. Calculate the LED lighting weighted average savings across all buildings with occupancy sensors.

Weighted LED Lighting Savings = Stacked LED Lighting Savings x % of Buildings with Stacking + Unstacked LED Lighting Savings x (100% - % of Buildings with Stacking)

Weighted LED Lighting Savings = 30% x 20.2% + 40% x (100% - 20.2%) = 38%

Table C-1 summarizes the example for the LED lighting and occupancy sensors before and after stacking. As expected, when treated independently the combined savings from the measures exceeds the combined savings after stacking.

Table C-1. Comparison of Savings Before and After Stacking

	LED Lighting	Occupancy Sensors
Applicable Buildings	720,200	145,300
Savings treated independently (no stacking)		
Savings Relative to Baseline (%)	40%	25%
Savings treated interactively (stacking)		
Savings Relative to Baseline (%)	38%	25%

Source: Navigant analysis

C.3 Impetus for Treating Measure Savings Independently

Although it is possible to find the lower bound on savings with just one driver and one engine measure, the process becomes intractable when multiple drivers and engines can be installed in the same facility. Table C-2 lists all the engine and driver measures included in this study that could have interactive effects within the commercial lighting end use, which is just one of many end uses across multiple sectors where stacking could occur.

Table C-2. Measures with Opportunity for Stacking in Commercial Lighting End Use

Engine Measures	Driver Measures
Exterior LED	Photocell
Interior LED Tube	Interior Daylighting Controls
Interior LED MR/PAR Lamps	Fixture or Wall-Mounted Occupancy Sensors
Interior Recessed LED Downlighting (Troffer LEDs)	-
Interior High Bay LED	-
LED Luminaire	-

Source: Navigant

Determining the appropriate stacking and correctly weighting the savings percentages from each of the engine measures requires the following:

- Case-by-case expert judgment about the combinations of driver and engine measures that might realistically be found in the same building given historic and future construction practices
- The conditional probability that a building has an inefficient driver “A” and an inefficient engine “B” for all drivers and engines relevant to a given end use
- In-depth knowledge of program design and how managers are considering pursuing participants and bundling measure offerings

Lastly, at low levels of customer participation, assuming savings are independent is the best representation of what the actual measure stacking would be. When customer participation is high, the real-world scenario is the best representation of actual measure stacking. Thus, under the plausible ranges of customer participation, the modelled (upper bound) scenario is likely to be a better representation of actual measure stacking than the lower bound scenario.

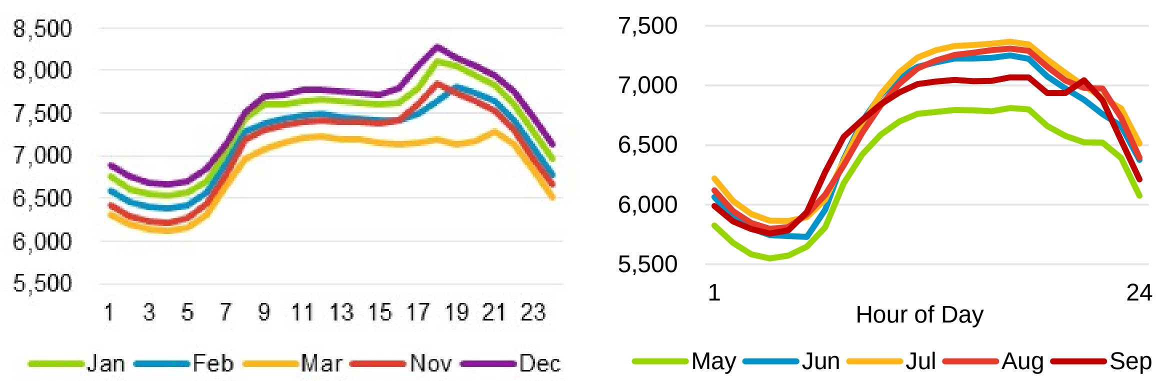
Although this report does not rigorously attempt to quantify the impact from efficiency stacking within the modelled service territories, Navigant’s experience indicates stacking can lead to a 5%-10% reduction in savings potential at high levels of technology adoption. This estimate is applicable to the residential and commercial sectors but is less applicable for the industrial sector because of reduced opportunity for stacking among the industrial measures considered in this study. Additionally, the 5%-10% reduction is highly uncertain and dependent upon the characteristics of any given building and bundling of measures.

APPENDIX D. DEMAND ANALYSIS

D.1 Peak Period Definition

Navigant analyzed 2 years of hourly load data from AESO[159] to determine the summer and winter peak periods. To complete this analysis, Navigant first calculated the hourly average loads by month (weekday versus weekend) over multiple years. This averaging normalizes any short-term weather differences. Using more than 1 year of data supports additional normalization due to weather or changes in consumption due to losses or gains of load specific to year. This analysis then can be used to observe any good separation between peak and non-peak hours as indicated in Figure D-1.

Figure D-1. Winter and Summer Average Hourly Load by Month – Average of 2015 and 2016 Data



Source: Alberta Electric System Operator

Table D-1. Winter and Summer Top 10 Hourly Loads by Hour – Average of 2015 and 2016 Data

Hour Ending	Month	Load	% of Max Load
18	Dec	8,276.7	100.0%
19	Dec	8,144.9	98.4%
18	Jan	8,110.5	98.0%
19	Jan	8,060.7	97.4%
20	Dec	8,051.8	97.3%
17	Dec	8,047.4	97.2%
20	Jan	7,951.9	96.1%
21	Dec	7,949.2	96.0%
18	Nov	7,844.1	94.8%
21	Jan	7,835.2	94.7%

Hour Ending	Month	Load	% of Max Load
17	Jul	7,366.5	100.0%
16	Jul	7,349.7	99.8%
18	Jul	7,344.7	99.7%
15	Jul	7,338.7	99.6%
14	Jul	7,330.7	99.5%
17	Aug	7,308.8	99.2%
16	Aug	7,296.5	99.0%
13	Jul	7,294.7	99.0%
18	Aug	7,291.7	99.0%
15	Aug	7,275.7	98.8%

Source: Alberta Electric System Operator

[159] Alberta Electric System Operator, "Data Requests," https://www.aeso.ca/market/market-and-system-reporting/data-requests/.

Navigant observed the highest peak hours in the winter period and considered each hour's load as a percentage of the peak load for the season. The observation per the graphs in Figure D-1 shows there is a peak occurring in certain hours and clear differences between the winter and summer months and shoulder months. This finding is confirmed in Table D-1, which displays the top 10 hours by load, averaged for 2015 and 2016 for the summer and winter months.

As a result of these observations, Navigant determined that the peak period definition should be:

- **Winter:** Hour-ending 17-21 on weekdays in December-January
- **Summer:** Hour-ending 14-18 on weekdays in June-August

D.2 Hourly 8,760 Analysis

Navigant developed an 8,760-hourly normalized end-use load shape library to support scenario-specific assessments of specific energy efficiency, demand response, and other technologies assessed as part of this study. For this task, Navigant created representative end-use load shapes for each customer segment. Navigant also used these load shapes to calculate the peak savings for energy efficiency measures.

In the absence of end-use metered consumption, the U.S. DOE prototype referenced building models, simulated with local weather files, provided reasonable end-use load shapes for use in potential studies and calculated peak savings. The end-use load profiles are sensitive to several of the building model inputs (temperature setpoints, operation schedules, etc.); however, Navigant put considerable thought into adjusting these inputs to model typical consumption profiles for each building segment.

End-use metering provides load shapes with considerably less uncertainty, but the costs far exceed those of using prototypical building models. Energy analysts are currently exploring techniques using non-intrusive load monitoring to algorithmically calculate end-use load shapes from high resolution whole building advanced metering infrastructure data; however, these methods only work well for certain end uses that provide high signal-to-noise ratio, such as central air conditioners. The resulting end-use load shape estimates may have high uncertainty. The valuation of energy efficiency and understanding of each electric-using equipment load profile should match each kilowatt, as tracked by supply side resource planning. When this occurs, additional rigor of the end-use load estimate becomes critical. In these instances, end-use metering may be warranted, or more in-depth calibration with an appropriate source of Alberta-specific consumption data.

D.3 End-Use Load Shape Development

The load profile development followed these steps:

1. **Assess measures and identify load profiles.** Following EEA approval of the final list of measures to be characterized and included in the analysis, Navigant staff identified a set of end-use/sector/segment combinations of load profiles such that each conservation measure and base technology has an assigned load profile.
2. **Identify appropriate baseload shapes.** To maximize value for EEA, Navigant used its existing database of end-use sectoral load profiles for this analysis.

3. **Adapt load shapes to Alberta.** To adapt load shapes, appropriate weather files are used. Additionally, if there is sufficient hourly data by sector, then the modeler calibrates to the system load shape, but such data did not exist.
4. **Apply load profiles to DSMSim outputs.** Navigant applied the final load shapes to the aggregated DSMSim outputs to deliver the 8,760-hourly profile of conservation impacts required by EEA.

Load Shape Development Approach

Navigant used the EnergyPlus building simulation software to run prototypical building energy models for residential and commercial customer segments. Updated versions of the U.S. DOE commercial and residential reference building models were used to complete the simulations, which are representative of typical building constructions and represent typical energy and demand for buildings within the building stock. Navigant maintains this model set for extracting end-use load shapes for potential studies. The team used EnergyPlus prototype models that include several updates made during a previous study to more accurately reflect typical hourly energy consumption of buildings. These updates include smoothing HVAC operation schedules and ramping HVAC setpoint changes over many hours, instead of a step-change in setpoint between 2 adjacent hours. Navigant also used various end-use load shape metering studies to make informed model updates to more accurately reflect real-world operation of these equipment:

- Navigant updated the lighting profiles contained in DOE commercial reference building models with Northeast Energy Efficiency Partnerships (NEEP) lighting profiles.[160] The NEEP lighting profiles are weather-normalized and were developed for the Northeast and Mid-Atlantic regions of the U.S. using data from integral lighting meters. The metered data was collected for energy efficiency project evaluations ranging from 2000 to 2011. The approximate daylight hours are deemed appropriate for this initial study. It is important to note that non-weather dependent end uses can be transferable from one region to another, such as lighting and appliances.[161]
- Navigant updated the lighting profiles for the residential reference building with the residential lighting load shapes from a metering study in the Northeast. The metered data was collected in 2015.

Navigant used typical meteorological year weather data for Calgary and Edmonton, Alberta in the EnergyPlus modeling environment. The resulting load shapes are a weighted average of the two regions. This weighted average is based on the population above and below the centerline between Calgary (58%) and Edmonton (42%). Regarding the urban versus rural population, Navigant assumed these customers to be proportionally split from those above and below the centerline.

Residential Load Shapes

Navigant used the residential building models from its model library and simulated typical load shapes using the 2016 Calgary and Edmonton weather files. Navigant input these load shapes into the EEA potential model.

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[160] Lighting hourly load profiles were taken from the July 19, 2011 C&I Lighting Load Shape Project for Northeast Energy Efficiency Partnerships (associated spreadsheet - Profiles v2.6_4_18-KIC.xls).

[161] Tables 3 and 4 identify the load shapes that are highly transferrable across regions. *End-Use Load Data Update Project Final Report*, www.neep.org/file/2693/download?token=aOWk8oud.

Commercial Load Shapes

Navigant used the commercial building models from its model library and simulated typical load shapes using the 2016 Calgary and Edmonton weather files. Navigant input these load shapes into the EEA potential model.

Industrial Load Shapes

Sufficient data and/or models were unavailable to develop sector-specific load profiles for the industrial sector. However, since the industrial sector accounts for a majority share of the overall load in Alberta, Navigant deemed overall metered data to be a sufficient representation of the industrial sector load for potential study purposes. The team sourced 2016 overall metered data for Alberta from AESO and used this data to develop typical daily consumption profiles for each industrial segment, excluding industrial lighting. Industrial lighting uses the same representative profile as the commercial warehouse/wholesale profile.

See Table D-2 and Table D-3 for modelled segments and use by sector.

Table D-2. Modelled Customer Segments by Sector

Residential	Commercial	Industrial
Apartments	Accommodation	Conventional Oil & Gas
Attached/Row Housing	Non-food Retail	Oil Sands (Mining)
Single-Family Detached Homes	Office	Oil Sands (In-Situ)
	Restaurant	Chemical
	School	Pulp and Paper
	University/College	Farms
	Warehouse/Wholesale	Other Manufacturing
	Food Retail	
	Hospital	

Source: Navigant

Table D-3. Modelled End Uses by Sector

Residential	Commercial	Industrial
Space Heating	Space Heating	Indirect Process Heating
Space Cooling	Space Cooling	Direct Process Heating
Water Heating	Water Heating	Process Cooling
Appliances	Cooking	Pumps
Lighting	HVAC Fans/Pumps	Fans and Blowers
Electronics	Lighting	Compressed Air
Other	Office Equipment	Industrial Process
	Refrigeration	Lighting
	Other	Material Transport
		Process Compressors
		Other

Source: Navigant

D.4 Calculating Peak Demand Savings

Navigant used the 8,760 load shapes developed for this project to calculate peak demand savings. The load shape development methodology and analysis are provided in in the next section. The team developed load shapes for each segment and end use and assigned a load shape to each measure. A load shape provides the hourly percentage of annual load for a specific end use, meaning the sum of hourly fractions over 1 year will result in 1 kWh. From these load shapes, Navigant calculated a peak load shape factor for winter and summer peak periods, as in Equation D-1.

Equation D-1. Peak Load Shape Factor

$$Peak\ Load\ Shape\ Factor = \sum_{i}^{n} Hourly\ Fractional\ Load_i$$

$$PLSF = HFL_{Hour\ 1} + HFL_{Hr\ 2} + HFL_{Hr\ 3} + HFL_{Hr\ 4} \ldots + HFL_{\ Hr\ (Peak\ Period\ Hours-1)} + HFL_{Hr\ Peak\ Period\ Hours}$$[162]

Where, *i* = the hour during the peak period for *n* hours. The sum of the hourly fractional load during these hours multiplied by the annual kWh savings for the measure equals the measure peak demand savings as shown in Equation D-2.

Equation D-2. Peak Demand Savings

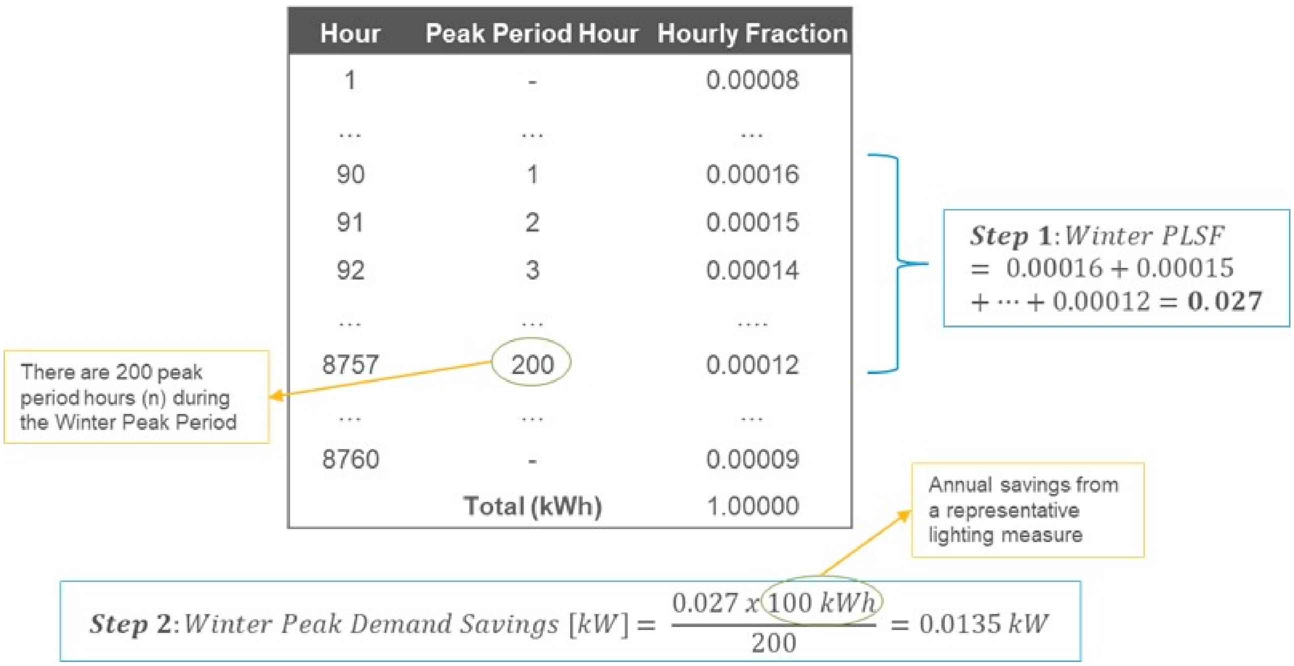
$$Peak\ Demand\ Savings\ [kW] = \frac{Peak\ Load\ Shape\ Factor\ x\ Annual\ kWh\ Savings}{Peak\ Period\ Hours}$$

[162] Units are dimensionless.

For this methodology, Peak Load Shape Factor (PLSF)/Peak Period Hours is equal to the percentage of a measure's average energy savings that occur on a single peak hour. The *Methodology for Peak Savings* workbook includes the calculations of the PLSFs used for this study.

Figure D-2 shows a sample calculation for winter peak demand savings, for a representative lighting measure in commercial offices.

Figure D-2. Peak Demand Savings – Sample Calculation



Hour	Peak Period Hour	Hourly Fraction
1	-	0.00008
…	…	…
90	1	0.00016
91	2	0.00015
92	3	0.00014
…	…	….
8757	200	0.00012
…	…	…
8760	-	0.00009
	Total (kWh)	1.00000

Source: Navigant

APPENDIX E. CESAR PATHWAYS PROJECT

E.1 CESAR Pathways Project

The CESAR Pathways Project defines credible, compelling, and cost-effective pathways to future human systems that will make it possible for Canada to meet its 2030 and 2050 GHG emissions reduction targets. The project applies technology-rich scenario modeling tools to explore strategies for systems change with the goal of identifying transformative emissions reduction pathways.

These tools are built around detailed narratives describing practical changes in human-managed systems that include, but are not limited to, managing greenhouse gas emissions. From the narratives, pathways are defined to inform decision makers in government and industry.

The project describes seven interacting narratives that define the energy pathways to meeting Canada's 2030 and 2050 targets. Each captures the timing and nature of technology, infrastructure, and behavioural changes required to meet these targets. These narratives are:

1. **Personal Transport.** Disruption from automated, shared, and EVs that will impact not only the personal mobility sector but also urban form, industrial demand, oil price, and electricity demand.
2. **Supply Chain.** Mode share changes, electrification (including fuel cells), and biofuels.
3. **Energy-using Industries.** Shifting demand, cogeneration, biofuels, new production technologies to reduce process and energy GHGs, carbon capture, and storage.
4. **Built Spaces.** Urban redesign, improved building envelopes, and electrification.
5. **Biological Systems.** Optimizing land/resource use for food, fiber, energy, and enhanced carbon stocks, dietary changes, and technology deployment to reduce methane and nitrous oxide emissions.
6. **Electricity Generation**. More renewables, distributed generation, interconnected power grids, electricity storage, and disruption of the utility business model.
7. **Fossil Fuel Recovery and Processing.** New, more efficient recovery/upgrading technologies, electrification, reduced regional and global demand/prices that reduces production.

The production and use of fuels and electricity (i.e., energy systems) represent the dominant—but not the only—way in which humans have altered the flows of energy and carbon, including GHG emissions in Canada. When developing future narratives, CESAR will also consider changes in how the annual flows of energy and carbon are managed through agricultural systems and managed forests. Adding flows through Canada's food and fiber systems to the fuel and electricity systems increases human-managed energy flows by about 21% and carbon flows by more than 40%. These flows need to be integrated into system-level strategies to address environmental and societal challenges.

E.2 Detailed Modeling Approach

CESAR narratives are converted into detailed, technology, infrastructure, and behaviour-rich scenarios that consider several factors. These include the infrastructure in-place and their rate of turnover, technology-readiness level, public acceptability of new innovations, and rates of change in market share.

Drawing on the scientific literature describing techno-economic and environmental assessments for each technology innovation, CESAR identifies key metrics or parameters (levers) that characterize and drive the five narratives.

At the core of the CESAR Pathways Project is the Canadian Energy Systems Simulator (CanESS) model by whatIf? Technologies Inc. (Ottawa, ON). CanESS is an integrated, multi-fuel, multi-sector stock and flow model with detailed accounting of the sources and uses of energy and the resulting GHG emissions across Canada. Built on historical data from 1990 to the present, CanESS was designed to explore biophysically and technology-rich pathways to low carbon energy systems for Canada and the provinces. The CanESS model is used to generate a business-as-usual or reference scenarios to 2060. Then, drawing on the levers that characterize the seven narratives, the reference scenario is modified to create at least two alternative scenarios that achieve deep decarbonization by 2030 and 2050, respectively.

E.3 Method and Assumptions

In both CanESS and compendium models, more than 800 public data sources are used to develop an understanding of base stocks of buildings, infrastructure, fuel and electricity supply and demand, demographics, and economic development. These are organized into a system dynamics model configured using published literature, which defines a bottom-up, technology-rich model of Canada's energy systems by province.

Historical data is used to calibrate the CanESS model, and to identify recent trends in key variables that relate to policy or technology intervention in the energy system. Variables are adjusted such that aggregate stock and energy flows match totals reported in public data sources. Once model levers are calibrated, future projections for stocks and energy flows are calculated given the trends identified for each of CanESS' model variables.

In the case of building stock, its growth is affected by variables like population, demographics, and economic growth. Respectively, building stock energy use is defined by variables that include building standards, regional climatic characteristics, and heating and cooling equipment standards. GHG emissions are then determined by fuel source.

APPENDIX F. ACHIEVABLE POTENTIAL MODELING METHODOLOGY DETAILS

F.1 Calculating Achievable Potential

This section demonstrates Navigant's approach to calculating achievable potential, including maximum achievable potential, which is fundamentally more complex than the calculation of technical or economic potential.

The critical first step in the process of accurately estimating achievable potential is to simulate market adoption of energy efficient measures. The approach to simulating the adoption of energy efficient technologies for purposes of calculating achievable potential can be broken down into the following two strata:

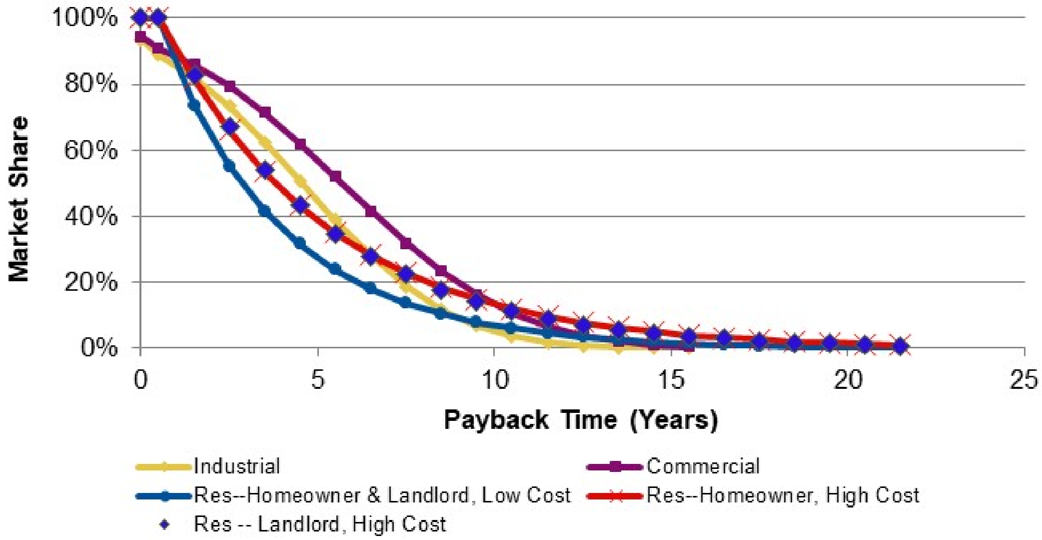
1. Calculation of the equilibrium market share
2. Calculation of the dynamic approach to equilibrium market share

F.1.1 Calculation of Dynamic Equilibrium Market Share

The equilibrium market share can be thought of as the percentage of individuals choosing to purchase a technology, provided those individuals are fully aware of the technology and its relative merits (e.g., the energy- and cost-savings features). For energy efficient technologies, a key differentiating factor between the base technology and the efficient technology is the energy and cost savings associated with the efficient technology. Additional efficiency often comes at a premium in initial cost. Thus, in efficiency potential studies, equilibrium market share is often calculated as a function of the payback time of the efficient technology relative to the inefficient technology. While such approaches have limitations, these are nonetheless directionally reasonable and simple enough to permit estimation of market share for the dozens or even hundreds of technologies often considered in potential studies.

Navigant uses equilibrium payback acceptance curves developed using primary research conducted in the U.S. Midwest in 2012. To develop these curves, Navigant conducted surveys of 400 residential, 400 commercial, and 150 industrial customers. These surveys presented decision makers with numerous choices between technologies with low upfront costs but high annual energy costs, and measures with higher upfront costs but lower annual energy costs. Navigant conducted statistical analysis to develop the set of curves shown in Figure F-1, which were used in this study. Though Alberta-specific data is not currently available to estimate these curves, Navigant considers the nature of the decision-making process is such that the data developed using these surveyed customers represents the best data available for this study at this time.

Figure F-1. Payback Acceptance Curves



Source: Navigant, 2015

Because the payback time of a technology can change over time as technology costs and/or energy costs change, the equilibrium market share can also change over time. The equilibrium market share is recalculated for every step within the market simulation to ensure the dynamics of technology adoption considers changing market share. Thus, the term equilibrium market share is an oversimplification and a misnomer, as it can itself change over time and thus is never truly in equilibrium. Nonetheless, it is used to facilitate understanding of the approach.

F.1.2 Participant Payback Period

Navigant calculates the customer payback period to assess customer potential to implement the energy-saving action. The payback period is used to assess the customer acceptance and adoption of the measure. Additional details are described in the achievable potential methodology section. The payback period is calculated after the incentive is applied to the measure cost. Equation F-1 demonstrates the calculation.

Equation F-1. Participant Payback Period

$$Payback = \frac{Annual\ kWh\ Saved\ \times Annualized\ Billing\ Rate\ \left(\$/_{kWh}\right) + Annual\ Natural\ Gas\ Saved\ \times Annualized\ Billing\ Rate\ \left(\$/_{GJ}\right)}{Incremental\ Measure\ Cost - Incentive}$$

Where:

- *Annual kWh Saved* and *Annual Natural Gas Saved* is calculated for each measure and segment (as appropriate).
- *Annualized Billing Rate* is the overall cost a customer pays per kWh or per GJ consumed (see Appendix B.3).
- *Incremental Measure Costs* are the costs the participant would pay (without an incentive) to implement the measure. In ROB and new construction (depending on the measure) the difference

in the cost of the efficiency and standard equipment is used instead of the full cost of installation (material and labor costs).

- *Incentives* are the incentive costs paid for the customer's out-of-pocket costs to be reduced.

F.1.3 Calculation of the Approach to Equilibrium Market Share

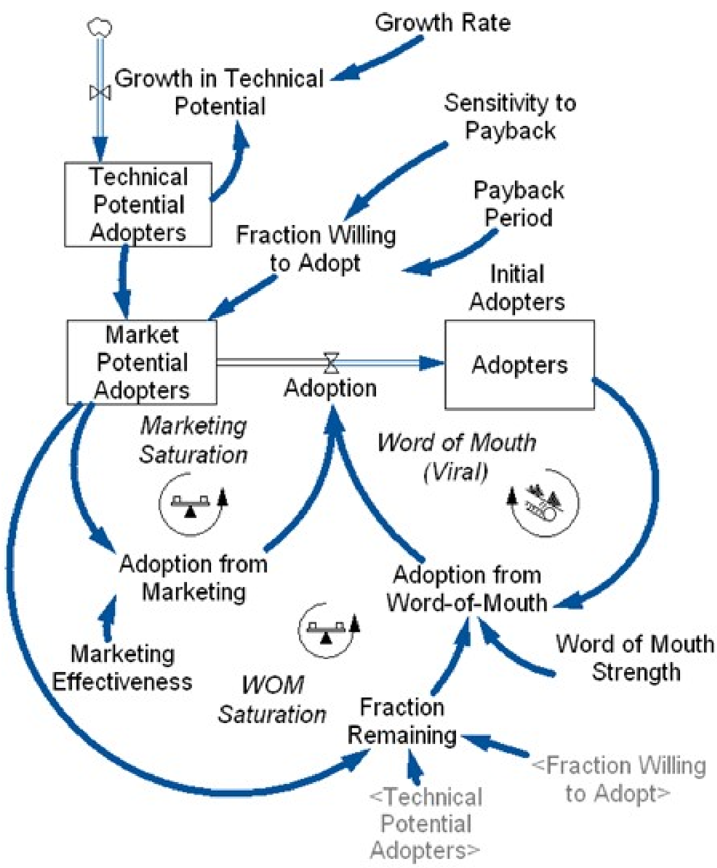
Navigant used two approaches to calculate the approach to equilibrium market share (i.e., how quickly a technology reaches final market saturation), for (1) new technologies or those being modelled as a retrofit (i.e., discretionary) measures, and (2) technologies simulated as ROB (i.e., lost opportunity) measures. A high-level overview of each approach is provided in the following sections.

F.1.4 Retrofit/New Technology Adoption Approach

Retrofit and new technologies employ an enhanced version of the classic Bass diffusion model to simulate the s-shaped approach to equilibrium commonly observed for technology adoption. Figure F-2 provides a stock/flow diagram illustrating the causal influences underlying the Bass model. In this model, market potential flows to adopters through two primary mechanisms, (1) adoption from external influences such as program marketing/advertising, and (2) adoption from internal influences including word of mouth. The fraction of the population willing to adopt is estimated using the payback acceptance curves illustrated in Figure F-2.

The marketing effectiveness and external influence parameters for this diffusion model are typically estimated upon the results of case studies where these parameters were estimated for dozens of technologies. Additionally, the calibration process outline previously permits adjusting these parameters as warranted (e.g., to better align with historic adoption patterns within the Alberta market). Recognition of the positive or self-reinforcing feedback generated by the word of mouth mechanism is evidenced by increasing discussion of concepts like social marketing and the term "viral," which was popularized most recently by social networking sites such as Facebook and YouTube. However, the underlying positive feedback associated with this mechanism has always been part of the Bass diffusion model of product adoption since its inception in 1969.

Figure F-2. Stock/Flow Diagram of Diffusion Model for New Products and Retrofits

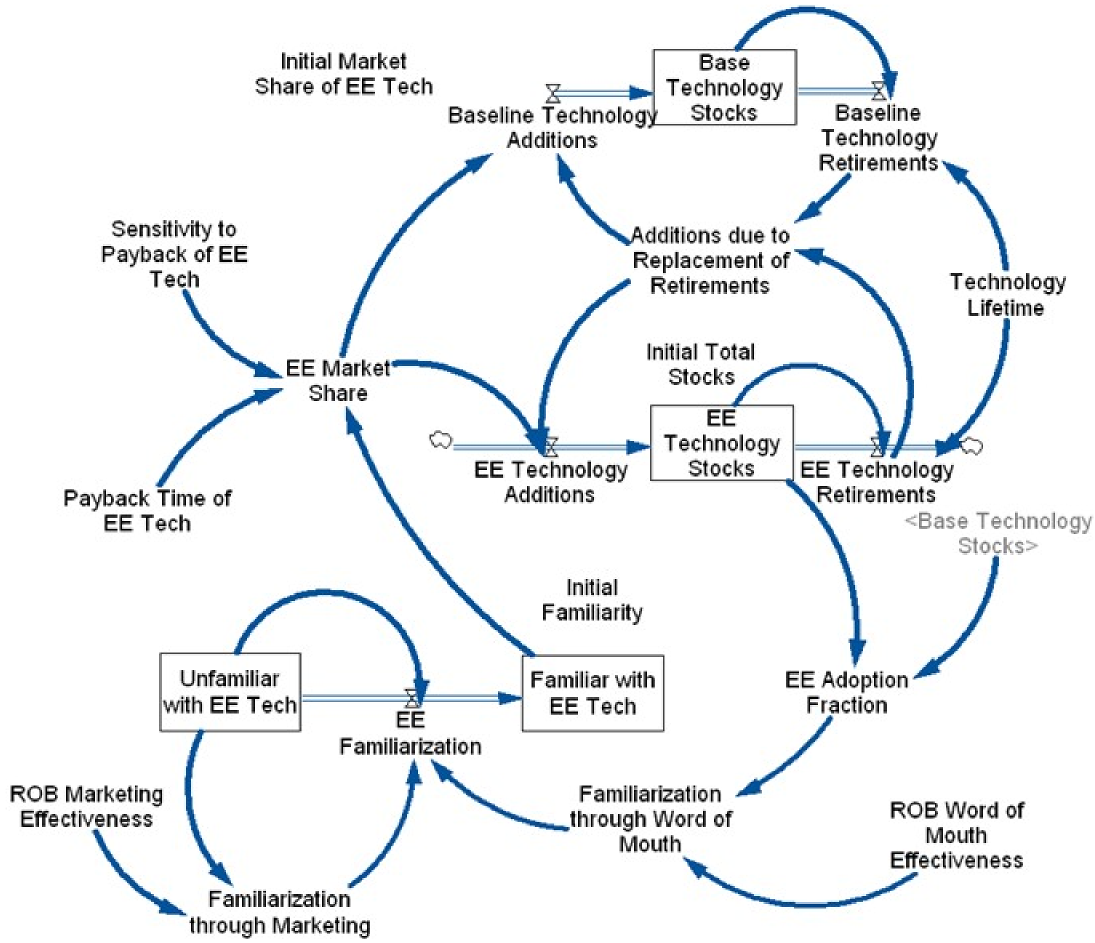


Source: Navigant, 2015

F.1.5 ROB Technology Adoption Approach

The dynamics of adoption for ROB technologies are somewhat more complicated than for new/retrofit technologies because it requires simulating the turnover of long-lived technology stocks. To account for this, the DSMSim model tracks the stock of all technologies—both base and efficient—and explicitly calculates technology retirements and additions consistent with the lifetime of the technologies. Such an approach ensures technology churn is considered in the estimation of market potential as only a fraction of the total stock of technologies is replaced each year. This affects how quickly technologies can be replaced. A model that endogenously generates growth in the familiarity of a technology, analogous to the Bass approach described above, is overlaid on the stock tracking model to capture the dynamics associated with the diffusion of technology familiarity. A simplified version of the model employed in DSMSim is illustrated in Figure F-3.

Figure F-3. Stock/Flow Diagram of Diffusion Model for ROB Measures



Source: Navigant, 2015

F.2 Model Calibration

The calibration of a predictive model imposes unique challenges as future data is not available to compare against model predictions. For example, while engineering models can often be calibrated to a high degree of accuracy because simulated performance can be compared directly with performance of actual hardware, predictive models do not have this luxury. DSM models must rely on other techniques to provide a level of comfort to both the developer and the recipient of model results that the simulated results are reasonable. For this project, Navigant took several steps to ensure forecast model results are reasonable and to consider historic adoption, including:

- Comparing forecast values by sector and end use against historic achieved savings (e.g., program savings). This is where the benchmarked cost value is used. Some studies indicate DSM potential models are calibrated to ensure first-year simulated savings precisely equal prior-year reported savings. Navigant notes that forcing such precise agreement has the potential to introduce errors into the modeling process by effectively masking the explanation for differences—particularly when the measures included may vary significantly.

In the case for Alberta, there is little to no data for doing this calibration to historical data especially since there is rapidly ramping up of portfolio spend.

- Calculating portfolio-level and sector-level $/first year kWh ($/first year GJ for natural gas) costs and comparing these with values Navigant's research through benchmarking of other program administrators.
- Calculating the split (percentage) in spending between incentives and variable PACs predicted by the model to benchmarking values.
- Calculating total spending by sector and comparing the resulting values to proposed level of investment