NAVIGANT
A Guidehouse Company

Memorandum

Date: 2020-06-01

Re: **Amendment to "Non-Wires Alternatives Study - How EE, DR and Managed Charging Can Cost-Effectively Offset EV Load Growth"**

Navigant has updated the "Non-Wires Alternatives Study – How EE, DR and Managed Charging Can Cost-Effectively Offset EV Load Growth" report to include an additional section (see Section 7, titled "*Additional Analysis – Societal Perspective"*). This additional analysis does not replace any of the existing analysis or findings, but provides complementary analysis intended to enhance the existing report and provide a broader societal perspective.

This amendment to the original study is intended to demonstrate supplementary valuation of energy efficiency that was not captured in the original study due to time constraints. The original study evaluates the least-cost option between traditional wires upgrades and a portfolio of non-wires alternatives, including energy efficiency, captured from the perspective of the utility. The additional analysis takes a more complete valuation of energy efficiency that includes societal benefits, such as avoided carbon emissions and energy savings, that are not captured in the framework of the original study.

This analysis was not included in the original report as the modelling effort required to generate additional measure-level data prior to the Alberta Utility Commission's Distribution System Inquiry's Module Two & Three submission deadline. This analysis was not originally excluded as an indication of lesser importance.

Navigant sees value in examining this study from multiple lenses. Non-wires alternatives, notably energy efficiency, include societal benefits that are not present in traditional wires investments. This amendment evaluates the least-cost option when taking these benefits into consideration.

Best,

Andrea Roszell

Andrea Roszell
Director

100 King St. W
Suite 4950
Toronto, ON M5X 1B1
416.777.2440 main
guidehouse.com

Non-Wires Alternatives Study

How EE, DR and Managed Charging Can Cost-Effectively Offset EV Load Growth

2020-06
Version 2.0

Prepared for:

Energy Efficiency Alberta

Submitted by:

Navigant, A Guidehouse Company
100 King St W
Suite 4950
Toronto, ON M5X 1B1

416.777.2440
guidehouse.com

DISCLAIMER

Disclaimer

This report ("report") was prepared for Energy Efficiency Alberta on terms specifically limiting the liability of Navigant Consulting, Inc., n/k/a Guidehouse Inc. ("Navigant") and is not to be distributed without Navigant's prior written consent. Navigant's conclusions are the results of the exercise of its reasonable professional judgment. By the reader's acceptance of this report, you hereby agree and acknowledge that (a) your use of the report will be limited solely for internal purpose, (b) you will not distribute a copy of this report to any third party without Navigant's express prior written consent, and (c) you are bound by the disclaimers and/or limitations on liability set forth in the report. Navigant does not make any representations or warranties of any kind with respect to (i) the accuracy or completeness of the information contained in the report, (ii) the presence or absence of any errors or omissions contained in the report, (iii) any work performed by Navigant in connection with or using the report, or (iv) any conclusions reached by Navigant as a result of the report. Any use of or reliance on the report, or decisions to be made based on it, are the reader's responsibility. Navigant accepts no duty of care or liability of any kind whatsoever to you, and all parties waive and release Navigant from all claims, liabilities and damages, if any, suffered as a result of decisions made, or not made, or actions taken, or not taken, based on this report.

Confidentiality

This report contains confidential and proprietary information. Any person acquiring this report agrees and understands that the information contained in this report is confidential and, except as required by law, will take all reasonable measures available to it by instruction, agreement or otherwise to maintain the confidentiality of the information. Such person agrees not to release, disclose, publish, copy, or communicate this confidential information or make it available to any third party, including, but not limited to, consultants, financial advisors, or rating agencies, other than employees, agents and contractors of such person and its affiliates and subsidiaries who reasonably need to know it in connection with the exercise or the performance of such person's business.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

EXECUTIVE SUMMARY

Electric vehicle ("EV") adoption is expected to increase over the next 10-years. Consequently, EVs can pose a threat to overall grid reliability if not managed in an intelligent way, due their coincidence with system loading and large power draws.

Navigant Consulting, Inc., n/k/a Guidehouse Inc. ("Navigant") was retained by Energy Efficiency Alberta ("EEA") to assess the value of energy efficiency measures and managed charging in reducing EV imposed costs on the distribution system. The demand-side management measures analyzed in this study are energy efficiency, demand response and managed charging. This study considers the impacts of two EV adoption scenarios on a distribution transformer. By 2030, both adoption scenarios clearly show capacity constraints on the transformer caused by increased EV adoption.

This report assesses whether a combination of energy efficiency, demand response and managed charging is a more cost-effective means of fulfilling these constraints than a traditional wires investment. For the transformer analyzed in this study, under both the Base and EV adoption scenarios modelled, the non-wires portfolio is able to completely mitigate overloading on the transformer caused by EV adoption and is cost-effective compared to the traditional wires investment. The study is completed through four milestones.

Milestone 1

The purpose of Milestone 1 is to characterize the impact of EV adoption on local distribution infrastructure in Alberta. Navigant's analysis is completed at a transformer-level and two EV adoption scenarios are considered; Base and Aggressive. Under the Base scenario, business-as-usual assumptions are made regarding battery pack prices, national EV incentives and model availability (such as light trucks). Under the Aggressive scenario, more optimistic assumptions are applied, such as larger decreases in battery pack prices.

Navigant analyzed loading data on the transformer provided by EPCOR Utilities Inc. and determined the annual peak on the study transformer. It was clear that in 2030, under both scenarios, capacity constraints exist.

Milestone 2

Milestone 2 characterizes the energy efficiency, demand response, and managed charging measures available to meet the system needs defined in Milestone 1. Each measure is defined including its unique characteristics to Alberta and the ability to fulfill need at the transformer.

For energy efficiency, characterization is largely driven by the results of EEA's 2017 potential study. The technical potential for years 2020-2030 from the potential study are scaled down to a transformer-level potential. The respective coincident transformer-level potential is also determined. The potential study is also used to obtain the acquisition costs for energy efficiency.

For demand response, technical potential values were obtained from the potential study as well as Navigant subject matter experts. These values were then scaled down to the transformer-level. A 2018 study by the Alberta Electric System Operator found the cost of new entry for capacity to be $148/kW-year in Alberta. In lieu of historical demand response costs in the province, this value was used as a conservative acquisition cost for all demand response end uses, consistent with approaches taken by Navigant in other jurisdictions.

For managed charging, the potential to defer demand at the transformer is taken as the difference between the unmanaged and managed load profiles during all hours when demand exceeds the transformer rating. The acquisition cost for managed charging was obtained from a prior Navigant demand response study and determined to be $756/kW. This study assessed the cost to implement a utility-controlled managed charging program in which 50% of the incremental cost is covered by the utility.

Milestone 3

Milestone 3 evaluates whether energy efficiency, demand response and managed charging can defer the need at the study transformer. The output from this Milestone is a resource stack diagram; the portfolio of technologies used to defer the need. The resource stack is developed using the potential values and acquisition costs described in Milestone 2. The acquisition costs are sorted from least-expensive to most-expensive, and the measures are depleted sequentially until need is fully deferred. This ensures that the resource stack is as cost-effective as possible.

In this Milestone, it was shown that in both EV adoption scenarios, the portfolio of energy efficiency, demand response and managed charging is capable of fully deferring the need at the transformer. In 2030, under the Base scenario, there are 10 hours of need – the portfolio of measures fully defers each of these hours. Under the Aggressive scenario, there are 349 hours of need. The portfolio of measures fully deferred the need in 348 of these hours - 1 hour of need remained on the transformer. However, the magnitude of need was small (1.2 kW) and does not occur in any consecutive hours.

Milestone 4

Milestone 4 analyzes the cost-benefit ratio of the non-wires alternatives versus upgrading traditional distribution system infrastructure and is provided for both EV adoption scenarios in 2030. In both scenarios, the non-wires alternative is significantly more cost-effective when compared to the traditional wires investment, with the present value of non-wires portfolio spending incurring a fraction of the cost compared to the present value of the wires investment.

This study found that there is a non-linear relationship between the cost-benefit ratio and the need on the study transformer. In the Aggressive scenario, the need on the transformer is approximately three times larger than in the Base scenario (9.7 kW versus 2.7 kW). However, the net present value of non-wires portfolio spending in the Aggressive scenario is over ten times larger ($5,178 versus $442). Even with the increased spending in the Aggressive scenario, the non-wires portfolio remains cost-effective compared to the wires investment. The portfolio of non-wires alternatives has a cost-benefit ratio of 23.8 in the Base scenario and 2.5 in the Aggressive scenario.

Conclusions

This study demonstrates that, at a local transformer-level, a portfolio of energy efficiency, demand response and managed EV charging can be a cost-effective alternative to a traditional wires investment. In both EV adoption scenarios, the portfolio of non-wires alternatives is capable of fully deferring need on the study transformer at a lower cost than the traditional wires investment.

This study shows that, as expected, the future loading on distribution transformers is highly dependent on EV adoption. In the Base scenario, energy efficiency and demand response alone can mitigate the transformer constraints. In the Aggressive scenario, a combination of managed charging, energy efficiency and demand response are required to mitigate the constraints.

Due to the conservative nature of this study, it is likely that the portfolio of non-wires alternatives is more cost-effective than stated. Navigant made conservative assumptions surrounding the wires investment cost, the cost of demand response, and the number of EVs adopted to the transformer, yet the results still demonstrate that the portfolio is cost-effective compared to the traditional wires investment.

1. INTRODUCTION

Navigant Consulting, Inc., n/k/a Guidehouse Inc. (“Navigant”) was retained by Energy Efficiency Alberta (“EEA”) to conduct a study assessing the value of energy efficiency in reducing electric vehicle (“EV”) imposed costs on the distribution system.

EV adoption is expected to increase over the next 10-years. If not managed in an intelligent way, EVs can pose a threat to overall grid reliability, as EV chargers can potentially create large spikes in demand leading to higher investment costs.

Energy efficiency is a readily available tool to improve customer targeting, improve visibility into grid infrastructure and capacity constraints and allow for geographically focused energy efficiency initiatives in regions where energy savings are of the highest value. Demand response involves the reduction or shifting of energy consumption away from high-stress, or peak, grid periods. Managed charging allows a utility or third party to control electric vehicle charging to better correspond to the needs of the grid similar to traditional demand response programs. Targeted energy efficiency and demand response, in combination with managed charging has the potential to reduce peak demand resulting from EV charging load additions at a lower cost than upgrades which would otherwise be required to the distribution system.

This report will quantify and assess the potential of energy efficiency, demand response, and managed EV charging to offer solutions that can cost-effectively defer wires infrastructure investment associated with EV adoption, over a 10-year period (2020 to 2030). This study is divided into four sections, as described below:

Table 1-1. Description of Study Sections

Section	Contents
System Characterization	• Characterize the current loading of the transformer • Project EV adoption on the transformer • Outline the needs of the transformer due to increased load
Potential by Measure	• Summarize the measures considered for meeting system needs and their relevant characteristics
Resource Stack	• Summarize how the relevant technologies are stacked to meet system needs
Cost-Benefit Analysis	• Outline cost-benefit analysis for deploying resources versus traditional wires investment
Conclusions	• Discuss risks of resources available to meet the system needs • Draw conclusions from the results of the study • Provide recommendations for portfolio of resources to meet system needs • Discuss actions for moving forward

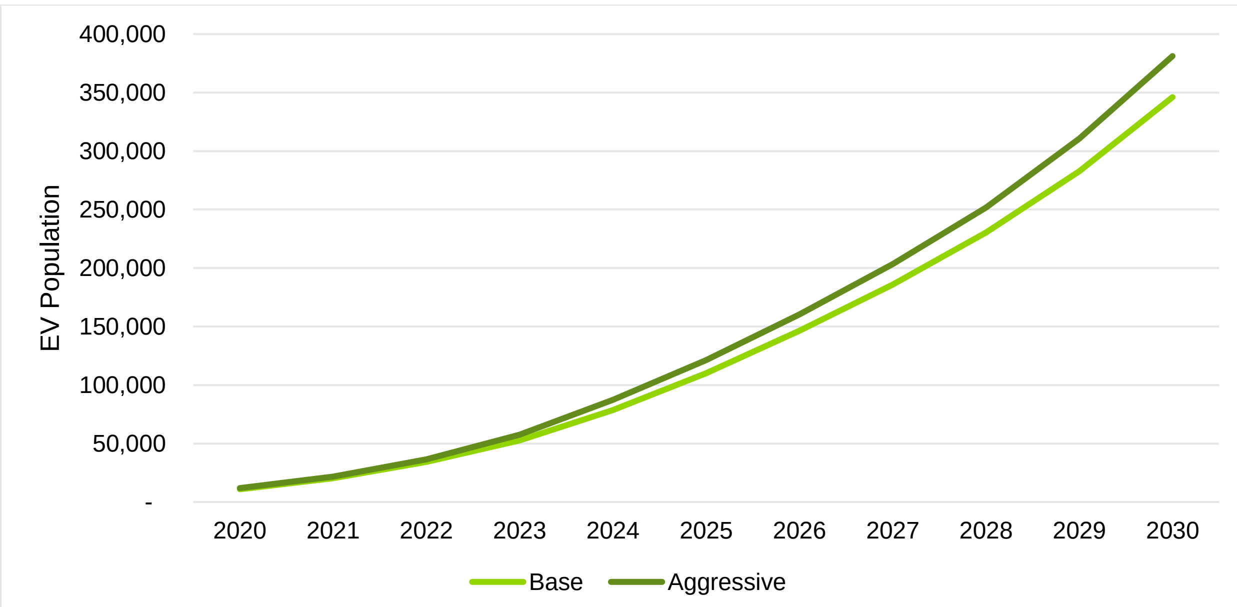
2. SYSTEM CHARACTERIZATION

2.1 Introduction

This study will assess the impacts of EV adoption on local distribution infrastructure in Alberta.[1] This study will evaluate the potential of energy efficiency, demand response, and managed EV charging at mitigating these impacts, and whether these solutions are cost-effective compared to traditional wires infrastructure investments.

As of September 2019, there were approximately 3,200 EVs in Alberta.[2] However, Navigant forecasts that EV adoption will increase significantly over the next 10 years, as shown in Figure 2-1, with the anticipated population of EVs in Alberta exceeding 340,000 by 2030.

Figure 2-1. Forecast EV Population in Alberta



Source: Navigant Research[3]

Navigant's vehicle adoption forecasts are developed independently of this study and are published in numerous sources. Navigant's adoption forecast considers two scenarios for EV growth: Base and Aggressive.

- **Base scenario:** EV battery pack prices continue to decrease under standard industry expectations, the national EV incentives in Canada stay as-is and phase out on their expected timelines, electric light trucks come to market as currently slated

[1] Throughout this study, the term "EVs" will be used to describe both plug-in hybrid electric vehicles ("PHEVs") and battery-electric vehicles ("BEVs").

[2] Electric Mobility Canada. https://emc-mec.ca/wp-content/uploads/EMC-Sales-Report-2019-Q3_EN.pdf

[3] Navigant Research. https://www.navigantresearch.com/reports/market-data-ev-geographic-forecast-north-america

- **Aggressive scenario:** EV battery pack prices decrease faster than current industry expectations, the national EV incentives in Canada are extended, electric light trucks come to market as currently slated

The IEA's global electric vehicle outlook set a target of 30% market share of EVs as a percentage of light-duty vehicle sales by 2030.[4] In 2019, 222,000 light-duty vehicles were sold in Alberta.[5] Under Navigant's Base scenario, 63,300 EVs are forecast to be sold in 2030. In today's market, this would represent a 28% market share of vehicle sales. Similarly, the Aggressive scenario would represent a 32% market share.

There are several factors driving the adoption of EVs in Alberta. Some of these factors include:

Battery Price Decline
Since EVs were first introduced on the market, battery prices have more than halved. Navigant Research expects these prices to decrease an additional 50% under base case assumptions. This cost decline is the result of commercialization of solid-state batteries, anticipating improved energy density and durability. As battery packs comprise a significant portion of the total cost of an EV, this reduction will help make EVs cost competitive with traditional combustion engine vehicles.

Table 2-1. Forecast of Battery Pack Cost Decline

Scenario	Units	2019	2030
Base	$/kWh	$200	$110
Aggressive	$/kWh	$200	$90

Source: Navigant Research

Model Availability
Although there are a number of new EVs coming to the North American market in the next 1-3 years, the current lack of electric trucks is a barrier for some consumers that want larger vehicles (such as SUVs and pickup trucks). There are very few EV pickup trucks or large SUVs currently on the market, and these segments currently make up a significant component of North American vehicles. Over the coming years, the introduction of light trucks is anticipated to expand the number of models available to consumers. Alongside the introduction of new passenger car models, the increased model availability is expected to reduce barriers for EV adoption for many customer groups.

Federal Purchase Incentive
A $5,000 federal purchase incentive was introduced in May 2019, improving the cost-competitiveness of EVs with traditional combustion engine vehicles.[6] The incentives range from $2,500 to $5,000, depending on the electric range of the vehicle, and are drawn from a pool of $300 million over a 3-year period. The Canadian government implemented the incentive to help meet their target of 100% zero emission new vehicle sales by 2040.

In most residential applications, EVs are expected to be charged using Level 2 chargers. A majority of the EV models available in the market today accept a maximum power input of 7.2 kW from a Level 2 charger – however, some manufacturers, such as Tesla, can accept larger power inputs. Prior to 2017, Tesla vehicles (Model S, Model X) came equipped with an onboard charger that could accept a maximum power input of 19.2 kW, through the use of a specialized dual-port charger. These dual-port chargers did not come standard with the vehicle. From 2018 onwards, all Tesla models, including the newly released

[4] IEA. https://www.iea.org/reports/global-ev-outlook-2019
[5] Government of Alberta. https://economicdashboard.alberta.ca/MotorVehicleSales
[6] Government of Canada. https://www.tc.gc.ca/en/services/road/innovative-technologies/zero-emission-vehicles.html

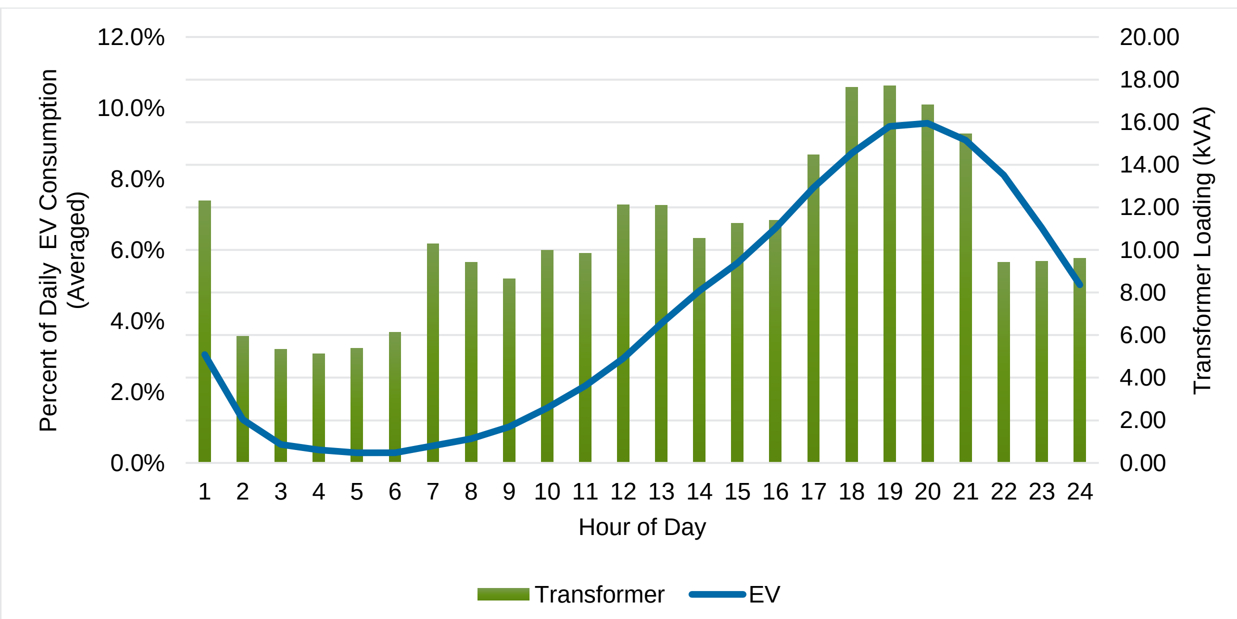
Model 3, have two optional charging inputs – 7.7 kW is standard and 11.5 kW is considered “long range”, or “performance”.[7] The actual charging rate of Tesla vehicles may vary depending on the household application; the maximum power input of the vehicle is 11.5 kW, but the size of the circuit breaker installed in the home can limit this to a lower power rating.

In this study, Navigant has used 7.2 kW as an average charging power demand. 7.2 kW is a standard charging rating for Level 2 chargers and is a midpoint between Tesla’s 11.5 kW and a Level 1 charger’s rating of 3.2 kW, recognizing that many vehicles are still charged with a Level 1 charger. According to the University of California, Davis, Level 1 charging can account for between 30% to 69% of total charging sessions for plug-in hybrid vehicles.[8]

For reference, a typical household impacts the distribution transformer at an average power demand of 2-3 kW, ranging from 2 kW from older homes up to 3 kW in newer homes during peak loading conditions.[9] In other words, from a load management perspective, the addition of a single EV on a residential transformer is comparable to two households. Increased adoption of EVs can lead to overloading of distribution equipment at a local level, such as a distribution transformer.[10]

EVs will present a particularly unique challenge for electric utilities, as existing infrastructure was planned and built over decades for household loads that are significantly less than modern EV charging powers. For example, a single EV with 7.2 kW charging power impacts the electric grid in a similar fashion to two large modern homes without EVs. Typically, EVs begin their charging cycle when their owners return home from work and plug in their vehicle. This end-of-workday period coincides with significant residential load, mostly caused by cooking and space conditioning applications. Figure 2-2 shows an averaged charging profile of several EVs and a residential transformer with 12 single-family customers.

Figure 2-2. Coincidence of EV Charging and Transformer Loading



[7] Tesla. https://www.tesla.com/model3
[8] University of California, Davis. https://ww3.arb.ca.gov/research/seminars/tal/12_319_seminar.pdf
[9] *Source:* Navigant subject matter experts
[10] IEA. https://www.iea.org/reports/global-ev-outlook-2019

Source: Navigant analysis, EPCOR

If not managed correctly, increased adoption of EVs can pose additional risks to utilities, potentially requiring significant costs to ensure grid reliability at both the local and system level. Alongside energy efficiency and demand response, another solution for mitigating grid impacts is managed EV charging often used synonymously with the term “smart charging”. With managed charging, charging is scheduled or shifted to periods that are less coincident with grid loads but still satisfy consumer needs.

A portfolio of energy efficiency measures, demand response and managed charging can be used to meet system constraints.

2.2 Methodology and Approach

This study assesses the impact of EV adoption at an individual transformer in Alberta. EPCOR Utilities Inc. (“EPCOR”) provided Navigant with hourly loading data for five residential transformers within their service territory. One full year of data was provided for 2018. The data provided from EPCOR is not necessarily representative of EPCOR’s entire distribution system.

Navigant analyzed the loading data for each of the transformers, as a percentage of their rated capacity (limited time rating, or “LTR”), and studied their maximum loading in 2018. Two of the transformers were considered to be at, or near, overloaded states by Navigant staff, with maximum annual power demand exceeding, or near exceeding the transformer’s rating.

Table 2-2. Loading of Transformers Considered for Study

Scenario	TX A	TX B	TX C	TX D	TX E
Max Loading as Percent of Rating (2018)	27%	57%	62%	93%	115%
Number of Hours LTR Exceeded	0	0	0	0	5
Max Consecutive Overloaded Hours	*N/A*	*N/A*	*N/A*	*N/A*	3

Source: EPCOR

For this study, Navigant selected the transformer with the median maximum load as percentage of capacity for its analysis (TX C). This transformer has the third largest power demand as a percentage of capacity, following the two transformers mentioned previously. This transformer was selected to be illustrative of an average transformer in EPCOR’s service territory.

EPCOR’s whitepaper titled “DER Impacts to Urban Utilities” states that the average load margin on distribution infrastructure is 33%,[11] indicating that the study transformer (TX C) has slightly more load margin (38%) than system average. However, of the transformer’s provided by EPCOR, the load margin available on the study transformer is closest to the whitepaper value.

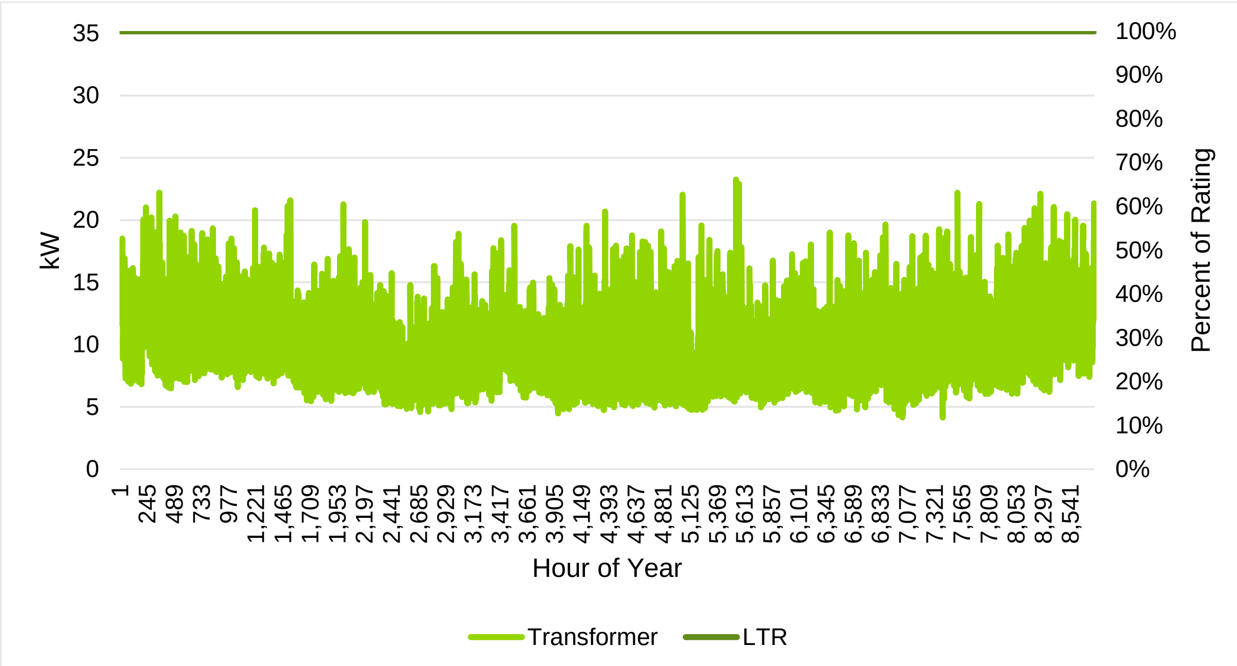
The transformer used for analysis in this study has a summer LTR of 37 kVA (or 35.15 kW),[12] a winter LTR of 37 kVA and 12 connected single-family households.

[11] EPCOR. https://www.epcor.com/products-services/power/Documents/micro-generation-research-solar-energy-electricity-grid-2019.pdf

[12] Throughout this report, loading data will be presented in units of kilowatts. A power factor of 0.95 is assumed for conversion between kilovolt-amps and kilowatts.

Figure 2-3 shows the 2018 historical hourly loading on the transformer used in this study.

Figure 2-3. Present Day Loading of Study Transformer



Source: EPCOR

To determine what the future loading profile of the transformer would look like, Navigant scaled the historical loading year-by-year based on a peak loading profile provided by EPCOR, keeping the present-day shape. To scale the loading data, Navigant used the ratio of annual peak load in 2018 with the estimated peak load in each year, provided by EPCOR. This ratio was applied to each hour in the load shape.

This scaling method does not account for the change in aggregate load shape caused by EV adoption. To determine the effect of EVs on the transformer profile, Navigant superimposed EV load profiles on the transformer. Navigant calculated the number of EVs that would be connected to the transformer year-over-year by scaling its adoption forecast based on a ratio of total households in Alberta and number of residential customers connected to the transformer.

Table 2-3 shows the projected number of EVs connected to the transformer year-over-year, for both the Base and Aggressive adoption scenarios. Note that in the Aggressive scenario, the number of EVs on the transformer is rounded up – for example, if the resulting value is 2.1 vehicles, Navigant rounds to 3. This allows for a more conservative estimate of vehicle adoption on the transformer and increases the capacity constraints on the transformer.

Table 2-3. Forecast of EV Population on Study Transformer, 2020 to 2030

Scenario	Units	2020	2030
Base	Vehicles per household	0.00	0.17
Aggressive	Vehicles per household	0.01	0.19
Base	Total vehicles on transformer	0	2
Aggressive	Total vehicles on transformer	1	3

Source: Navigant analysis

2.3 Results

In 2030, under both the Base and Aggressive EV adoption scenarios, the annual peak on the study transformer occurs on a weekday in August. The maximum loading for the transformer occurs at the hour ending 19:00. Figure 2-4. and Figure 2-5. show the hourly loading for this same day in 2030, with the Base and Aggressive EV adoption scenarios superimposed on the loading profile.

Figure 2-4. Loading of Transformer in Present Day and 2030 (Base EV Scenario)

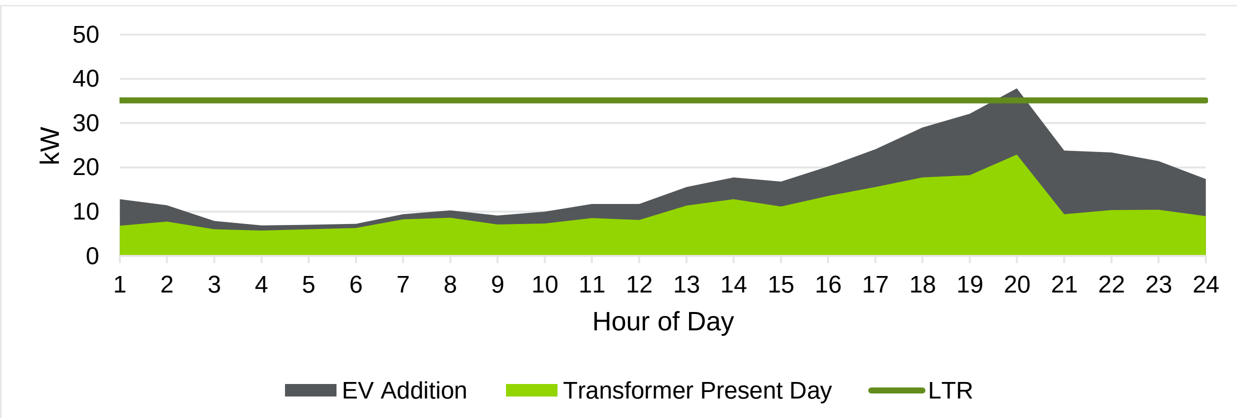
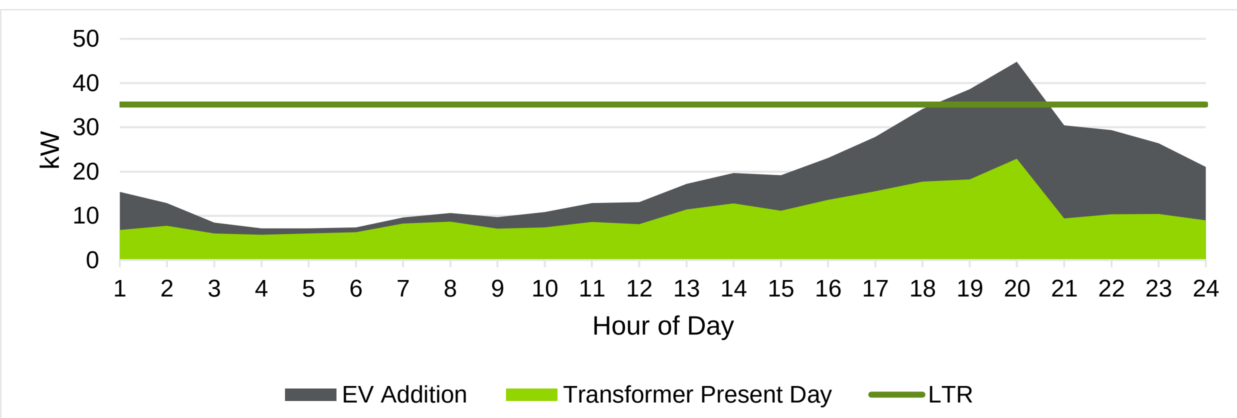


Figure 2-5. Loading of Transformer in Present Day and 2030 (Aggressive EV Scenario)



The Base scenario shows one hour of overloading for a period of 24 hours out of the total 8760 hours. There are nine other instances throughout the full year of 8760 hours in which overloading occurs. Therefore, in this scenario the LTR of the transformer is exceeded in 10 hours of the year.[13]

The maximum annual peak loading for the transformer in the Aggressive scenario is 44.82 kW, exceeding the LTR of the transformer by 9.67 kW. In 2030, in this scenario, the LTR of the transformer is exceeded in 349 hours of the year.

Under both adoption scenarios, there are clear capacity constraints on the transformer – this report will assess whether a combination of energy efficiency, demand response and managed charging is a more cost-effective means of fulfilling these constraints than a traditional wires investment.

[13] Assuming the average person drives 20,000 kilometers per year, an electric efficiency of 20 kWh per 100 km would result in an average daily charge requirement of 10 kWh. At a charger rating of 7.2 kW, this equates to roughly 80 minutes of charging. However, this charging duration could be much larger if a driver does not charge every day (e.g., charging for 250 minutes, or 4.2 hours, could fulfill their charging requirement for 3 days.

3. POTENTIAL BY MEASURE

3.1 Introduction

This section of the report will characterize the energy efficiency, demand response, and managed charging measures available to meet the system needs defined in Section 2. Each measure will be defined, including unique characteristics specific to Alberta where applicable, and the ability of each measure to fulfill need at the transformer will be summarized.

3.2 Methodology and Approach

Each of the following subsections will outline measure-specific approaches used to characterize the relevant technologies.

As this study assesses the potential of measures to offset demand at a residential transformer, only potential associated with residential end uses are considered. Table 3-1 shows the end uses considered as measures in this study for energy efficiency and demand response.

Table 3-1. End Uses Considered in Study

End Use
Residential Space Heating
Residential Space Cooling
Residential Water Heating
Residential Appliances
Residential Lighting
Residential Electronics
Residential Whole Building[14]

Source: EEA 2017 Potential Study

3.2.1 Energy Efficiency

Energy efficiency programs involve the management and reduction of consumer energy consumption. Energy efficiency is often considered an alternative to increasing supply – if all customers achieve a reduction in consumption through the adoption of efficient technologies, there may no longer be a need for new generation or distribution and transmission system upgrades.

The characterization of energy efficiency measures in this study is largely driven by the results of EEA's 2019-2038 potential study (the "potential study").[15] The objective of the potential study was to assess the energy efficiency potential in the residential, commercial and industrial sectors by analyzing the cost-effectiveness of energy efficiency measures at reducing greenhouse gas emissions. The potential study was modelled using several scenarios – in this report, all outputs are derived from the Reference Case

[14] In this study, measures associated with the 'Other' end use have been aggregated with the 'Whole Building' end use.

[15] For a full list of measures considered in this study, please refer to the 2019-2038 potential study report: Energy Efficiency Alberta. https://eea-assets.s3.amazonaws.com/documents/EEA-Potential-Study-Report-2019-2038.pdf?mtime=20190312163434

Scenario. Only measures found in the potential study are utilized for this study. Navigant did not alter any measure characterization inputs for this study, such as assumptions regarding market saturation of efficient and baseline technologies.

The province-wide technical potential of each end use to reduce demand is shown in Table 3-2, for 2020 to 2030. The values represent cumulative potential during the peak period defined in the potential study. In winter months, the peak period is defined from 17:00 to 21:00. In summer months, the peak period is defined from 14:00 to 18:00.

Table 3-2. Provincial Technical Potential of Energy Efficiency Measures, 2020 to 2030

End Use	Demand Potential, 2020 (MW)	Demand Potential, 2030 (MW)
Space Heating	0.1	0.1
Space Cooling	10.9	12.4
Water Heating	0.0	0.0
Appliances	76.0	86.5
Lighting	90.2	105.4
Electronics	50.9	57.5
Whole Building	22.2	25.0

Source: EEA Potential Study

To determine the potential associated with the transformer-specific to this study, Navigant developed an annual scaling factor based on the ratio of households in Alberta to households connected to the study transformer. The potential study developed a forecast of residential households in Alberta from 2019 to 2038. This scaling factor assumes that the energy efficiency potential per household is identical across all households in Alberta.

The forecast of households, as well as the scaling factors used to scale potential to the transformer, are shown in Table 3-3.

Table 3-3. Scaling Factors for Energy Efficiency Potential, 2020 to 2030

Measurement	Units	2020	2030
Households in Alberta	Households	1.78M	1.99M
Households Connected to Transformer	Households	12	12
Scaling Factor	%	0.00067%	0.00060%

Source: EEA Potential Study, EPCOR

The resulting transformer-level potential is shown in Table 3-4, and is derived by multiplying the values in Table 3-2 with the scaling factors in Table 3-3.

Table 3-4. Transformer-Level Potential of Energy Efficiency Measures, 2020 to 2030

End Use	Demand Potential, 2020 (kW)	Demand Potential, 2030 (kW)
Space Heating	0.00	0.00
Space Cooling	0.07	0.07
Water Heating	0.00	0.00
Appliances	0.50	0.52
Lighting	0.71	0.63
Electronics	0.34	0.34
Whole Building	0.15	0.15

Source: EEA Potential Study, Navigant analysis

As noted previously, these values represent potential to reduce demand during the potential study defined peak period. This period does not necessarily align with the local peak observed on the study transformer. To ensure that the potential values utilized align with the local transformer peak, Navigant calculated the hourly potential for each end use using an 8,760-load shape provided in the potential study. The 8,760-load profile calculates the percent of annual load occurring in each hour of the year. Navigant multiplied the maximum potential value (Table 3-4) by these load shapes to calculate the hourly demand.

To modify the transformer potential of each end use to a *coincident* potential, Navigant assessed the available potential for all hours where transformer demand exceeds the transformer rating. This coincident potential is defined as the available potential for these resources to mitigate demand during overloaded hours. As such, if the transformer's loading does not exceed its rating, there is *no potential.*

To ensure that the overall portfolio is as cost-effective as possible, Navigant considered only measures with a cost-benefit ratio greater than 1. Navigant used the Total Resource Cost Test ("TRC test") from the potential study to assess cost-effectiveness of each measure.[16] The potential value used for analysis is shown in Table 3-5.

[16] 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.

Table 3-5. Transformer-Level Potential of Energy Efficiency Measures, 2020 to 2030[17]

End Use	Demand Potential, 2020 (kW)	Demand Potential, 2030 (kW)
Space Heating	0.00	0.00
Space Cooling	0.00	0.01
Water Heating	0.00	0.00
Appliances	0.00	0.49
Lighting	0.00	0.45
Electronics	0.00	0.33
Whole Building	0.00	0.09

Source: EEA Potential Study, Navigant analysis

To calculate the acquisition cost by end use, Navigant utilized measure-level outputs from the potential study. One key output from the potential study is the levelized cost of demand savings, expressed in $/kW.[18] This value is output for every measure, in every segment and sector. As this study is focused on end use level data, Navigant aggregated the measure-level data to the end use level.

Navigant also screened for measures with negative potential values. Negative costs and potential are most commonly associated with fuel switching measures. As this study assesses electricity savings, a negative value indicates that more consumption is added from fuel switching (transitioning from a gas water heater to electric heater) than is reduced through efficiency programs (transitioning from one electric water heater to another). After screening out these measures, Navigant developed the end use level acquisition costs as the average of measure-level costs, weighted by demand potential. The resulting costs are shown in Table 3-6.

Table 3-6 Acquisition Costs for Energy Efficiency

End Use	Acquisition Cost, 2020 ($/kW)	Acquisition Cost, 2030 ($/kW)
Space Heating	$122	$148
Space Cooling	$0	$0
Water Heating	$53	$63
Appliances	$568	$693
Lighting	$682	$482
Electronics	$279	$355
Whole Building	$171	$208

Source: EEA Potential Study, Navigant analysis

[17] Note that the coincident potential is non-existent for all end uses in 2020. In 2020, there are no need hours at the study transformer, as the rating is not exceeded.

[18] Note that as per the potential study, the levelized cost represents the entire lifetime of the associated measure. The potential study assumes that, following the end of this measure lifetime, the efficient measure will become the new baseline. As such, the savings persist without requiring additional costs.

3.2.2 Demand Response

Demand response involves the reduction or shifting of energy consumption during high-stress, or peak, grid periods. Demand response programs involve the incentivization of targeted energy reduction, either through rate design, such as time-of-use periods, or through other means, such as direct load control programs which allow the utility to control consumer appliances and curtail load during peak periods in exchange for incentives, or behavioural load control programs, where the administrator provides notification (via mobile application for example) to consumer's to decrease their consumption in exchange for incentives.[19]

The characterization of demand response measures in this study is based on outputs from the potential study's reference forecast, and Navigant subject matter expert consultation. Demand response and energy efficiency measures are derived from the same set of end uses, but do not have overlapping savings. Energy efficiency savings, for example, involve the inherent reduction in consumption during peak periods due to the upgrade from an inefficient to an efficient technology. Demand response savings provide *additional* savings, due to behavioural or controlled load shifting during these peak periods. For instance, a consumer could upgrade to an efficient technology *and* participate in a demand response program.

To determine the ability of demand response to reduce capacity constraints on the study transformer, Navigant required an hourly profile of demand, by end use, for each hour of the study (2020 to 2030). The potential study's reference forecast projects annual energy consumption for each year from 2020 to 2030, shown in Table 3-7.

Table 3-7. Provincial Annual Energy Consumption by End Use, 2020 to 2030

End Use	Annual Energy Consumption, 2020 (MWh)	Annual Energy Consumption, 2030 (MWh)
Space Heating	2,135,700	2,411,600
Space Cooling	86,600	98,000
Water Heating	572,100	649,000
Appliances	3,205,200	3,642,000
Lighting	2,055,600	2,327,000
Electronics	1,448,100	1,639,600
Whole Building	967,300	1,094,000

Source: EEA Potential Study

To scale these values to the transformer, Navigant applied the same scaling factors as shown in Table 3-3. These scaling factors assume that the energy consumption per household connected to the transformer, for each end use, is identical to the average household provincially. However, some weather-sensitive end uses, such as space heating, may see decreased per capita consumption in northern regions of the province which would offset this scaling factor. The resulting transformer-level energy consumption is shown in Table 3-8.

[19] The technology required to implement a demand response program varies depending on the program type. A behavioural demand response program, for example, requires a notification-delivery system. This may require the administrator to develop a web or mobile application to push notifications to consumers regarding upcoming events. For a direct load control program, a load control switch must be installed for the user. These devices require two-way enabled communication infrastructure, such as broadband internet for example, to respond to events.

Table 3-8. Transformer-Level Annual Energy Consumption by End Use, 2020 to 2030

End Use	Annual Energy Consumption, 2020 (kWh)	Annual Energy Consumption, 2030 (kWh)
Space Heating	14,181	14,416
Space Cooling	575	586
Water Heating	3,796	3,879
Appliances	21,268	21,764
Lighting	13,646	13,908
Electronics	9,612	9,801
Whole Building	6,422	6,536

Source: EEA Potential Study, Navigant analysis

To determine the hourly demand by end use, Navigant calculated the hourly potential for each end use using an 8,760-load shape provided in the potential study. The 8,760-load profile calculates the percent of annual load occurring in each hour of the year, expressed as a percentage.

Navigant determined that only a fraction of the load for each end use would be available for demand response. Navigant subject matter experts have been involved in the design and evaluation of demand response programs with utility partners across North America. This experience provided a baseline to determine the percent of load available for demand response from each end use.

Table 3-9. Percent of Load Available for Demand Response by End Use

End Use	Percent of Load Available for Demand Response
Space Heating	50%
Space Cooling	50%
Water Heating	25%
Appliances	0%
Lighting	0%
Electronics	0%
Whole Building	0%

Source: Navigant analysis

The potential of demand response was calculated by multiplying the percent of load available by the hourly demand for each end use and averaging the result for each hour when transformer demand exceeds the rated capacity.[20] Note that as with energy efficiency, potential is defined only for periods where the transformer's loading exceeds its rating. As such, there is no potential if the transformer is not overloaded.

[20] Note that averaged values are used for illustrative purposes. In Navigant's model, the demand response potential varies in each hour, and is used for calculating the portfolio's ability to offset transformer need within that hour. Rather than publishing the hour-by-hour results, Navigant averages the results to provide a sense of magnitude without sacrificing legibility.

The resulting potential is shown in Table 3-10.

Table 3-10. Demand Response Potential by End Use, 2020 to 2030[21]

End Use	Demand Potential, 2020 (kW)	Demand Potential, 2030 (kW)
Space Heating	0.0	0.95
Space Cooling	0.0	0.07
Water Heating	0.0	0.17
Appliances	0.0	0.0
Lighting	0.0	0.0
Electronics	0.0	0.0
Whole Building	0.0	0.0

Source: EEA Potential Study, Navigant analysis

In July of 2019, the Government of Alberta announced that the implementation of a capacity electricity market would not be pursued further.[22] As such, there is no established pricing structure to value the aggregation of demand response activities.

Many of the factors associated with valuing demand response are highly jurisdictionally specific. For example, the value of a consumer's decreased energy consumption (kWh) and decreased peak demand contributions (kW) vary depending on the pricing structure of the utility's rates and their associated costs imposed on the system. These variables depend on several factors specific to the jurisdiction including the age of the electric infrastructure, the capacity available on the infrastructure and the weather of the region, among others. Further, costs for the technology that allows enablement of demand response vary by region. For these reasons, in this study, Navigant has chosen not to use the costs associated with demand response in other jurisdictions for Alberta.

An alternative method of determining the value of demand response is using the gross cost of new entry – the cost to install new capacity on the Alberta grid. From a supply perspective, reducing demand and increasing supply are equivalent - as the alternative to reducing demand is adding generation. This method of valuing demand response allows the costs to be specific to the Albertan system. A 2018 study by the Alberta Electric System Operator ("AESO") modelled the gross cost of new entry based on the development of a simple-cycle gas turbine plant.[23] The study found the cost of new entry to be $148/kW-yr.

The value found in the AESO study likely overvalues demand response. The cost of new entry provides a cost for generators, which are inherently more reliable and flexible than aggregated demand response resources. As such, the value for demand respond is likely some point below this threshold. For example, the demand response auction in Ontario resulted in an annual clearing price of $53/kW-yr in 2018,[24] and $59/kW-yr in 2019.[25] The Ontario market valued demand response at less than half the cost of new entry

[21] Note that the potential is non-existent for all end uses in 2020. In 2020, there are no need hours at the study transformer, as the rating is not exceeded.
[22] Government of Alberta. https://www.alberta.ca/electricity-capacity-market.aspx
[23] AESO. https://www.aeso.ca/assets/Uploads/Summary-of-Integrated-Capacity-and-Energy-Revenue-Modelling.pdf
[24] IESO. http://www.ieso.ca/en/Sector-Participants/IESO-News/2018/12/IESO-Announces-Results-of-Demand-Response-Auction
[25] IESO. http://www.ieso.ca/Sector-Participants/IESO-News/2019/12/IESO-Announces-Results-of-Demand-Response-Auction

in Alberta. For this study, Navigant selected the $148/kW-yr value, coinciding with the cost of new entry calculated by AESO, as it is a more conservative value.

Note: the potential study completed evaluates demand savings associated with upgrading inefficient technologies to efficient technologies. These demand savings did not include savings associated with demand response programs. As such, the measure-level costs are not applicable for assessing the value of demand response in Alberta. The cost of new entry has been used as a proxy in lieu of available historical demand response costs in Alberta.

3.2.3 Managed EV Charging

Managed charging (or smart charging) involves the intelligent charging of a vehicle based on the needs of the grid. Managed charging allows a utility or other third party to control, delay, or curtail the charging of an EV to reduce consumption during peak periods.

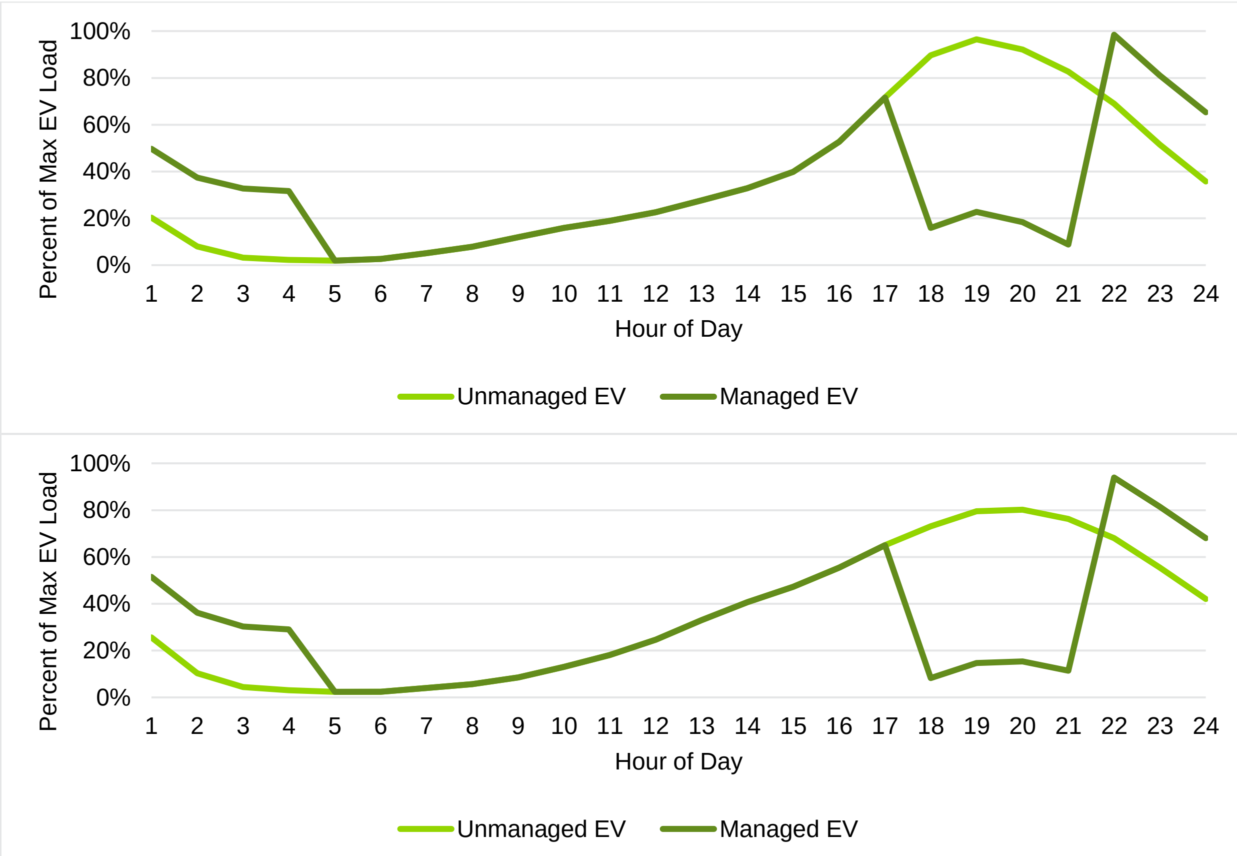
A managed charging program offers consumers monetary incentives for enrolment in a program that permits controlled charging at times when the grid requires curtailment. Managed charging is the alternative to unmanaged charging where the charging station immediately draws power once plugged in by the user (which is often coincident with peak loads).

Navigant develops custom managed charging load profiles based on the peak period definition of a jurisdiction's grid characteristics. In the potential study, results showed that Alberta experiences its system peak in the winter – the study defined the winter peak period occurring from 17:00 to 21:00. Navigant's managed load profile involves the curtailment of load during this peak period from the standard unmanaged profile[26]. Navigant's subject matter experts identified that typically 80% of the total EV load consumed during the traditional peak period can be deferred through managed charging.

Figure 3-1. shows the unmanaged and managed load shapes developed for weekdays and weekends.

[26] Navigant's managed charging profile is designed to mitigate demand during the system peak, not the study transformer peak. Navigant assumes that any managed charging program would be designed at a broader scale than the transformer-level (12 customers). As such, Navigant assumes the system peak is a better representation of a realistic program design.

Figure 3-1. Unmanaged and Managed EV Load Shapes for Weekday (Top) and Weekend (Bottom)



Source: Navigant analysis

The potential for managed charging to defer demand at the transformer is calculated as the average of the difference of the two load profiles during all hours when demand exceeds the transformer rating, multiplied by the forecast EV population on the transformer.

The potential of managed EV charging, on a per vehicle basis, is shown in Table 3-11. Note that the EV adoption forecast shown in Table 2-3 does not account for any current EVs on the study transformer – as such, the potential in 2020 is 0.

Table 3-11. Managed EV Charging Potential, 2020 to 2030

Scenario	End Use	Demand Potential, 2020 (kW)	Demand Potential, 2030 (kW)
Base	Managed EV Charging	0.0	10.63
Aggressive	Managed EV Charging	0.0	15.89

Source: Navigant analysis

Managed charging was not considered as an energy efficiency measure in the EEA potential study. However, like the energy efficiency measures considered in the study, managed charging programs involve various costs to the program administrator. Costs to administer a managed EV charging program include costs associated with program development and delivery, marketing and recruitment of participants, administration of the program, technology enabling costs (i.e., the incremental cost to upgrade from an unmanaged to a managed charger), and any applicable customer incentives for participation.

In prior potential studies, Navigant has assessed the cost to administer such a program in Canada. The levelized acquisition cost that Navigant has used in these studies is $756/kW.[27]

This levelized cost is based on a managed charging program that incentivizes participants to purchase DR-enabled charging stations (charging stations capable of two-way power flows). Under this pricing structure, 50% of the incremental technology cost is paid for by the program administer and 50% is paid for by program participants. Technology costs for this study are largely based on a 2017 study from Lawrence Berkeley National Laboratory ("LBNL").[28] Other costs included marketing and recruitment efforts, a software licensing fee to enable two-way power flows and demand response, and in-house labour costs and program development costs.

[27] EfficiencyOne, "*Nova Scotia Energy Efficiency and Demand Response Potential Study for 2021-2045*". Reproduced at: "https://nsuarb.novascotia.ca/. Matter M08929, Exhibit N1.

[28] LBNL.
https://emp.lbl.gov/sites/default/files/demand_response_advanced_controls_framework_and_cost_assessment_final_published.pdf

3.3 Conclusions

The acquisition cost and total potential, by measure, to fulfill the need at the study transformer in 2030 is summarized below in Table 3-12.

Table 3-12. Summary of Potential and Cost by Measure, 2030

Measure	Acquisition Cost ($/kW)	Demand Potential, Base Scenario (kW)	Demand Potential, Aggressive Scenario (kW)
EE - Space Cooling	$0	0.01	0.01
EE - Water Heating	$63	0.00	0.00
DR - Space Heating	$148	1.36	0.95
EE - Space Heating	$148	0.00	0.00
DR - Space Cooling	$149	0.06	0.07
DR - Water Heating	$150	0.18	0.17
DR - Appliances	$151	0.00	0.00
DR - Lighting	$152	0.00	0.00
DR - Electronics	$153	0.00	0.00
DR - Whole Building	$154	0.00	0.00
EE - Whole Building	$208	0.09	0.08
EE - Electronics	$355	0.33	0.33
EE - Lighting	$482	0.45	0.46
EE - Appliances	$693	0.49	0.49
Managed Charging	$756	10.63	15.89

4. RESOURCE STACK

This section of the report will evaluate whether the non-wires alternatives identified in Section 3 can defer the need at the study transformer. The resource stack, or supply curve, is the portfolio of technologies used to defer the need, and is developed using the potential (kW) and acquisition costs ($/kW) found in Table 3-12.

Table 4-1. Measures in Consideration for Resource Stack

Resource Stack Measures
EE - Space Heating
EE - Space Cooling
EE - Water Heating
EE - Appliances
EE - Lighting
EE - Electronics
EE - Other
DR - Space Heating
DR - Space Cooling
DR - Water Heating
DR - Appliances
DR - Lighting
DR - Electronics
DR - Other
Managed Charging

4.1 Methodology and Approach

To build the resource stack, the measures in Table 4-1 are sorted by their acquisition cost, from least-expensive to most-expensive. The least expensive measure will be the first measure drawn into the portfolio to defer need, followed by the second-least expensive measure, ensuring the resource stack is as cost-effective as possible.

When a measure is drawn into the resource stack, its available potential (kW) is acquired until the measure is fully depleted or the transformer need is fully deferred.[29] In other words, the resource stack is a stepwise function; one measure is fully depleted of available potential before another measure is drawn into the stack.

[29] This analysis assumes that there is no minimum threshold of potential required to implement an energy efficiency or demand response program. Traditionally, only programs with manageable potential are developed into programs, as the administration and overhead costs to implement a program with limited potential likely outweigh the benefits achieved. In this analysis, for example, if only 500 W of potential is available for a measure it is still included in the resource stack, as Navigant assumes the remaining potential is available through other transformers in the region.

The measures, sorted by their acquisition costs, are shown in Table 4-2 for the year 2030. Their acquisition costs and potential are specific to 2030. The cost curves (levelized cost by year) for each individual measure are shown in Appendix A.

Note: available potential shown in this table are averaged values. As such, available potential differs between scenarios for the same end use, due to varying coincidence across need hours. Averaged results are used for illustrative purposes. Actual availability in individual need hours are used to assess portfolio performance – average values are used to generate illustrative figures and tables.

Table 4-2. Resource Stack Measures by Acquisition Cost, 2030

Rank	Measure	Acquisition Cost ($/kW)	Available Potential, Base Scenario (kW)	Available Potential, Aggressive Scenario (kW)
1	EE - Space Cooling	$0	0.01	0.01
2	EE - Water Heating	$63	0.00	0.00
3	DR - Space Heating	$148	1.36	0.95
4	EE - Space Heating	$148	0.00	0.00
5	DR - Space Cooling	$148	0.06	0.07
6	DR - Water Heating	$148	0.18	0.17
7	DR - Appliances	$148	0.00	0.00
8	DR - Lighting	$148	0.00	0.00
9	DR - Electronics	$148	0.00	0.00
10	DR - Whole Building	$148	0.00	0.00
11	EE - Whole Building	$208	0.09	0.08
12	EE - Electronics	$355	0.33	0.33
13	EE - Lighting	$482	0.45	0.46
14	EE - Appliances	$693	0.49	0.49
15	Managed Charging	$756	10.63	15.89

Source: Navigant analysis

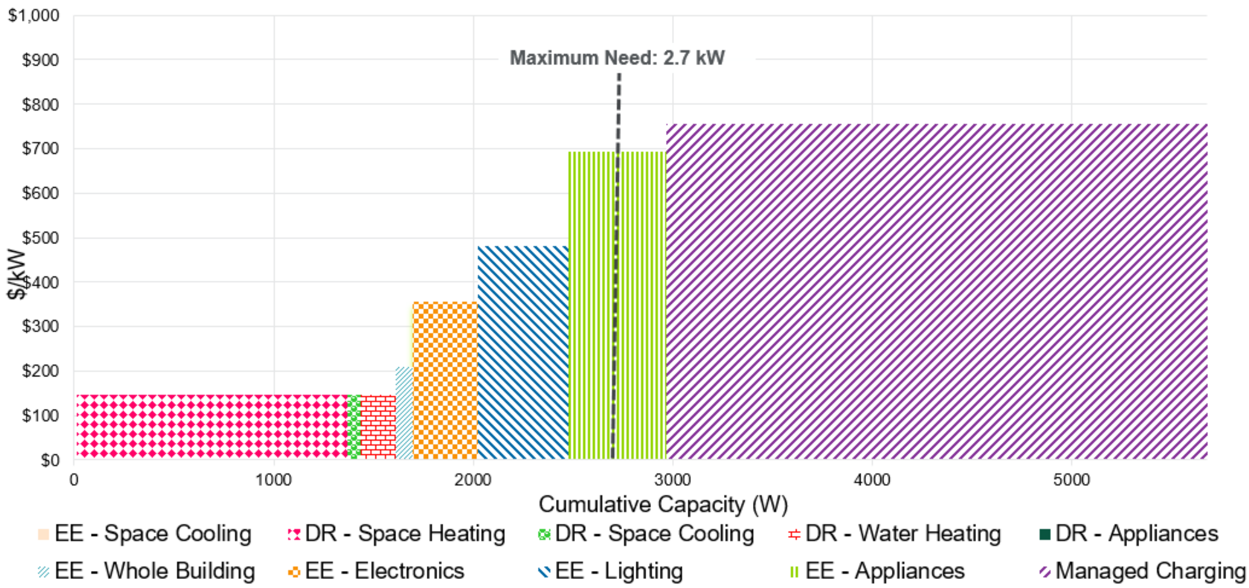
4.2 Results

As stated in Section 2, in the Base EV adoption scenario, the study transformer has a 2030 peak load of 37.9 kW, which exceeds the 35.15 kW rating of the transformer by 2.7 kW. Under the Aggressive EV adoption scenario, the need expands to 9.67 kW.

The resource stack is developed such that the width of the columns represents the potential of the resource to defer peak load at the transformer in kW, and the height of the columns represents the levelized cost of procuring the resource. The dotted line demonstrates the magnitude of the transformer need in each of the EV adoption scenarios. The capacity contribution of all resources to the left of the dotted line are required to defer the transformer need in 2030. In 2030, the resource stack for the Base and Aggressive scenarios are shown in Figure 4-1. and Figure 4-2. respectively.

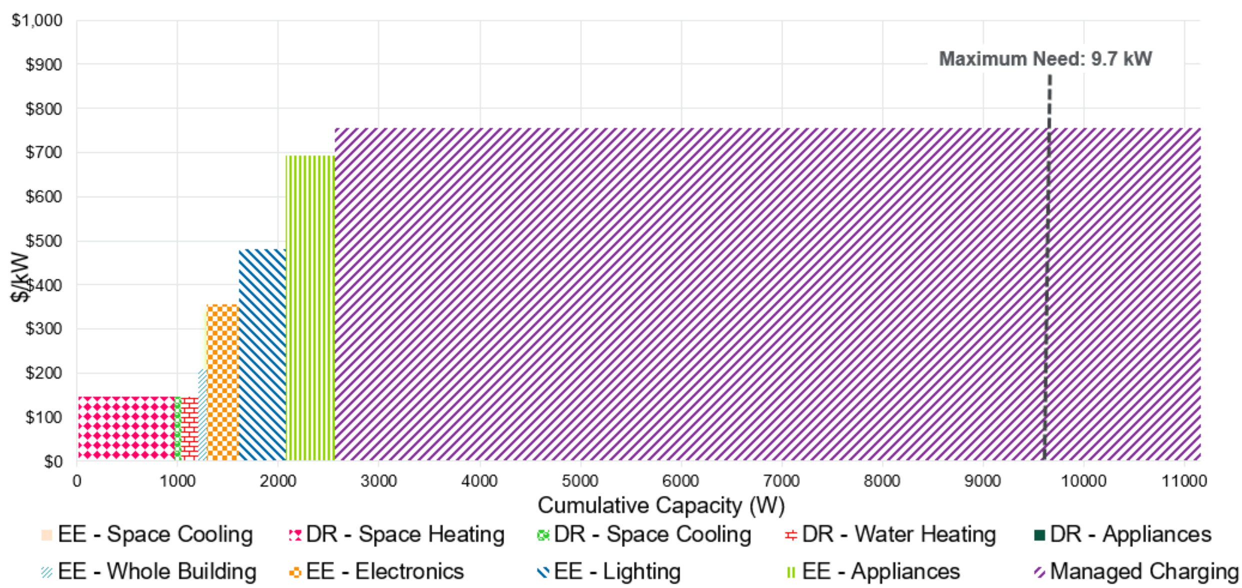
Note: The scale in these figures is adjusted to show highest level of granularity surrounding the need (dashed line). As such, all potential to the right of the dashed line is not pictured. The potential values for each measure in their entirety in shown in Table 4 2. The total cumulative capacity is 13.6 kW in the Base scenario, and 18.4 kW in the Aggressive scenario.

Figure 4-1. 2030 Resource Stack, Base EV Scenario



Source: Navigant analysis

Figure 4-2. 2030 Resource Stack, Aggressive EV Scenario



Source: Navigant analysis

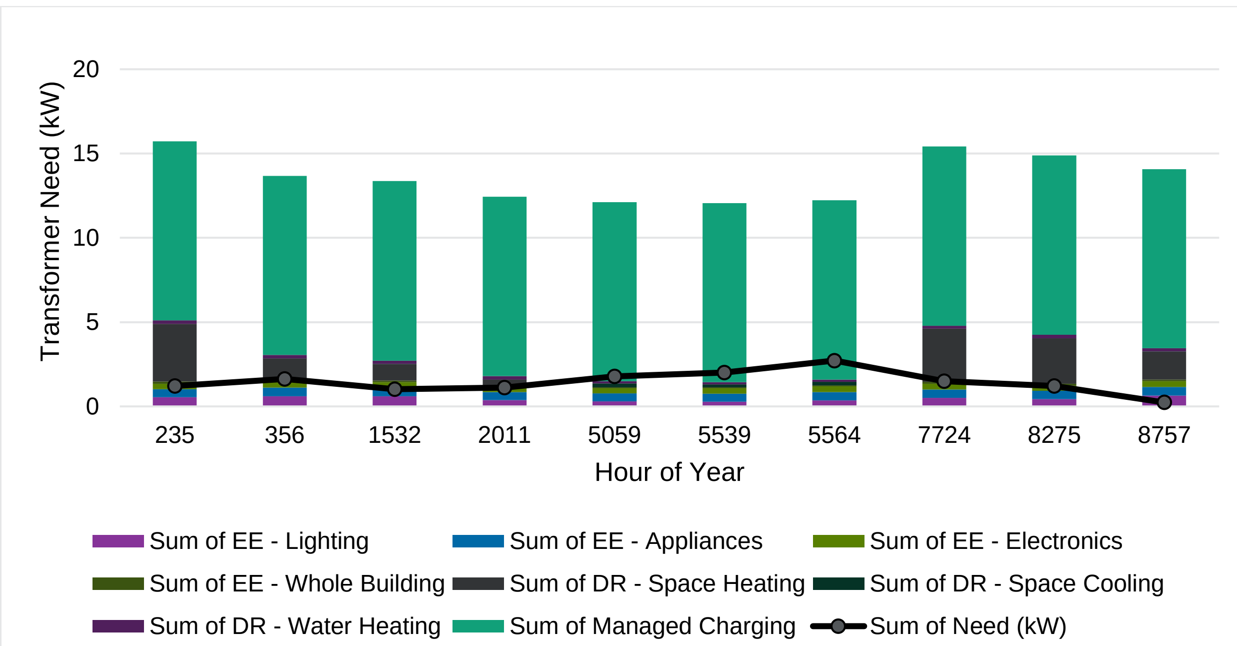
Under both adoption scenarios, the resources identified are capable of fully deferring the maximum need at the transformer. Under the Base scenario, the transformer need is fully deferred using a combination of energy efficiency and demand response – managed charging is not required to meet system needs.[30] As energy efficiency and demand response have lower acquisition costs than managed charging, deferring the need with these measures ensures the lowest possible cost. In other words, as resources are depleted in order of their acquisition cost, the load from EVs can be deferred using only energy efficiency and demand response.

Alternatively, in the Aggressive scenario, managed charging is used to mitigate a large portion of the transformer need, with the less expensive energy efficiency and demand response alternatives fully depleted.

To ensure this portfolio of measures can defer every hour of need on the transformer, Navigant assessed the hourly potential of its portfolio compared to the hourly magnitude of need. This visualization is provided in Figure 4-3. and Figure 4-4. for the Base and Aggressive scenarios respectively.

These figures show each hour where the loading is forecast to exceed the transformer rating, in black. The y-axis represents the magnitude of need on the transformer (difference between transformer rating and loading). The stacked bars show the aggregate potential of the portfolio of energy efficiency, demand response and managed charging to defer the hourly need.

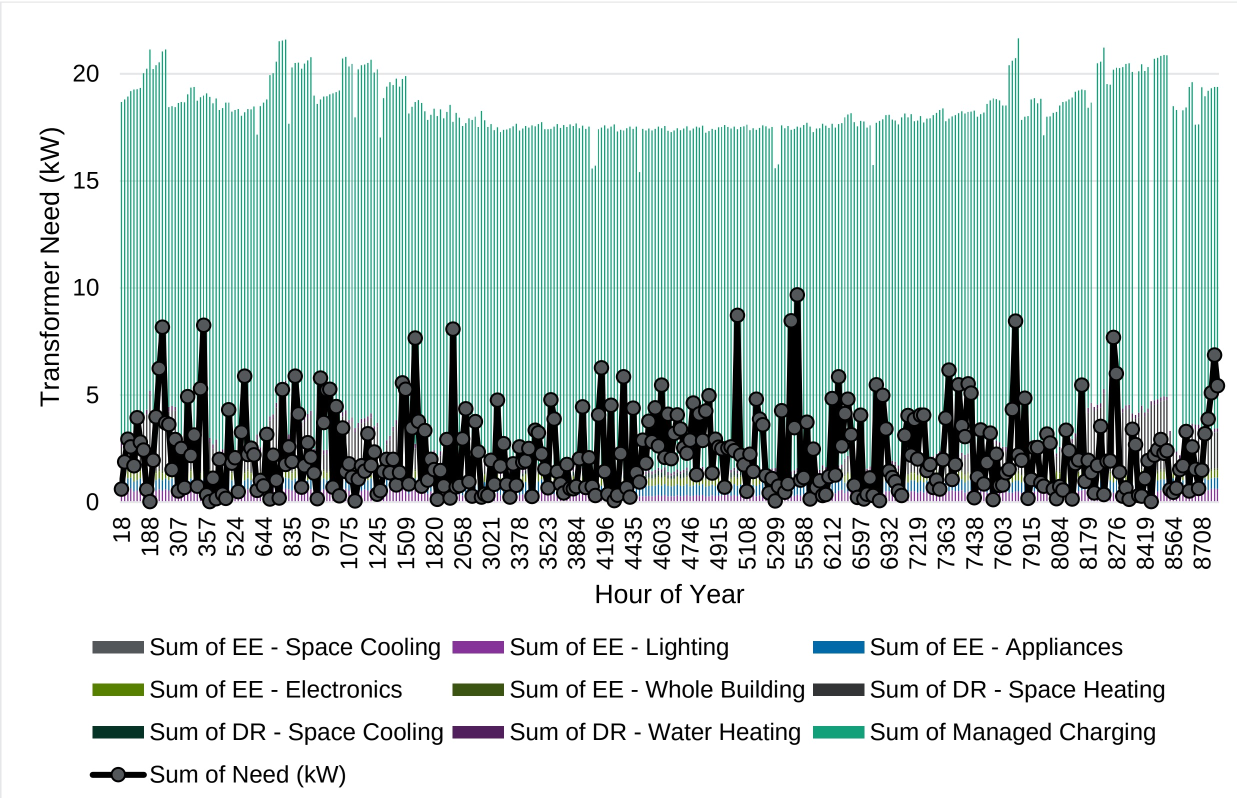
Figure 4-3. Hourly Need Curve for 2030, Base EV Scenario



In 2030, under the Base scenario, the load is deferred in all of the 10 need hours presented.

[30] Note: This is not to say that there is insufficient managed charging potential available to defer need. The resource stack depletes the least expensive measures first – energy efficiency and demand response, which are cheaper than managed charging, are able to fully defer the need.

Figure 4-4. Hourly Need Curve for 2030, Aggressive EV Scenario



In 2030, under the Aggressive scenario, there are 349 hours of need. The portfolio of measures fully defers the need for 348 of these hours. In 1 instance, there remains a need of 1.2 kW. There are no need hours which occur in consecutive hours – the hours before and after do not exceed the transformer rating. As the transformer is only temporarily overloaded, and only in one hour of the year, the portfolio sufficiently meets the transformer constraints.

5. COST-BENEFIT ANALYSIS

5.1 Introduction

This section of the report will evaluate the cost-benefit ratio of the resource stacks presented in Section 4.2 compared to a traditional wires investment.

The total cost of upgrading/replacing the study transformer will be compared to the cost of deferring the transformer need using the portfolio of measures,[31] for both the Base and Aggressive EV scenarios. The cost-effectiveness analysis will be conducted for 2030, the last year of this study period.

5.2 Methodology and Approach

5.2.1 Cost of Traditional Wires Investment

In order to determine if the portfolio of measures required in the resource stack is cost-effective compared to the traditional wires solution of upgrading/replacing the study transformer, Navigant first determined the cost of the traditional wires solution.

EPCOR provided Navigant the total cost to replace the study transformer, including materials and labour. The cost of the traditional wires investment was determined to be $18,000.

5.2.2 Cost of Non-Wires Alternative

The cost of deploying the non-wires alternative solution is calculated using the incremental potential available for each resource in each year, and its associated acquisition cost in that year.

The portfolio of measures in the resource stacks are assumed to be components of one program, managed from 2020 to 2030. The first year of program spending coincides with the first year of need at the transformer (i.e., the first year that transformer demand exceeds the transformer rating), as no potential is required to mitigate demand prior to that year.[32]

The incremental potential available for each measure is shown in Table 5-1 and Table 5-2 for the Base and Aggressive EV scenarios respectively. The values provided represent the potential 'acquired' by the program in that year and does not represent total cumulative program potential. Cumulative potential is calculated as the sum of all years prior to and including the year of consideration. For example, the cumulative potential in 2022 is the sum of the incremental potential in 2020, 2021 and 2022.

Note: As defined in other sections of this study, the term potential refers to the ability to offset demand during need hours. In years where the transformer is not overloaded, there is no potential provided (shown with a '-').

[31] In this context, 'defers' indicates that the transformer upgrade/replacement is avoided.

[32] Some costs, such as program planning, recruitment and marketing, would be incurred prior to the acquisition of the energy efficiency measures. As Navigant utilizes all-in levelized costs for these measures as output from the potential study, it is not possible to itemize these costs into different years. Navigant has assumed that all spending occurs when the measure is installed and able to mitigate demand.

Table 5-1. Incremental Potential by Measure by Year, Base Scenario (kW)

Measure	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
EE - Space Heating	-	-	-	-	-	-	-	-	-	-	0.0
EE - Space Cooling	-	-	-	-	-	-	-	-	-	-	0.0
EE - Water Heating	-	-	-	-	-	-	-	-	-	-	0.0
EE - Appliances	-	-	-	-	-	-	-	-	-	-	0.2
EE - Lighting	-	-	-	-	-	-	-	-	-	-	0.5
EE - Electronics	-	-	-	-	-	-	-	-	-	-	0.3
EE – Whole Building	-	-	-	-	-	-	-	-	-	-	0.1
DR - Space Heating	-	-	-	-	-	-	-	-	-	-	1.4
DR - Space Cooling	-	-	-	-	-	-	-	-	-	-	0.1
DR - Water Heating	-	-	-	-	-	-	-	-	-	-	0.2
DR - Appliances	-	-	-	-	-	-	-	-	-	-	0.0
DR - Lighting	-	-	-	-	-	-	-	-	-	-	0.0
DR - Electronics	-	-	-	-	-	-	-	-	-	-	0.0
DR – Whole Building	-	-	-	-	-	-	-	-	-	-	0.0
Managed Charging	-	-	-	-	-	-	-	-	-	-	0.0
Total	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**2.7**

Table 5-2. Incremental Potential by Measure by Year, Aggressive Scenario (kW)

Measure	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
EE - Space Heating	-	-	-	-	-	-	0.0	0.0	0.0	0.0	0.0
EE - Space Cooling	-	-	-	-	-	-	0.0	0.0	0.0	0.0	0.0
EE - Water Heating	-	-	-	-	-	-	0.0	0.0	0.0	0.0	0.0
EE - Appliances	-	-	-	-	-	-	0.0	0.0	0.1	0.1	0.4
EE - Lighting	-	-	-	-	-	-	0.3	0.1	0.0	0.0	0.0
EE - Electronics	-	-	-	-	-	-	0.3	0.0	0.0	0.0	0.0
EE – Whole Building	-	-	-	-	-	-	0.1	0.0	0.0	0.0	0.0
DR - Space Heating	-	-	-	-	-	-	1.3	0.0	0.0	0.0	-0.4
DR - Space Cooling	-	-	-	-	-	-	0.1	0.0	0.0	0.0	0.0
DR - Water Heating	-	-	-	-	-	-	0.2	0.0	0.0	0.0	0.0
DR - Appliances	-	-	-	-	-	-	0.0	0.0	0.0	0.0	0.0
DR - Lighting	-	-	-	-	-	-	0.0	0.0	0.0	0.0	0.0
DR - Electronics	-	-	-	-	-	-	0.0	0.0	0.0	0.0	0.0
DR – Whole Building	-	-	-	-	-	-	0.0	0.0	0.0	0.0	0.0
Managed Charging	-	-	-	-	-	-	0.0	0.0	0.0	0.0	7.1
Total	-	-	-	-	-	-	**2.3**	**0.1**	**0.1**	**0.1**	**7.1**

To determine the program spending in each year, the potential is multiplied by the measure acquisition cost. The acquisition cost (per kW) does not vary for the Base and Aggressive scenarios and is shown in Table 5-3 in nominal dollars. These values are used to derive the cost curves for each measure, which are presented graphically in Appendix A.

Table 5-3. Acquisition Cost by Measure by Year ($/kW)

Measure	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
EE - Space Heating	$122	$125	$127	$130	$132	$135	$137	$140	$143	$146	$148
EE - Space Cooling	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
EE - Water Heating	$53	$54	$55	$56	$57	$58	$59	$60	$61	$62	$63
EE - Appliances	$568	$579	$591	$603	$615	$627	$640	$653	$666	$679	$693
EE - Lighting	$682	$627	$590	$559	$538	$518	$504	$491	$496	$489	$482
EE - Electronics	$279	$286	$294	$301	$309	$316	$324	$331	$339	$347	$355
EE – Whole Building	$171	$175	$178	$182	$185	$189	$193	$196	$200	$204	$208
DR - Space Heating	$148	$148	$148	$148	$148	$148	$148	$148	$148	$148	$148
DR - Space Cooling	$148	$148	$148	$148	$148	$148	$148	$148	$148	$148	$148
DR - Water Heating	$148	$148	$148	$148	$148	$148	$148	$148	$148	$148	$148
DR - Appliances	$148	$148	$148	$148	$148	$148	$148	$148	$148	$148	$148
DR - Lighting	$148	$148	$148	$148	$148	$148	$148	$148	$148	$148	$148
DR - Electronics	$148	$148	$148	$148	$148	$148	$148	$148	$148	$148	$148
DR – Whole Building	$148	$148	$148	$148	$148	$148	$148	$148	$148	$148	$148
Managed Charging	$756	$756	$756	$756	$756	$756	$756	$756	$756	$756	$756

The total program spending by year is shown in Table 5-4 and Table 5-5 for the Base and Aggressive scenarios.

Table 5-4. Program Spending by Year, Base Scenario ($)

Measure	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
EE - Space Heating	-	-	-	-	-	-	-	-	-	-	$0
EE - Space Cooling	-	-	-	-	-	-	-	-	-	-	$0
EE - Water Heating	-	-	-	-	-	-	-	-	-	-	$0
EE - Appliances	-	-	-	-	-	-	-	-	-	-	$168
EE - Lighting	-	-	-	-	-	-	-	-	-	-	$218
EE - Electronics	-	-	-	-	-	-	-	-	-	-	$116
EE – Whole Building	-	-	-	-	-	-	-	-	-	-	$18
DR - Space Heating	-	-	-	-	-	-	-	-	-	-	$201
DR - Space Cooling	-	-	-	-	-	-	-	-	-	-	$9
DR - Water Heating	-	-	-	-	-	-	-	-	-	-	$27
DR - Appliances	-	-	-	-	-	-	-	-	-	-	$0
DR - Lighting	-	-	-	-	-	-	-	-	-	-	$0
DR - Electronics	-	-	-	-	-	-	-	-	-	-	$0
DR – Whole Building	-	-	-	-	-	-	-	-	-	-	$0
Managed Charging	-	-	-	-	-	-	-	-	-	-	$0
Total	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**$756**

Table 5-5. Program Spending by Year, Aggressive Scenario ($)

Measure	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
EE - Space Heating	-	-	-	-	-	-	$0	$0	$0	$0	$0
EE - Space Cooling	-	-	-	-	-	-	$0	$0	$0	$0	$0
EE - Water Heating	-	-	-	-	-	-	$0	$0	$0	$0	$0
EE - Appliances	-	-	-	-	-	-	$0	$0	$41	$84	$338
EE - Lighting	-	-	-	-	-	-	$138	$191	$216	$226	$231
EE - Electronics	-	-	-	-	-	-	$106	$106	$106	$106	$106
EE – Whole Building	-	-	-	-	-	-	$16	$16	$16	$16	$15
DR - Space Heating	-	-	-	-	-	-	$198	$198	$198	$202	$141
DR - Space Cooling	-	-	-	-	-	-	$10	$10	$10	$9	$10
DR - Water Heating	-	-	-	-	-	-	$27	$27	$27	$27	$26
DR - Appliances	-	-	-	-	-	-	$0	$0	$0	$0	$0
DR - Lighting	-	-	-	-	-	-	$0	$0	$0	$0	$0
DR - Electronics	-	-	-	-	-	-	$0	$0	$0	$0	$0
DR – Whole Building	-	-	-	-	-	-	$0	$0	$0	$0	$0
Managed Charging	-	-	-	-	-	-	$0	$0	$0	$0	$5,373
Total	-	-	-	-	-	-	$495	$548	$614	$670	$6,240

5.3 Results

To calculate the cost-benefit ratio of the non-wires alternative, the present value of both the non-wires alternative and the traditional wires investment will be calculated in 2020 dollars. For this analysis, the nominal discount rate used is 5%, consistent with the rate used for EEA's potential study.

For the Base EV adoption scenario, the traditional wires investment occurs in 2030, the first year there is need on the transformer. In present value, discounted 5% annually, the traditional wires investment costs $10,524. The net present value of the total program spending for the non-wires resource stack is $442. As the portfolio of non-wires alternatives is significantly less expensive than the traditional investment, the resource stack is a cost-effective alternative to the traditional wires investment.

For the Aggressive EV adoption scenario, the traditional wires investment occurs in 2026, the first year there is need on the transformer. In present value, discounted 5% annually, this investment costs $12,792. The net present value of the total program spending for the non-wires resource stack is $5,178. As the portfolio of non-wires alternatives is less expensive than the traditional investment, the resource stack remains a cost-effective alternative to the wires investment in the Aggressive scenario.

Table 5-6. Cost-Benefit Ratio of Non-Wires Alternatives vs. Traditional Wires Investment

Scenario	Present Value of Traditional Wires Investment Cost ($)	Present Value of Non-Wires Alternative Cost ($)	Cost-Benefit Ratio
Base	$10,524	$442	23.8
Aggressive	$12,792	$5,178	2.5

In both scenarios considered, the non-wires alternative is cost competitive compared to the traditional wires investment.

The Base scenario presents a much more cost-effective result than the Aggressive scenario. In the Base scenario, roughly 3 kW of need must be offset. This need triples in the Aggressive scenario – however, the present value of the non-wires portfolio spending in the Aggressive scenario is over 10 times larger than the value of the Base scenario. This indicates that the relationship between need and portfolio spending is non-linear, as less expensive measures are fully depleted (i.e., acquired in the resource stack) prior to acquiring expensive measures.

6. CONCLUSIONS

The objective of this study was to assess the value of energy efficiency, demand response and managed EV charging at reducing the imposed costs of electric vehicles on the distribution system from 2020 to 2030. Specifically, this study assessed the impacts of EV adoption on a 12-customer distribution transformer.

The key findings of this study are:

1. A portfolio of energy efficiency measures and managed charging can be more cost-effective than a traditional wires investment. In this study, under both the Base and Aggressive EV adoption scenarios, the portfolio of non-wires alternatives was less costly than the traditional wires investment.

    a. The portfolio of non-wires alternatives has a cost-benefit ratio of 23.8 in the Base scenario and 2.5 in the Aggressive scenario, compared to the traditional wires investment.

2. The future loading on a distribution transformer is highly dependent on EV adoption. For the Base EV adoption scenario, which models business-as-usual EV adoption, the study transformer is slightly overloaded in 2030 (108% of rating) but is significantly overloaded in the Aggressive scenario (128% of rating).

3. For the Base scenario in 2030, it was shown that energy efficiency and demand response alone can mitigate the transformer constraints when the transformer is slightly overloaded.

4. For the Aggressive scenario in 2030, it was shown that all non-wires alternatives are required to mitigate the transformer constraints, including managed charging when the overloading on the transformer becomes more significant.

5. Due to the conservative nature of this study, the portfolio of non-wires alternatives is likely more cost-effective than stated. This study assumed aggressive EV adoption, presented a conservative valuation of demand response, and considered only distribution costs for the traditional wires investment – all factors which contribute to a lower cost-benefit ratio.

6. The scalability of non-wires alternatives can allow for flexible, cost-effective mitigation of transformer loading. This study has shown the relationship between overloading and cost-effectiveness is non-linear – costs escalate as the overloading on the transformer increases. The scalability of non-wires alternatives allows for precise control of what is acquired.

6.1 Risks Identified

Navigant has identified the following risks and areas of sensitivity for this analysis. This list outlines possible risks for the portfolio of resources to meet system needs.

1. **Energy efficiency potential by household is not uniform as assumed**

    The outputs from the potential study utilized in this analysis assume that every household has the same demand reduction potential. This assumption may be oversimplifying and could impact the actual energy efficiency potential available at the study transformer.

Energy efficiency potential is highly dependent on the saturation of baseline and efficient technologies. These saturations likely vary at the localized level – for example, if the saturation of efficient technologies for the households connected to the transformer currently exceeds the provincial average, the available potential of future energy efficiency would be reduced. This risk is possibly compounded by the nature of EV adoption – consumer's purchasing an EV may be more likely to already own efficient technologies. EV owners may have higher than average household income and may be more environmentally inclined, making them likely candidates to pursue efficient technologies on their volition.

2. **Conservative estimate of demand response acquisition cost may be worsening cost-benefit results of non-wires portfolio**

   In lieu of historical administrator costs for a residential demand response program in Alberta, Navigant has valued the acquisition cost of demand response based on an AESO study determining the cost of new entry for generators.

   Navigant recognizes that this may be overvaluing demand response, and that the actual acquisition cost may be lower than stated. Generators are inherently more valuable than aggregated demand response resources, as generators are more flexible and reliable. The actual value of residential demand response in Alberta may be less costly to the administrator – as such, the cost-benefit results of the non-wires portfolio compared to a traditional wires investment is conservatively low in this analysis.

3. **Electric vehicle population may differ from forecasts at local level**

   The key driver for load growth at the transformer in this analysis is the forecast population of EVs. As mentioned, EVs can have significant coincident peak impacts if unmanaged. Managed charging greatly reduces this impact but cannot mitigate the entirety of the load for various reasons, such as lack of consumer participation, phantom electricity consumption, or customers temporarily opting out of the program due to individualized charging needs (such as departing on a lengthy road trip, etc.).

   Navigant's forecast of EVs on the study transformer is based on the Base and Aggressive scenarios developed by Navigant Research. These results are then scaled to the transformer based on a ratio of households. This transformer-level population value is highly sensitive. The customers connected to this transformer may not purchase a single EV – on the other hand, it is within the realm of possibility that every customer could purchase an EV. Navigant's forecast estimates the scenarios with the highest likelihood of occurring; scenarios that are likely representative of the average transformer in EPCOR's service territory. It is not possible to know with certainty what the population of EVs will be on the study transformer in 10 years – as such, the need on the transformer may under/over-exceed Navigant expectations.

4. **Load shape of study transformer may change over study period, impacting coincidence**

   EPCOR provided Navigant with the hourly loading for the study transformer in 2018. Navigant modified this load shape to include natural load growth and the superimposition of EV adoption throughout the study period.

   Navigant's forecast largely assumes that the general loading profile of the transformer (excluding EV growth) is unchanged throughout the study period, and that the loading in 2018 is not irregular compared to historical years of loading. For example, the magnitude of non-EV load changes in each hour, but the ratio of consumption hour-to-hour is unchanged. Should consumer behaviour alter over the period, the load profile will be altered from its 2018 shape. As Navigant's availability calculations depend on coincidence during need hours, potential results may vary with the load shape.

5. **Cost-benefit results are specific to this transformer and may not be representative of all distribution equipment**

   The defining result of this study is whether a portfolio of energy efficiency, demand response and managed EV charging is less expensive compared to a traditional wires investment. This analysis depends on a variety of transformer-specific inputs, such as customer count, upgrade cost, and present-day loading, among others.

   Results may vary significantly for a different transformer. At present-day, the transformer could be much closer to an overloaded state – as such, more potential will need to be acquired from the resources to defer need. Or the loading on the transformer may be less coincident with the load profiles for the load profiles of the measures, resulting in less available potential. Further, if the upgrade cost for the transformer is different, the cost-benefit results will differ.

6.2 Conservative Assumptions

This section summarizes the conservative nature of this study. The list below outlines components of the analysis conducted by Navigant, or assumptions made by Navigant that undervalue the portfolio of non-wires alternatives.

1. **At the local level, it is possible that EV adoption on the transformer is less than assumed by Navigant's Base and Aggressive adoption scenarios**

   This study utilizes a Base and Aggressive adoption scenario but does not include a 'Conservative' scenario (if for example, the cost of EVs declines at a slower rate than predicted). It is possible that the actual loading on the study transformer is less than predicted in 2030 due to EV adoption on the transformer being lower than assumed. Navigant's Base scenario assumes that 2 out of 12 households connected to the transformer (17%) will adopt an EV by 2030. The actual EV adoption on the transformer could be less than modelled.

   As such, in 2030, the need on the transformer may be lower than anticipated. This study showed that, at lower levels of loading, the cost-benefit ratio is higher, as energy efficiency can mitigate the overloading. Under a 'Conservative' EV adoption scenario, the portfolio of non-wires alternatives may be more cost-effective than shown.

2. **Navigant has assumed that the demand reduction potential of energy efficiency measures has not increased since the 2017 potential study**

   The potential for energy efficiency measures to reduce coincident peak demand on the transformer is modelled based on outputs from the 2017 potential study. Navigant has assumed that the demand reduction potential from these measures has not increased since the time of this study.

   It is possible that technologies released since the potential study analysis was conducted, or increases in measure efficiency that exceeded modelling assumptions, could increase the demand reduction potential of energy efficiency used in this study. This would improve the cost-benefit ratio in the Aggressive scenario, as energy efficiency has a cheaper acquisition cost than managed charging.

3. **Navigant has utilized a conservative estimate for the acquisition cost of demand response**

   In lieu of historical costs for a residential demand response program in Alberta, Navigant equated the acquisition cost to the gross cost of new entry – the cost to install new capacity on the grid.

   This likely overvalues the cost of demand response, as new capacity is more reliable and flexible than demand response. As such, the acquisition cost for demand response is likely lower, improving the cost-effectiveness results in this study, compared to the traditional wires investment.

4. **Navigant has assumed that the traditional wires investment does not include any costs upstream of the distribution transformer**

   EV adoption increases loading on all equipment upstream of the distribution transformer, such as the feeder and transformer-station. If increased EV adoption on a transformer necessitated upgrades upstream of the transformer, a portion of these costs could be considered in the wires investment cost.

   The cost that Navigant is considering as the alternative to the non-wires portfolio does not include any upstream costs, yet the portfolio of non-wires alternatives remains cost-effective. If Navigant considered upstream costs in the wires investment (such as allocating a portion of the feeder upgrade to this transformer, for example), the portfolio of non-wires alternatives would be more cost-effective than presented.

6.3 Recommended Next Steps

Navigant has the following recommendations for moving the non-wires alternative portfolio forward and for conducting future analyses.

1. **Investigate ability to increase energy efficiency demand reduction potential through revision of potential study measure-level inputs and/or scenario modelling**

   EEA's potential study was published in 2017. The potential study developed a forecast of electricity consumption, pricing of efficient technologies, market saturation of efficient technologies, and other forward-looking data.

   For several measures considered in this study, it is possible the market saturation and incremental costs differ slightly from their 2017 projections. It is also possible that technologies currently available on the market, which weren't available in 2017, could increase the demand reduction potential of energy efficiency. If these measure-level data points were revised, new technologies were characterized, or a potential study was completed to target demand-based savings (such as Scenario D in the 2019 Integrated Ontario Electricity and Natural Gas Achievable Potential Study),[33] the total energy efficiency demand reduction potential may be increased.

2. **Test cost-benefit results for variety of transformers with different loading conditions and costs**

   This study has demonstrated that a portfolio consisting of energy efficiency, demand response and managed charging *can* be a cost-effective alternative to traditional wires investments.

[33] IESO, OEB. http://www.ieso.ca/en/Sector-Participants/Energy-Efficiency/Energy-Efficiency-Resources-and-Reports

However, as described in Section 6.1, these results are dependent on a number of inputs specific to the study transformer. There may be instances where the portfolio of measures identified *is not* cost-effective compared to the traditional wires investment.

Navigant recommends that similar analyses be conducted by EEA for transformers with a range of loading conditions. To a certain extent, under the same set of analyses, EEA may be able to identify the requisite loading data and upgrade costs of a transformer such that the non-wires portfolio of energy efficiency, demand response and managed charging will be the least-cost deferral option.

3. Consider impacts of societal benefits in measure-level cost-benefit results on overall portfolio performance

In the 2017 potential study, measures were considered cost-effective if their TRC value was greater than 1.[34] For Navigant's analysis, the results of these cost tests were applied directly to determine whether measure-level savings and costs would be included in the aggregated end use level results.

The potential study analysis screened some measures with greenhouse gas emissions reductions benefits less than or equal to a $30 per tCO2e threshold. The same screening could be applied to this study – allowing measures that meet this threshold into the portfolio regardless of their TRC test result. Considering measures cost-effective if they pass the TRC test or meet the greenhouse gas emissions reductions may result in a portfolio of measures that *remains* cost-effective compared to the traditional wires alternative. This would allow EEA to test the sensitivity of their cost-effectiveness results when considering societal benefits.

[34] 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.

7. ADDITIONAL ANALYSIS – SOCIETAL PERSPECTIVE

7.1 Summary

The analysis completed in sections 1 through 6 in this report compared the costs to mitigate need at a local transformer for either a traditional wires upgrade, or the procurement of a portfolio of non-wires alternatives. That analysis was approached from the perspective of the host-utility. In this Section, the least-cost analysis is re-evaluated from a societal perspective. Societal factors are often considered, for example, by government or regulatory bodies with environmental or economic mandates driving decision making.

Energy efficiency measures contain many societal benefit streams that are not captured in the original analysis. Therefore, in this analysis, the acquisition costs of energy efficiency measures were re-calculated to include societal benefits, including the value of avoided carbon emissions and energy savings. After including these benefit streams in the levelized cost calculations, the resulting net levelized costs for all energy efficiency measures resulted in a negative levelized cost. This indicates that from a societal perspective, the acquisition of energy efficiency presents a net benefit – in other words, the need at the study transformer can be deferred without presenting a net cost to society.

After modifying the acquisition costs to include the additional benefit streams, an amended resource stack was developed – as the available capacity potential available at the time of need is unaffected by modifying the levelized costs, only the order in which measures are pulled into the resource stack differs. Energy efficiency measures which were more costly than demand response in the original analysis, such as the electronics and lighting end uses, are now pulled into the resource stack earlier, having a lower acquisition cost.

The comparison of costs between the non-wires alternatives and the traditional wires investment was re-calculated. In the Aggressive EV scenario, the present value of the non-wires portfolio was determined to be negative. This indicates that from a societal perspective, the benefits of acquiring the non-wires portfolio outweigh the costs associated with procurement. This analysis highlights the importance of perspective when conducting costing exercises; although a purchasing decision may be made based on costs to a specific party, such as the host utility, the benefits and costs have consequences that can impact a much larger audience and should not be excluded from consideration. While this additional analysis may not change the purchasing decision of the utility, it demonstrates that by considering a more comprehensive set of costs and benefits, specific program choices, such as energy efficiency, may be prioritized if the utility considers costs and benefits to society or if a regulatory body requires it.

7.2 Introduction

The analysis completed previously in this report evaluated the least-cost option between a traditional wires investment and a portfolio of non-wires alternatives for mitigating need at a local distribution transformer. This least-cost analysis was approached from the perspective of the host utility and considered all costs and benefits taken by the utility (and associated participants) to reduce demand on a local transformer. The utility perspective only considers the costs and benefits that impact the utility or utility participants.

While this analysis accurately captures the investment decision that would be undertaken by a utility, it does not necessarily capture all benefit streams associated with energy efficiency. Energy efficiency has many benefits that serve a broader societal audience. These benefits, such as reduced carbon emissions, are additional benefits not available with the traditional wires upgrades.

There is value in considering the least-cost analysis from multiple perspectives – a regulator, for example, may consider societal benefits in their approval decisions[35]. Societal benefits can be strong factors for consideration by regulators in jurisdictions with economic or environmental mandates, or for government policymakers with impetus to reduce system constraints and greenhouse gas emissions. This section reconsiders the analysis conducted in Sections 3 through 6 but takes into consideration the societal benefits associated with energy efficiency.

Note: The scope of this analysis is to evaluate the societal benefits associated with energy efficiency measures. These benefit streams also have a direct impact on the consumer; for example, the inclusion of energy savings represents a benefit to the customer through reduced consumption, and thus, lower bills. Consumer savings from bill charges are not modelled in the societal analysis, as the savings represent no net gain to society – the value detracted from the utility is gained by the consumer and represents a "break-even" for society. If this analysis were modelled from the consumer perspective, these societal cost streams would result in larger benefits from energy efficiency (i.e. bill charges added to the analysis). Also, unless GHG reduction benefits are reflected on an energy bill through a carbon levy or tax to the consumer, these would not be considered "consumer" benefits.

7.3 Methodology and Approach

In Section 3.2.1, the acquisition costs for energy efficiency measures were calculated using outputs from the EEA potential study. Measure-level levelized costs ($/kW) were taken as primary inputs. These values were aggregated to the end-use level after screening for measures with negative potential values, noting that negative values are a result of fuel-switching potential (i.e., more consumption is added from switching gas to electric measures than is reduced through energy efficiency). Additionally, measures with a TRC test value less than 1 were screened out to ensure the total portfolio was cost effective.

The levelized costs used in the potential study, and original analysis, were generated using Equation 1.

Equation 1. Original Levelized Cost Calculation

$$\textbf{\textit{Levelized Cost}}\ (\text{"LC"}) \left(\frac{\$}{\textbf{\textit{kW}}}\right) = \frac{\textbf{\textit{Incremental Measure Cost}} - \textbf{\textit{O\&M Savings}}}{\textbf{\textit{kW Savings}}}$$

In this section, the high-level methodology will not differ. However, the inputs (levelized costs) will be altered to include additional societal benefit streams. To consider the analysis from a broader, societal perspective (e.g., from the point-of-view of a regulatory body), the levelized costs for energy efficiency measures must be re-calculated to include the following the benefit streams.

1. Energy savings
    a. The monetary benefits resulting from the gross avoided cost of energy, including the electricity pool price and retail charges developed in the EEA potential study.
2. Avoided carbon costs ($/tCO$_2$e)
    a. The monetary or quantifiable benefits resulting from greenhouse gas emissions reductions. Values in levelized cost equation were based on reference case of EEA

[35] Guidehouse. https://guidehouse.com/-/media/www/site/downloads/energy/2018/pages-from-aesp-magazine-2018navigantarticle.pdf

potential study, which considered an initial carbon price floor of $30/tCO_2e$ which escalates throughout the study period.

Note: This analysis does not include transmission and distribution capacity costs as a societal benefit stream.

For the analysis conducted in this section, Navigant developed two sets of levelized costs. The first, shown in Equation 2, considers only the impact of energy savings. The second, shown in Equation 3, considers the impact of both energy savings and avoided carbon costs.

Equation 2. Modified Levelized Cost Calculation – Energy Savings

$$LC\left(\frac{\$}{kW}\right) = \frac{Incremental\ Measure\ Cost - (O\&M\ Savings + Avoided\ Energy\ Cost + Gross\ Avoided\ Cost)}{kW\ Savings}$$

Equation 3. Modified Levelized Cost Calculation – Energy Savings and Avoided Carbon

$$LC\left(\frac{\$}{kW}\right) = \frac{Incremental\ Measure\ Cost - (O\&M\ Savings + Avoided\ Energy\ Cost + Avoided\ Carbon\ Costs + Gross\ Avoided\ Cost)}{kW\ Savings}$$

Navigant aggregated the measure-level data resulting from Equation 2 and Equation 3 to the end-use level, after conducting the same screening exercises described above. The resulting acquisition costs for energy efficiency from Equation 2, which considers only the addition of energy savings, are shown in Table 7-1.

Table 7-1. Modified Acquisition Costs for Energy Efficiency – Energy Savings

End Use	Acquisition Cost, 2020 ($/kW)	Acquisition Cost, 2030 ($/kW)
Space Heating[36]	-$220	-$347
Space Cooling	$0	$0
Water Heating	-$397	-$486
Appliances	-$81	-$98
Lighting	-$1,127	-$1,523
Electronics	-$228	-$310
Whole Building	-$361	-$501

Source: EEA Potential Study, Navigant analysis

The acquisition costs for energy efficiency from Equation 3, which considers the addition of energy savings as well as the avoided cost of carbon, are shown in Table 7-2.

[36] Note: With residential natural gas space heating prominent in Alberta, space heating related savings also consider electricity savings from the use of the electric blower motors to distribute heat throughout homes.

Table 7-2. Modified Acquisition Costs for Energy Efficiency – Energy Savings and Avoided Carbon

End Use	Acquisition Cost, 2020 ($/kW)	Acquisition Cost, 2030 ($/kW)
Space Heating	-$805	-$1,072
Space Cooling	$0	$0
Water Heating	-$1,170	-$1,449
Appliances	-$1,180	-$1,464
Lighting	-$3,051	-$3,870
Electronics	-$1,139	-$1,540
Whole Building	-$1,463	-$1,972

Source: EEA Potential Study, Navigant analysis

Note: The potential to reduce demand associated with energy efficiency measures is not modified in this analysis. Only the acquisition costs have been altered. As such, the potential values contained in Table 3-5 are utilized in this analysis.

The values in Table 7-1, Table 7-2 and Table 3-6 are three sets of energy efficiency levelized costs being considered from different perspectives. The sets of levelized costs offer perspectives on the costs and benefits of reducing demand on the study transformer – however, the results are not directly comparable. In Table 7-1 and Table 7-2, additional societal benefits are present (which are not included earlier), resulting in decreased levelized costs.

In the original acquisition costs, the values represent a cost to the utility. In the amended levelized costs, the values are negative which indicates from society's perspective there are more benefits than costs for including energy efficiency programming in the non-wires portfolio. This indicates that the energy efficiency measures present a net benefit to society. The impacts on the levelized costs from considering the additional societal benefits from energy efficiency cause the values to deviate significantly from our original results.

Note that the acquisition costs in Table 7-2, which include both the energy savings and avoided cost of carbon are more negative than the acquisition costs in Table 7-1, which include only the energy savings. However, the values in Table 7-1 are negative nonetheless, indicating that the inclusion of energy savings alone is sufficient to decrease the levelized costs into negative values. The avoided carbon costs contribute by decreasing the values further but are not necessary to achieve a net benefit.

This analysis demonstrates that energy efficiency presents an overall benefit to society *prior* to the least-cost comparison with the traditional wires investment (i.e., would present a benefit even if acquired not solely for the purpose of being the least-cost option for deferring transformer demand). When acquired for the purpose of offsetting demand, this benefit increases.

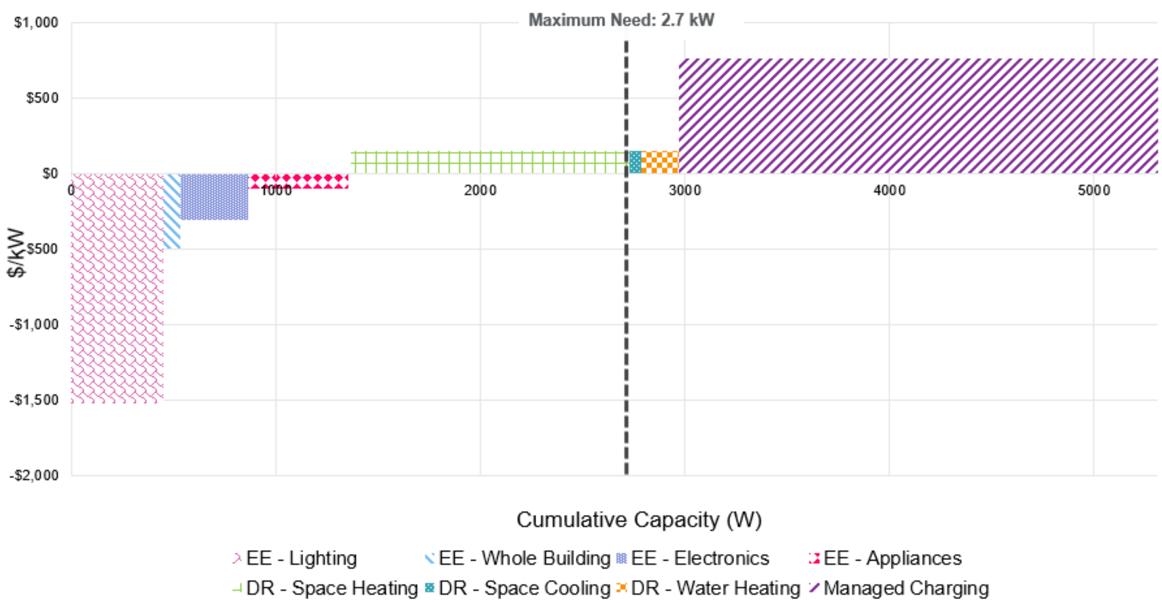
7.4 Amended Resource Stack

In Section 4, Navigant developed a resource stack of the non-wires alternatives to determine whether the portfolio could defer the need at the study transformer. In the resource stack, the non-wires measures are sorted by their acquisition cost from least-expensive to most-expensive. When a measure is pulled into the resource stack, its potential (kW) is acquired until its available potential is fully depleted.

The order in which measures are acquired (or pulled into the resource stack) is dependent on their acquisition cost. As the analysis conducted in Section 7.3 has altered the acquisition cost of all energy efficiency measures, a new resource stack has been developed. As the available potential for each measure has not been impacted, only the order in which measures are pulled into the resource stack has changed (based on cost) – the ability to defer the need at the transformer is unchanged.

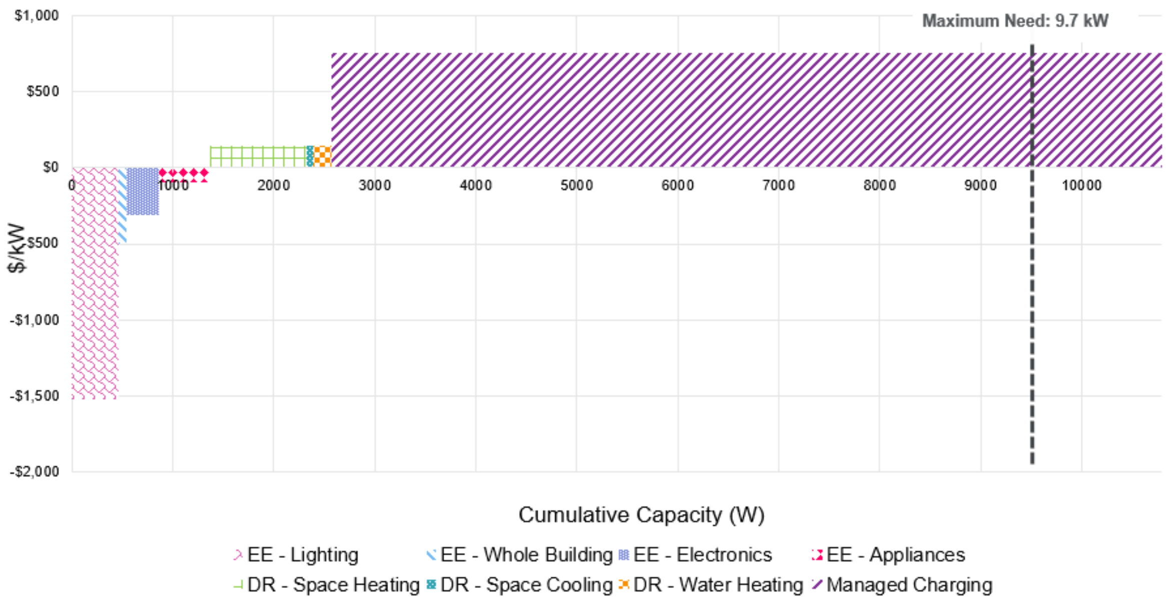
Two sets of amended resource stacks, accounting for the modified levelized costs, have been developed. In Figure 7-1 and Figure 7-2, resource stacks for the Base and Aggressive EV scenarios are shown, developed using the levelized costs in Table 7-1.

Figure 7-1 Amended 2030 Resource Stack, Base EV Scenario – Energy Savings



Source: Navigant analysis

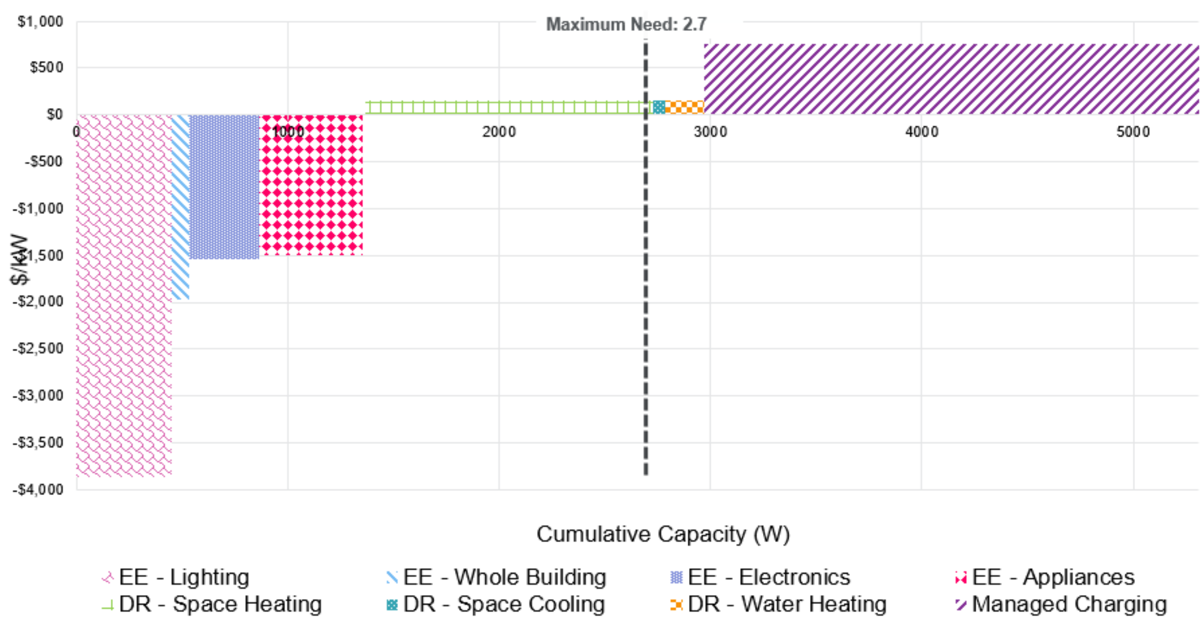
Figure 7-2 Amended 2030 Resource Stack, Aggressive Scenario – Energy Savings



Source: Navigant analysis

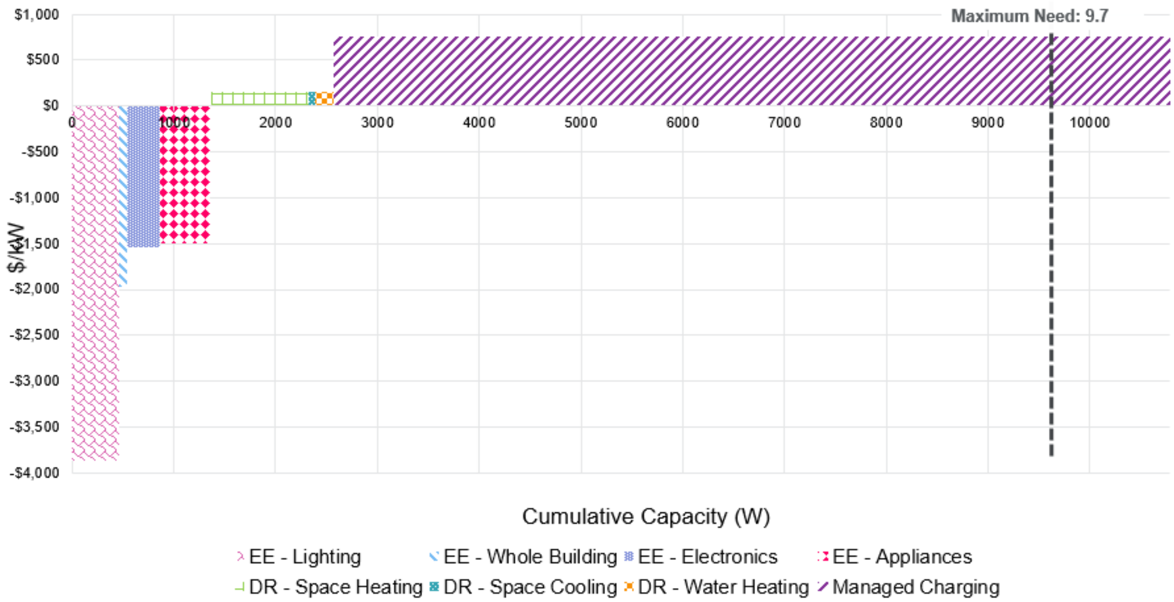
In Figure 7-3 and Figure 7-4, the same scenarios are shown, developing using the levelized costs in Table 7-2.

Figure 7-3 Amended 2030 Resource Stack, Base EV Scenario – Energy Savings and GHG Savings



Source: Navigant analysis

Figure 7-4 Amended 2030 Resource Stack, Aggressive Scenario – Energy Savings and GHG Savings



Source: Navigant analysis

These figures vary from the resource stacks presented in Figure 4-1. and Figure 4-2.. Firstly, the negative acquisition costs are apparent. This figure illustrates that need on the study transformer is deferred without societal cost. The societal benefits received from the acquisition of energy efficiency measures outweigh the purchase cost, resulting in a net benefit. Secondly, the order in which the non-wires alternatives are pulled into the resource stack is modified. In Figure 4-1. and Figure 4-2., energy efficiency measures for the whole building, electronics, lighting, and appliances end uses were more costly than all demand response measures. Due to their negative levelized cost, these measures are now acquired and fully depleted prior to the acquisition of demand response.

7.5 Cost Comparison Analysis

In Section 5, Navigant evaluated the cost-benefit ratio of the original resource stack diagrams compared to the traditional wires investment. Navigant compared the cost of upgrading or replacing the study transformer with the cost of deferring transformer need by acquiring the portfolio of non-wires alternatives. As the acquisition cost for energy efficiency measures has been modified through this analysis, all cost figures are impacted. In this section, the analysis is updated to include the modified levelized costs.

The same methodology from the previous analysis is applied; the portfolio of measures in the resource stacks are assumed to be components of one program, managed from 2020 to 2030, and the first year of program spending coincides with the first year of need at the transformer. The incremental potential available for each measure is multiplied by the measure acquisition cost to determine the annual spending. For the Base EV scenario, the first year of need occurs in 2030; for the Aggressive EV scenario, the first year of need occurs in 2026.

To calculate the cost effectiveness, the present value of the non-wires alternative portfolio and the traditional wires investment are calculated in 2020 dollars, using a nominal discount rate of 5%. The analysis has been conducted twice; once for the levelized costs developed in Table 7-1 (see Table 7-3) and once for the levelized costs developed in Table 7-2 (see Table 7-4).

Table 7-3. Cost Comparison of Non-Wires Alternatives vs. Traditional Wires Investment – Energy Savings

Scenario	Present Value of Traditional Wires Investment Cost ($) (A)	Present Value of Non-Wires Alternative Cost ($) (B)	Net Benefit ($) (C) = (A) – (B)
Base	$10,524	-$397	$10,291
Aggressive	$12,792	$1,094	$11,699

Table 7-4. Cost Comparison of Non-Wires Alternatives vs. Traditional Wires Investment – Energy Savings and Avoided Carbon

Scenario	Present Value of Traditional Wires Investment Cost ($) (A)	Present Value of Non-Wires Alternative Cost ($) (B)	Net Benefit ($) (C) = (A) – (B)
Base	$10,524	-$1,728	$12,252
Aggressive	$12,792	-$5,587	$18,379

Note: In Section 5.3, the cost comparison results in a cost-benefit ratio of the present value of the traditional wires investment and the non-wires portfolio. In this section, the values are presented as a net benefit, or the difference between the two present values. As these values contain negatives (benefits instead of costs), Navigant has chosen not to present the result as a ratio. This avoids confusion regarding the sign magnitude of the ratio.

In both scenarios considered, excluding the Aggressive scenario in Table 7-3, the present value of acquiring the non-wires alternatives is negative. This indicates that deferring the transformer need through the purchase of the non-wires portfolio presents a benefit to society, as opposed to a cost. From a societal perspective, the non-wires portfolio is significantly more cost-effective.

All scenarios present a net benefit to society; this benefit increases as the EV growth increases (from Base to Aggressive scenario), and as more societal benefit streams are considered. In Table 7-3, the net benefit is shown when considering energy savings in the levelized cost. In Table 7-4, which considers energy savings and avoided cost of carbon, this net benefit increases for both the Base and Aggressive scenarios.

7.6 Conclusions

Navigant has the following conclusions surrounding the amended analysis.

1. **This analysis underpins the importance of evaluating cost-effectiveness from multiple perspectives.**

   In this analysis, a portfolio of non-wires alternatives was acquired to offset or defer the need at a local distribution transformer – the present value of that acquisition was shown to be negative. In other words, the need at the transformer was mitigated *while* accomplishing a net benefit to society, including energy savings and reduced carbon emissions. This is a different result than when evaluating the decision from the utility perspective, which shows cost savings compared to the traditional wires investment – but still requires cost to the utility to acquire.

When making decisions, it is helpful to consider multiple perspectives. For instance, in the original analysis, in a hypothetical scenario where the present value of both investments is similar, the utility may choose to move forward with the traditional wires investment, as this investment is more familiar to business operations. However, considering the additional societal benefits associated with the non-wires portfolio, that are not present in the traditional investment, may change or impact this decision.

2. **While carbon savings contribute to lower levelized costs, the inclusion of energy savings alone is sufficient to turn the levelized costs into a net benefit.**

   Throughout this additional analysis, two sets of amended levelized costs have been developed for energy efficiency. These levelized costs consider additional societal benefit streams not considered in the original analysis. The first set of levelized costs includes energy savings only – the second, includes energy savings and the avoided cost of carbon.

   The first, which considers the addition of energy savings, results in a net levelized cost that is negative, indicating that the measure presents a net benefit from a societal perspective. The inclusion of this benefit stream alone is sufficient for achieving a negative levelized cost. The inclusion of avoided carbon further decreases these values (i.e., drives the values more negative, or presents more benefit to society), but is not necessary to result in a net benefit.

3. **Altering the perspective of analysis impacts the order in which measures are acquired to mitigate capacity constraints in the resource stack.**

   This analysis has demonstrated the altering the analysis from the perspective of the utility (i.e., our original analysis) to the perspective of society (i.e., the analysis conducted in Section 7) varies the order in which measures are pulled into the resource stack. The resource stack diagrams represent the acquisition of measures to mitigate demand; measures are acquired based on the ranking of cost from lowest to highest.

   In the original analysis, many energy efficiency measures were acquired following the depletion of demand response, including the whole building, electronics, lighting, and appliances end uses. However, the new analysis, which considers additional societal benefit streams, results in these measures having a lower acquisition cost than demand response and are thus acquired first.

4. **The inclusion of societal benefits in analysis may impact the investment timing decision for non-wires alternatives.**

   This analysis has demonstrated that the increased adoption of EVs will have a measurable impact on demand at local transformers, causing overloading and need for utility intervention. However, this need is not immediate; in the Base scenario, the transformer is not overloaded until 2029, as EV adoption slowly increases over the decade.

   This analysis also demonstrated that the inclusion of societal benefits drives energy efficiency into a net benefit. If the utility (or regulatory body) includes these benefit streams in their decision process, they may choose to implement energy efficiency programming (a net benefit investment) prior to the required investment date, despite a lack of capacity constraints at the transformer. This could allow the utility to plan for the upcoming EV constraints that will occur in the medium to long-term, and in the interim, benefit from the energy efficiency programming.

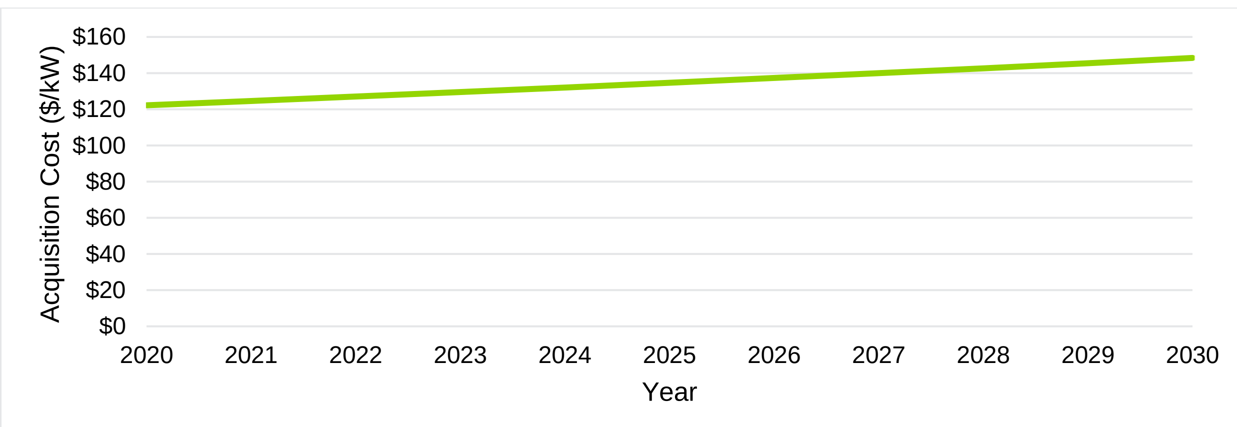
APPENDIX A. COST CURVES

This Appendix will present the acquisition cost calculated for each measure, from 2020 to 2030. These costs represent levelized costs and are presented in units of $/kW. The cost curves presented in this appendix are based on the acquisition costs developed in Section 3.

These acquisition costs are used to calculate the cost-benefit ratio of the non-wires alternative as shown in Section 5.3. The cost curves are presented for the following measures, in this order:

1. Energy efficiency – space heating
2. Energy efficiency – space cooling
3. Energy efficiency – water heating
4. Energy efficiency – appliances
5. Energy efficiency – lighting
6. Energy efficiency – electronics
7. Energy efficiency – whole building
8. Demand response – all end uses[37]
9. Managed electric vehicle charging

Figure 7-5. Cost Curve – Energy Efficiency, Space Heating



[37] As per Section 3, acquisition costs for demand response do not vary by end use.

Figure 7-6. Cost Curve – Energy Efficiency, Space Cooling[38]

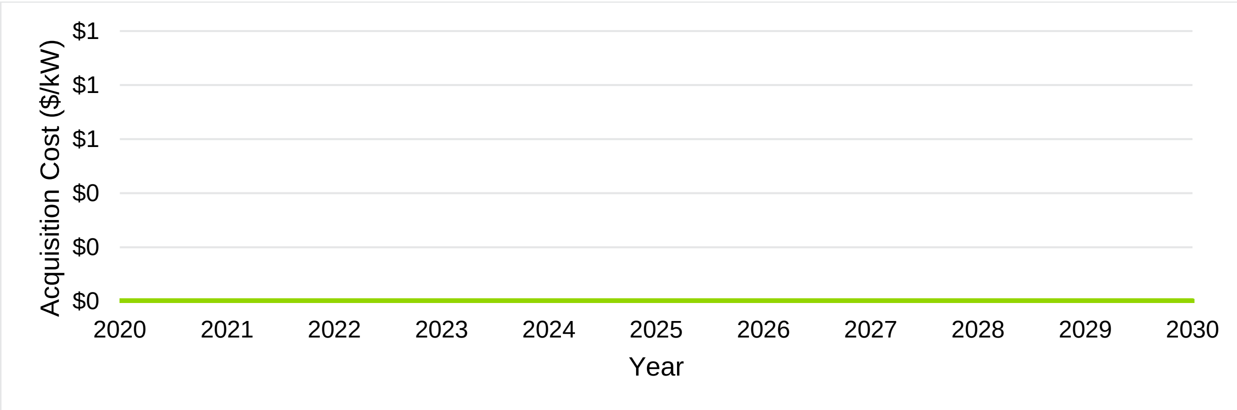


Figure 7-7. Cost Curve – Energy Efficiency, Water Heating

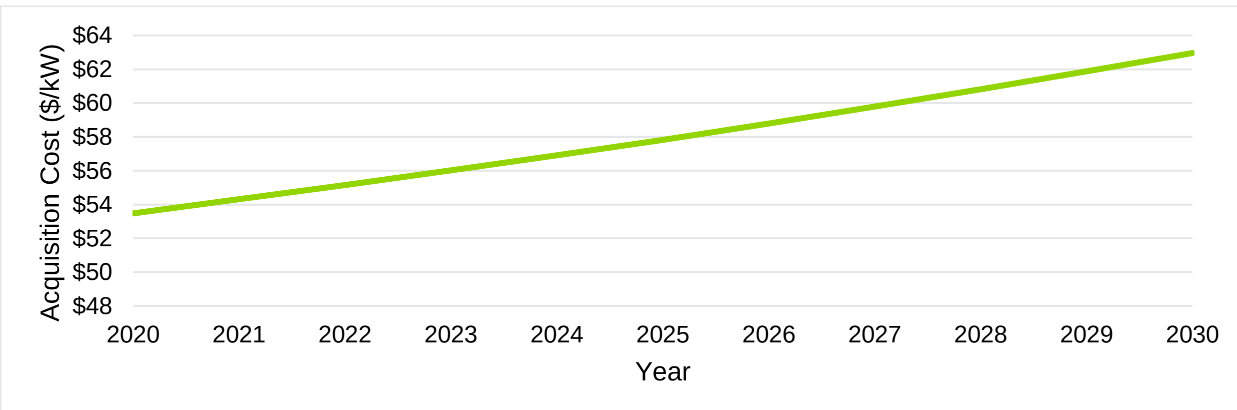
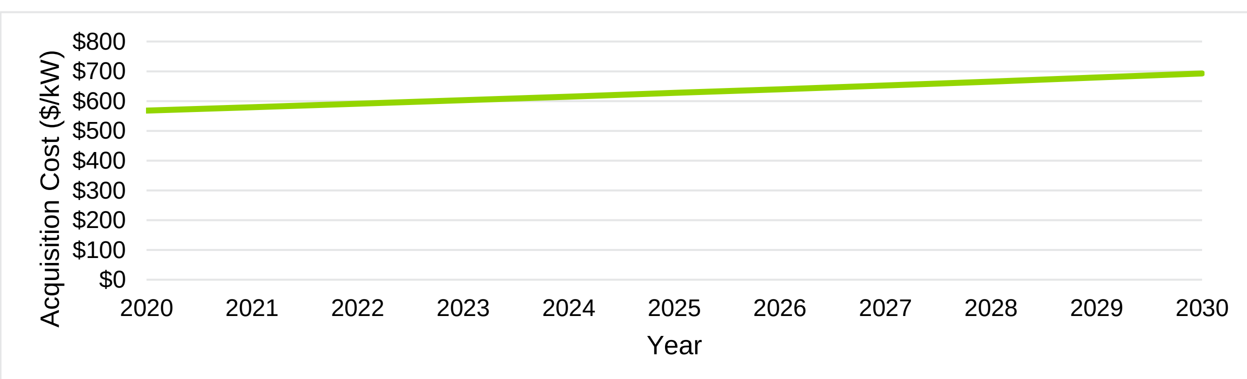


Figure 7-8. Cost Curve – Energy Efficiency, Appliances



[38] Note that there were no space cooling measures with a TRC test greater than 1. As such, there is no potential for this end use.

Figure 7-9. Cost Curve – Energy Efficiency, Lighting

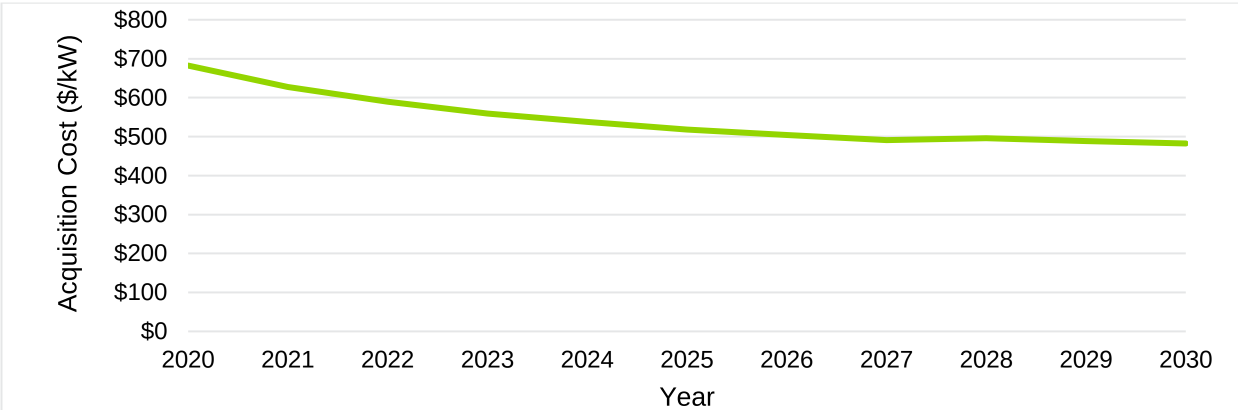


Figure 7-10. Cost Curve – Energy Efficiency, Electronics

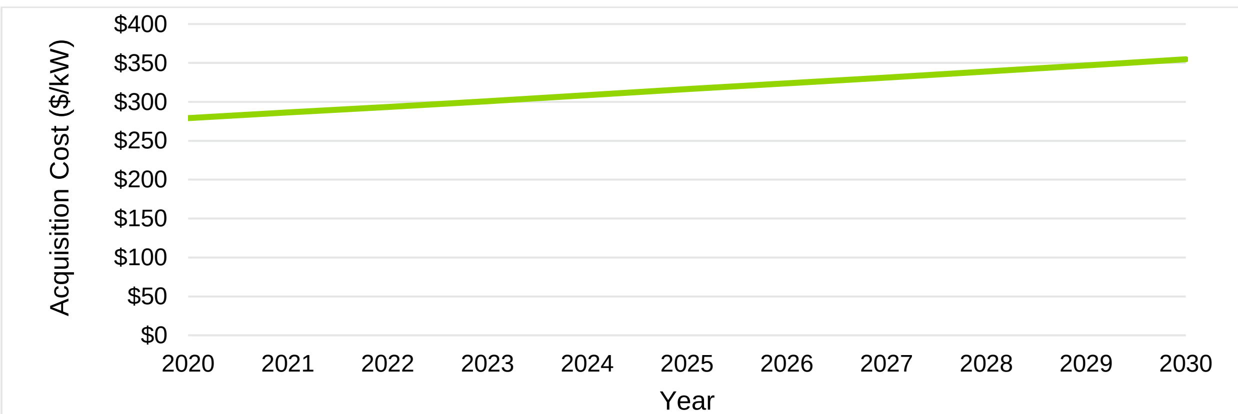


Figure 7-11. Cost Curve – Energy Efficiency, Whole Building

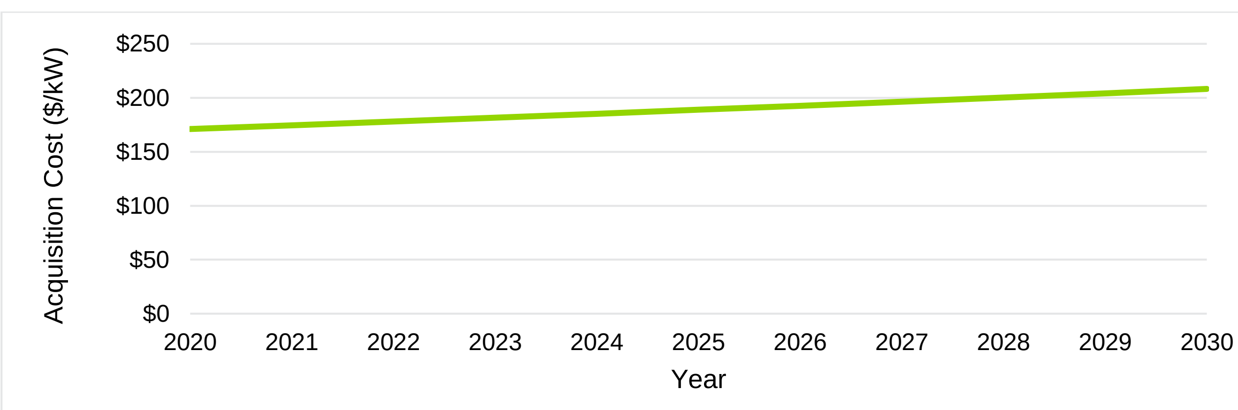


Figure 7-12. Cost Curve – Demand Response[39]

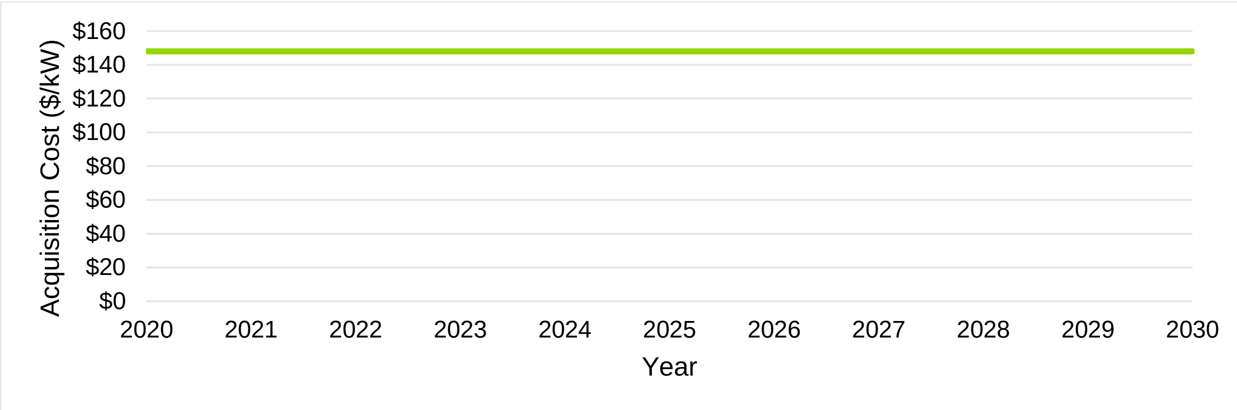
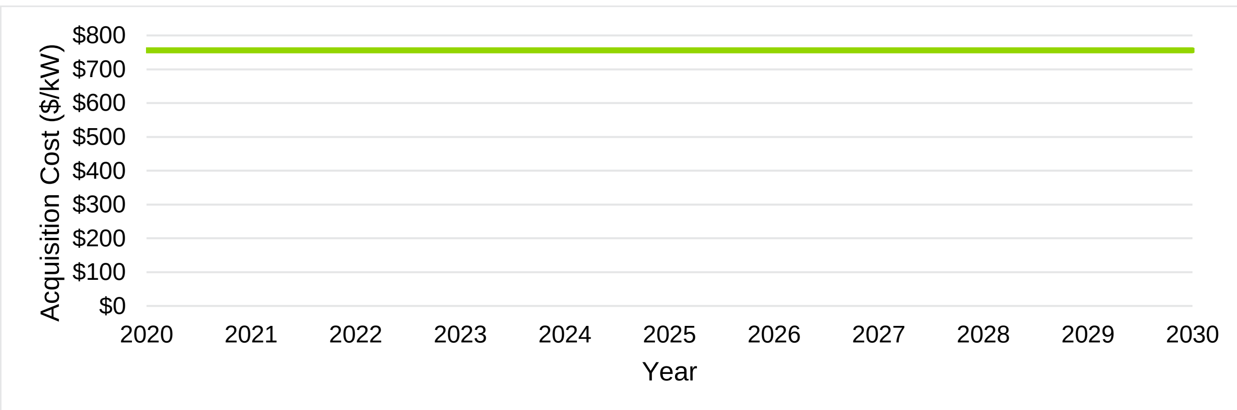


Figure 7-13. Cost Curve – Managed EV Charging



[39] Note that the costs for all Demand Response end uses are the same. Therefore, the cost curve for all end uses is represented by a single cost curve.