TACOMA POWER
TACOMA PUBLIC UTILITIES

Electrification (converting from using a carbon emitting fuel source like gasoline or natural gas to electricity) is a critical piece of policy efforts to move toward a decarbonized future and could yield large and potentially unprecedented changes to customer demand. It is critical that Tacoma Power is prepared to reliably meet future customer demand as it evolves. Tacoma Power's Electrification Assessment addresses the question "How might electrification contribute to changes in the future trajectory of Tacoma Power customers' demand for electricity?" The study aims to create a set of thoughtful and internally consistent projections of how electrification will change customer demand in the Tacoma Power service area over the next 20 years to inform internal planning processes.

The study is expansive in its treatment of electrification. It addresses electrification in nearly every end use and sector, projects impacts for every hour of the year over 20 years and provides substation-level projections. Recognizing that there is substantial uncertainty around how electrification will unfold, the study also provides projections for a range of plausible scenarios using different assumptions about future policy and market developments. It is important to note, however, that electrification is just one of many factors that will affect the trajectory of customer demand. We expect the next 20 years to bring many other changes to Tacoma Power's service area besides electrification, some of which may further increase demand for electricity and some of which will decrease it. We expect that conservation and efficiency standards in particular will likely provide a material reduction in demand, which will help offset much of the increase from electrification. The results of this study do not represent Tacoma Power's projections of the overall growth in customer demand but rather are important inputs used in conjunction with other projections to forecast future demand.

Tacoma Power staff have started incorporating projections from this study into our demand projections and into various internal planning processes. As with all of the inputs we use to forecast customer demand, we expect to revisit the projections in this study at regular intervals as time goes on and we see how the future unfolds.

Sincerely,

Chris Robinson

Chris Robinson
Power Superintendent

CADMUS

Tacoma Power Electrification Forecast

Study of Building, Transportation, and Industrial Electrification in Tacoma Power Service Territory

January 31, 2024

Prepared for:

Tacoma Power
3628 South 35th Street
Tacoma, WA 98409

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Executive Summary

This study forecasts peak energy demand and energy sales impacts from Tacoma Power's customer adoption of commercial, residential, and industrial electrification equipment, as well as transportation electrification and the installation of rooftop solar systems. The study also considers potential mitigating impacts from future demand response programs and energy efficiency installations but does not report the impacts of energy efficiency in cross sector results.

Tacoma Power designed six scenarios for this study, each of which considers market and policy drivers for replacing fossil fuel equipment with electric alternatives, purchasing electric vehicles (EVs), and installing rooftop solar systems. Table 1 shows the four core scenarios and two mitigation scenarios that include the option for customers to participate in demand response programs. The current landscape scenario assumes current policy drivers, whereas the anticipated electrification and expansive policy scenarios assume additional policies to reduce greenhouse gas emissions. The policy regression scenario indicates conditions of potential policy reversals.

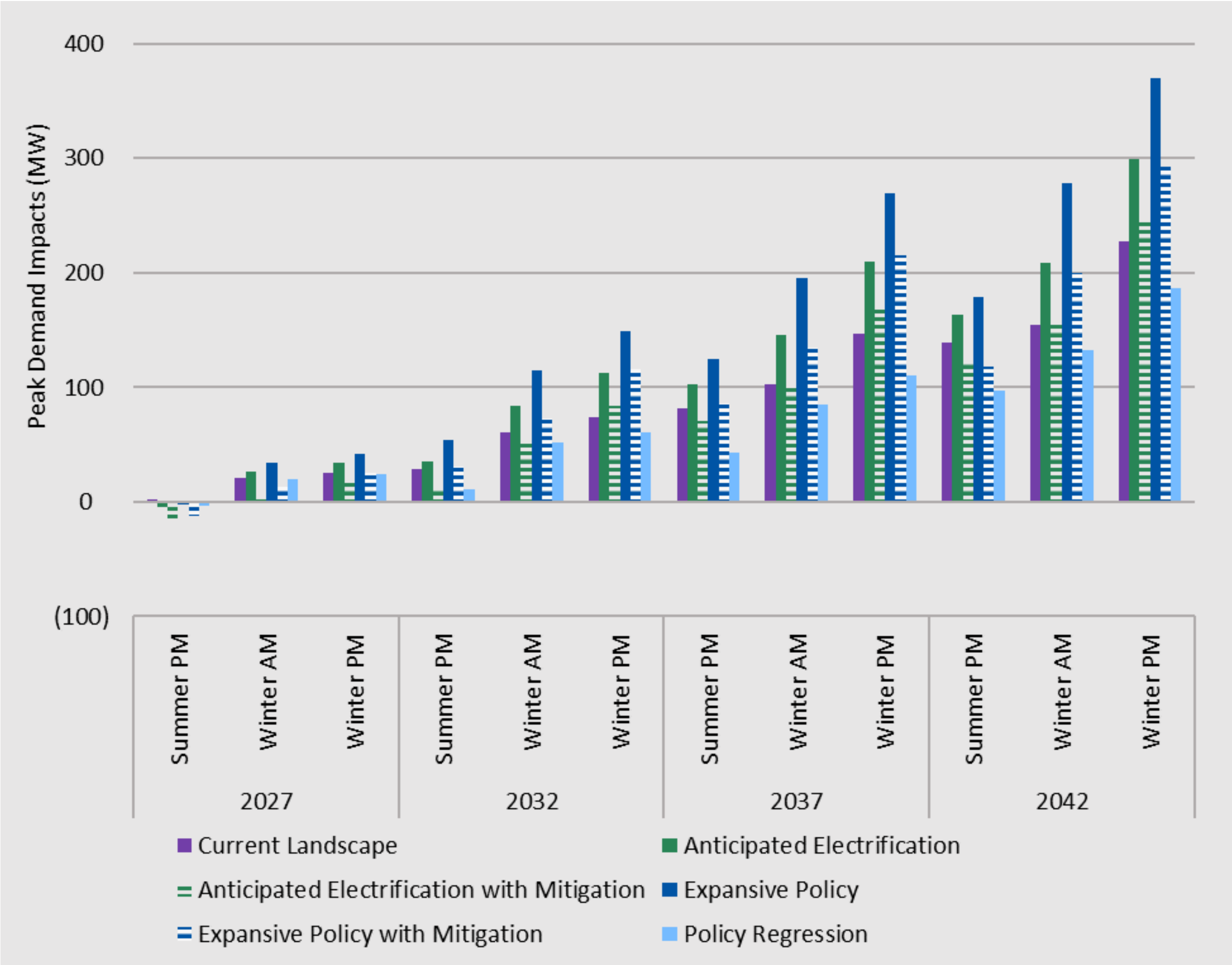
Table 1. Electrification Scenarios

Scenario Name	Scenario Description
Current Landscape	Reflects the equipment adoption trajectory under current policy and market conditions
Anticipated Electrification	Represents the equipment adoption trajectory under likely policy and market conditions, even though these conditions are not yet present
Anticipated Electrification with Mitigation	Reflects the market and policy conditions of the Anticipated Electrification scenario but also includes effects from Tacoma Power taking additional measures to reduce peak load impacts
Expansive Policy	Presents a scenario in which significant changes occur in the market and policy environment to accelerate electrification
Expansive Policy with Mitigation	Reflects the market and policy conditions of the Expansive Policy scenario but also includes effects from Tacoma Power taking additional measures to reduce peak load impacts
Policy Regression	Reflects policy conditions less favorable to electrification than those in the Current Landscape scenario

Electrification Scenario Impacts

This study focused its reporting on demand impacts during Tacoma Power's summer PM, winter AM, and winter PM peaks and on impacts of annual electric sales. According to the study's adoption scenarios, Tacoma Power's winter PM peak demand will experience an increase of 21% to 41% by 2042, depending on the scenario. The winter AM and summer PM peak demand impacts are less pronounced because of two primary factors: First, daily usage patterns of EV charging is more energy intense in the afternoon and evening than in the morning. Second, rooftop solar offsets a significant portion of summer PM peak demand. Demand impacts will be further mitigated through energy efficiency programs, which can reduce electric demand in Tacoma Power service area significantly. Because Tacoma Power already includes energy efficiency impacts in its forecasts, the study does not illustrate these impacts in the cross-sector results. Figure 1 shows peak impacts in the study's scenarios in MWs.

Figure 1. Additional Peak Demand from Building and Industrial Electrification, Electric Vehicle Chargers, and Rooftop Solar Adoption by Scenario (MW)



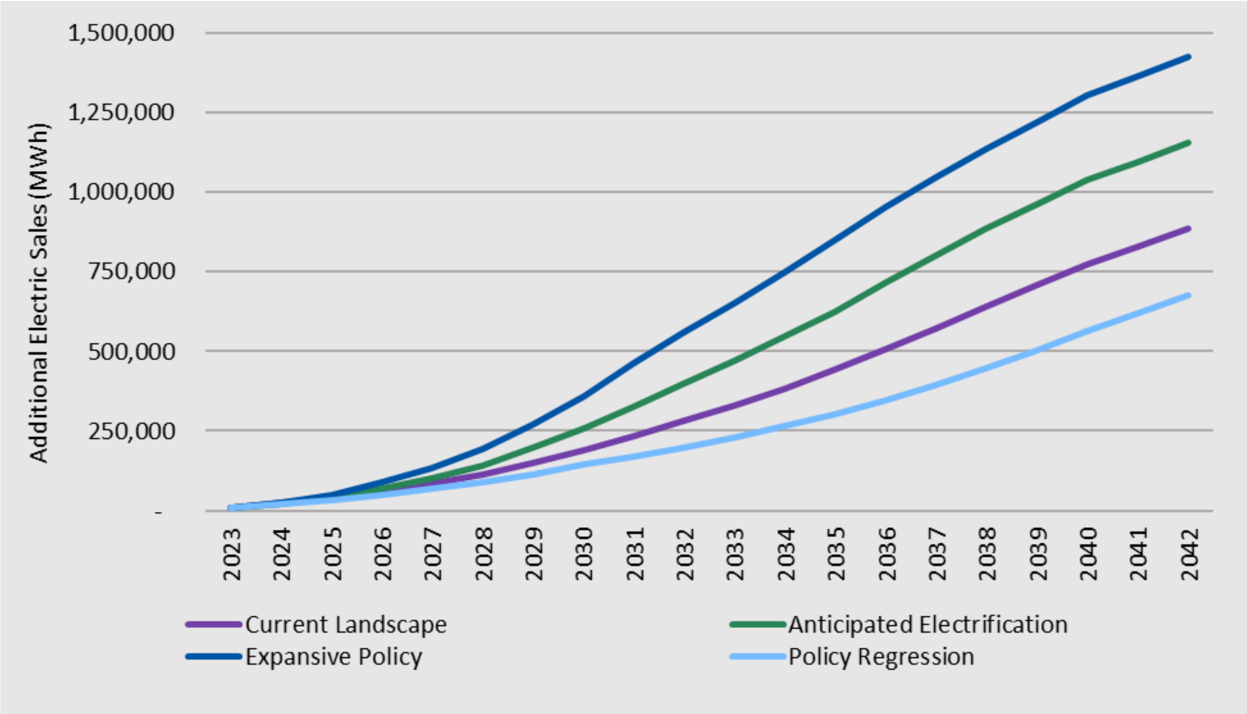
The residential sector is not projected to experience a summer PM peak demand impact until after 2027, whereas the study projections show peak demand increasing in winter starting in 2027. The industrial sector also contributes significant peak demand impacts starting in 2027, which are more evenly distributed across seasons given the relatively less time-variable load of the industrial sector. Demand response programs can play a significant role in mitigating peak demand impacts in all seasons, although they have the most significant impact in the winter season, especially in the early years of the study, when rooftop solar does not mitigate the peak load impacts of electrification as significantly as in the later years of the study.

- **Peak Impacts from Building Electrification:** The peak load additions from residential and commercial building electrification equipment are primarily concentrated in the winter peak periods, and although the impacts are relatively similar in 2032 in the two sectors, by 2042 the commercial sector contributes significantly more than the residential sector to winter PM peak demand. In 2042 the residential sector does see some summer PM peak demand impacts, but these impacts are relatively small compared with winter AM and winter PM load additions.

- **Peak Impacts from Rooftop Solar and Demand Response Programs:** Peak impacts from rooftop solar are concentrated during the summer PM peak period, due to coincidence of rooftop solar production with summer PM peak demand. During the winter AM and PM peak periods, battery storage dispatch provides the greatest demand reduction impacts compared with other potential demand response programs.
- **Peak Impacts from Transportation Electrification:** Peak load additions from residential and commercial electric vehicle adoption occur primarily in the summer and winter PM peak periods because most vehicle charging occurs in the late afternoon or early evening.
- **Peak Impacts from Industrial Electrification:** In the industrial sector boiler electrification will provide the most peak demand impact relative to other industrial process and end uses. However, given significant barriers to electrifying boilers, the study estimates that the pace of electrifying boilers will be slow compared with the Port of Tacoma's shore power electrification which has the greatest peak demand impacts early in the study period.

This study estimates that Tacoma Power's electric sales will increase between 16% and 33% compared to 2023 sales due to building, transportation and industrial electrification, and accounting for reduced sales from rooftop solar installations. Figure 2 shows the net additional electric sales for the core scenarios. The figure does not show the mitigation scenarios since these scenarios primarily impact peak demand and not total electric sales. Gas sales in Tacoma Power service territory in 2022 were approximately 11,000 billion British thermal units (BBtu). The 2042 electric sales impact in the expansive policy scenario is approximately 5,000 BBtu.

Figure 2. Additional Electric Sales from Building and Industrial Electrification, Electric Vehicle Chargers, and Rooftop Solar Adoption by Scenario (MWh)



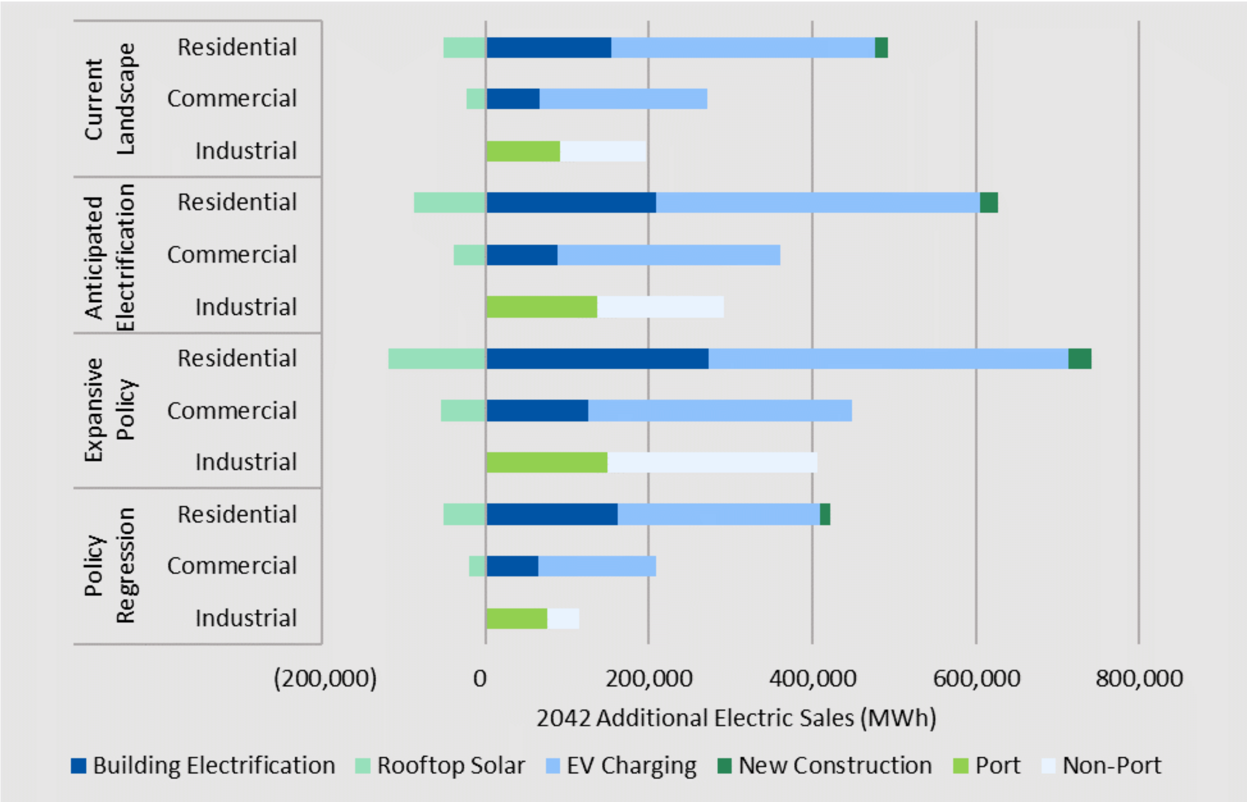
The residential, commercial, and industrial sectors contribute significantly to additional electric energy demand, with the industrial sector making a proportionally large contribution in the study's early years. By 2042, however, the residential sector makes to strongest contribution to additional electric sales under every scenario. Table 2 shows these impacts, showing the impacts in the industrial sector for the Port of Tacoma (Port) and other industries (Non-Port) separately.

Table 2. Additional Electric Sales from Building and Industrial Electrification, Electric Vehicle Chargers, and Rooftop Solar by Scenario and Sector (MWh)

Scenario	Sector	2027	2032	2037	2042
Current Landscape	Residential	18,100	92,800	248,900	440,600
	Commercial	21,000	75,500	157,800	248,600
	Industrial Port	31,500	57,300	74,600	91,300
	Industrial Non-Port	15,000	54,800	91,134	105,677
Scenario Total		**85,700**	**280,300**	**572,300**	**886,200**
Anticipated Electrification	Residential	19,500	148,500	346,800	540,000
	Commercial	26,300	102,700	217,800	322,200
	Industrial Port	33,300	66,000	102,000	137,100
	Industrial Non-Port	22,800	82,000	134,300	155,200
Scenario Total		**101,900**	**399,100**	**801,000**	**1,154,500**
Expansive Policy	Residential	31,100	218,300	434,300	623,000
	Commercial	32,100	142,200	281,900	395,100
	Industrial Port	34,700	69,700	109,600	149,200
	Industrial Non-Port	34,400	129,200	220,800	257,500
Scenario Total		**132,300**	**559,300**	**1,046,600**	**1,424,800**
Policy Regression	Residential	24,700	84,800	189,600	370,800
	Commercial	16,900	55,900	113,000	189,600
	Industrial Port	23,900	44,800	59,900	75,400
	Industrial Non-Port	2,100	13,300	31,700	39,100
Scenario Total		**67,600**	**198,900**	**394,200**	**675,000**

Figure 3 shows additional electric sales from building, industrial and transportation electrification, as well as sales reductions from rooftop solar projects in the residential and commercial sectors. The figure shows that in 2042 EV charging is the biggest driver of additional electric sales in all sectors, with a greater impact in residential buildings.

Figure 3. Additional Electric Sales from Building and Industrial Electrification, Electric Vehicle Chargers, and Rooftop Solar by Scenario and Sector (MWh)



Introduction

Tacoma Power commissioned this Electrification Impact Forecast to understand the potential 20-year electric sales and peak load impacts from building and transportation electrification, building energy efficiency equipment installations, demand response programs, rooftop solar and battery installations, and electrification of industrial processes for six market scenarios.

Study Overview

This study forecasts load impacts from customer adoption of this study's electrification, energy efficiency, demand response, and rooftop solar and storage equipment at each of Tacoma Power's electric distribution feeders. Given its locational focus, this study relies on Tacoma Power's mapping of customer premises to electric distribution feeders and intelligence on each premise, including building type, heating fuel, and square footage, among other characteristics.

This study presents a diverse set of equipment and program choices that Tacoma Power's residential, commercial, and industrial customers can adopt over the next twenty years. Some of these equipment options, such as electric vehicles (EVs) and heat pumps instead of gas furnaces, will increase Tacoma Power's electric sales and peak demand impacts. Other customer choices, such as installing rooftop solar systems or ductless heat pumps instead of baseboard heaters, will reduce Tacoma Power's electric sales and peak load. Tacoma Power has already accounted for some of these impacts, such as energy efficiency installations, in its load forecast but has not yet accounted for others, such as the impacts of transportation electrification.

To provide transparency into the composition of this study's electric sales and peak demand impacts, the report distinguishes between four classes of customer equipment and program choices:

- **Building Electrification and Energy Efficiency** includes impacts from installing electric space and water heating systems, electric cooking equipment, and electric clothes dryers. Because the study examines replacing equipment with options that are more energy-efficient, the installations cause a load increase when replacing gas equipment and a load decrease when replacing existing electric equipment. Because Tacoma Power already accounts for energy efficiency in its load forecasts, this study only shows the impacts of energy efficiency when compared to building electrification and does not include the impacts of energy efficiency in cross-sector results.
- **Transportation Electrification** includes impacts from installing EV chargers at residential and commercial customer premises throughout Tacoma Power's service territory.
- **Rooftop Solar and Demand Response** includes impacts from installing rooftop solar systems and potential impacts from participating in future Tacoma Power demand response programs (Tacoma Power does not currently offer demand response programs to its customers).

- **Industrial Electrification** includes impacts from converting fossil fuel–consuming industrial processes to electric processes, including process heating and equipment handling. The Port of Tacoma is one of Tacoma Power's major industrial customers and is already developing electrification goals. This study therefore relied significantly on the South Harbor Electrification Roadmap (SHERM), which is not yet published, for modeling inputs.

Electrification Scenarios

Tacoma Power designed six scenarios for this study, each of which considers market and policy drivers for replacing fossil fuel equipment with electric alternatives, purchasing EVs, installing solar systems, and participating in demand response programs:

- **Current Landscape** reflects the equipment adoption trajectory under current policy and market conditions.
- **Anticipated Electrification** represents the equipment adoption trajectory under likely policy and market conditions, even though these conditions are not yet present.
- **Anticipated Electrification with Mitigation** reflects the market and policy conditions of the Anticipated Electrification scenario but also includes effects from Tacoma Power taking additional measures to reduce peak load impacts.
- **Expansive Policy** presents a scenario in which significant changes occur in the market and policy environment to accelerate electrification.
- **Expansive Policy with Mitigation** reflects the market and policy conditions of the Expansive Policy scenario but also includes Tacoma Power taking additional measures to reduce peak load impacts.
- **Policy Regression** reflects policy conditions less favorable to electrification than those in the Current Landscape scenario.

To model the impacts of these scenarios, this study adjusted equipment adoption curves according to adoption drivers specific to each scenario. The study designed the scenarios to reflect realistic policy and market drivers that can impact the adoption of electric equipment, vehicles, and rooftop solar systems. As such the scenarios do not necessarily have the same magnitude of impact across equipment types.

This report provides details about the impacts of the electrification scenarios in five sections: Cross Cutting (system-level impacts), Building Electrification and Energy Efficiency, Transportation Electrification, Rooftop Solar and Demand Response, and Industrial Electrification. The methodology section also presents details on each scenario's assumptions and explains how this study translated scenario assumptions into equipment adoption and program participation trajectories.

Reporting Metrics

This study reports the annual peak electric demand and annual electric sales impacts of simulated customer adoption of electric equipment and vehicles, rooftop solar, and participation in Tacoma Power's demand response programs. This study was conducted primarily in 2023, so the base year of the study is 2022, with forecasts starting in 2023. Because this study spans a 20-year forecast horizon, it primarily reports impacts in five (2027), ten (2032), fifteen (2037), and twenty-year (2042) periods. The impacts reported for each period reflect the outcome of cumulative simulated adoption of the study equipment, vehicle, and program options in the given reporting year.

Tacoma Power has three electric demand peak periods: a summer afternoon/evening peak (PM) and two winter peak periods; one in the morning (AM) and one in the evening (PM). This study reports summer PM, winter AM, and Winter PM peak demand impacts separately.

The Study Team

A team of consultants from Cadmus and Cadeo developed this study. Cadmus was primarily responsible for developing model inputs, report drafting, and project management; Cadeo was primarily responsible for modeling locational impacts using its AdopDER tool.

Methodology

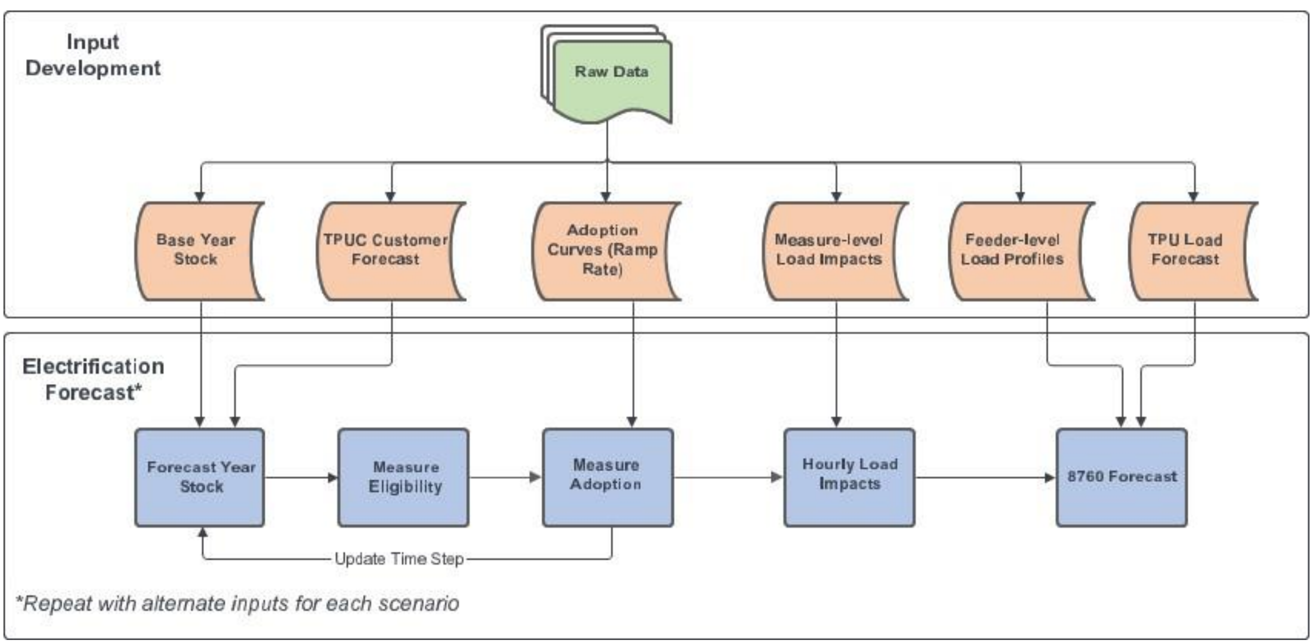
This section provides the methodology the study used to estimate load impacts from the equipment and program options of this study, beginning with an overview of the modeling mechanics. As this study modeled commercial and residential impacts separately from the industrial sector, this section first describes the locational modeling (in AdopDER) and inputs used for the residential and commercial sectors, followed by the approach for the industrial sector.

This study included two primary phases for developing locational impacts from study equipment and program choices in the commercial, residential, and industrial sectors. In the first phase, the study developed model inputs, including a geo-localized customer database of the 2022 building and vehicle stock, equipment, and program load shapes, and equipment adoption and program participation rates. In the second phase, the study modeled energy impacts across Tacoma Power's service territory.

Residential and Commercial Locational Model Mechanics

This study used AdopDER to estimate the electric energy impacts from residential and commercial equipment and program choices in Tacoma Power's service territory. Cadeo developed the AdopDER software application in Python with Portland General Electric (PGE) for use in PGE's integrated resource planning and distribution system planning activities. AdopDER can calculate long-term, hourly load impacts from equipment adoption at a granular level across a utility distribution system. The flow diagram in Figure 4 shows how AdopDER uses a consistent framework to forecast adoption and load impacts for each of the study's equipment and program choices.

Figure 4. AdopDER Process Flow Diagram



AdopDER Input Data

As illustrated in Figure 4, AdopDER's input data structure includes the following elements:

- **Base Year Stock Assessment** encompasses the existing stock of buildings and vehicles at each service point in Tacoma Power's service territory in 2022. These data are primarily from a customer dataset originally developed for Tacoma Power's Conservation Potential Assessment (CPA database) that includes characteristics such as building use, year of construction, heating system types, heating fuels, feeder assignment, and equity zone designation.
- **TPU Customer Forecast** is Tacoma Power's corporate customer forecast, which describes how the number of premises in Tacoma Power's service territory is projected to change over time.
- **Adoption Curves,** or ramp rates, describe the time-variant proportion of eligible premises that the study assumes will adopt each measure in each year.
- **Equipment and Program-Level Load Impacts** are the expected hourly load impacts (in kWh) from each measure for each premise.
- **Feeder-Level Load Profiles** are a set of parametrized load profiles informed by advanced metering infrastructure (AMI) and other interval-metered consumption data that Tacoma Power provided for this study.
- **TPU Load Forecast** is Tacoma Power's corporate load forecast, which describes how service territory–level energy consumption is projected to change over time.

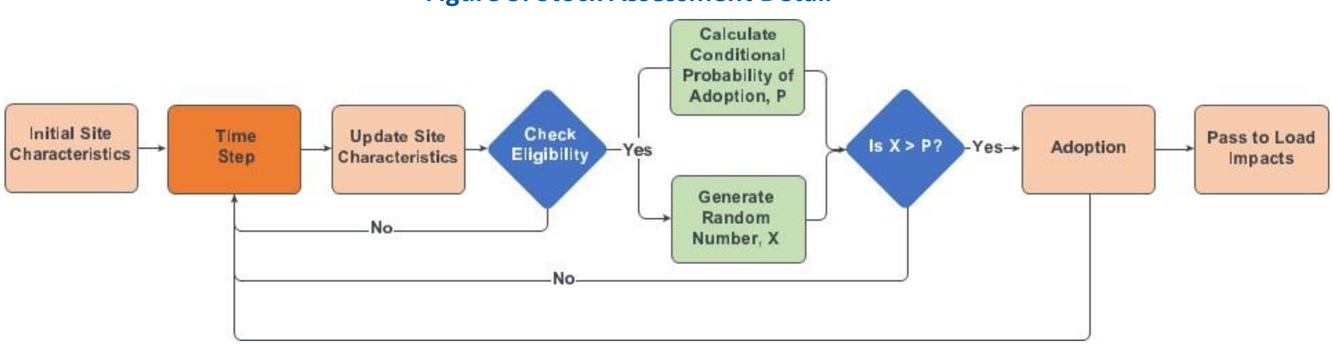
Electrification Forecast

This section details the three discrete steps of AdopDER's forecasting workflow.

Base Year Stock Assessment

AdopDER's stock assessment creates service-point equipment, vehicle, rooftop solar adoption, solar, and program participant forecasts using stochastic, site-level process flow that repeats for each site, household technology adoption (equipment, EVs, rooftop solar, etc), and year. Figure 5 and the subsequent text describe in detail the process flow introduced at a high-level.

Figure 5. Stock Assessment Detail



- **Update Site Characteristics.** As described above, this study's modeling process began with the initial characteristics of each premise in the base year of the forecast. For each subsequent year of the forecast horizon, the study updated the equipment stock based on a stock turnover mechanism and assumed measure adoption from previous years. The stock turnover mechanism uses a Weibull distribution that assigns a probability of turnover in each year that is a function of the equipment's age.[1] Under this construct, equipment can turn over at any age rather than having an assigned lifetime of fixed length. For example, the study estimated the number of air-source heat pumps present in the year 2024 by applying a calculation that estimates equipment lifetime to the types of heating systems used in 2023, and whether the stock turnover mechanism retired the system in 2023.
- **Check Eligibility.** After updating the site characteristics for each subsequent year of the forecast horizon, the study updated the eligibility of each measure at each service point. The primary purpose of this step was to estimate the retirement year for equipment such as heating systems, water heating systems, and vehicles to determine how many sites were eligible to adopt electrification equipment.
- **Adoption.** The study simulated adoption using measure-specific adoption rates based on the probability that a service point will adopt an eligible piece of equipment in the current year. AdopDER made an adoption decision for each measure by generating a random number X between 0 and 1, comparing X to the adoption probability P (from the adoption curve), and assuming that the site will adopt the measure if X < P. AdopDER also calculated the size units of each adopted unit of equipment, which allowed it to determine the hourly load impacts in a subsequent step. For the equipment in this project's scope, the study typically tied the unit sizes to building square footage or nameplate ratings, such as direct current kW (kW-DC) for rooftop solar and kW for EV chargers.
- **Time Step.** After each year, the study incremented the time step and ran through the process described above for each service point and measure.
- **Pass to Load Impacts.** After simulating measure adoption using the above process, the stock assessment module passed the following service point-level data to the load impact module:
  - Site and location identifiers, including the premise and feeder for each adopter
  - Segmentation variables, including any variable needed to assign the adopter to its load impact segment
  - Units sizes for each adopter

Load Impacts

AdopDER passes premise-level adoption and sizing assumptions from the stock assessment module to the load impact module, where it applies 8,760 hourly load impacts for each measure. These hourly load

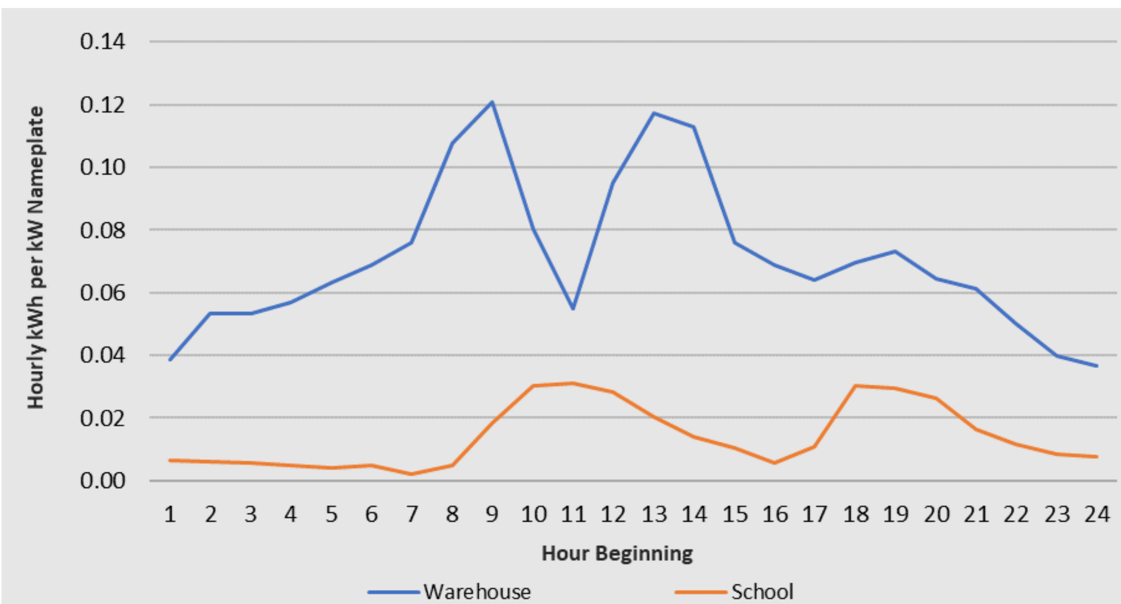
[1] The United States Department of Energy characterizes equipment lifetimes using a Weibull function with parameters described in Chapter 8 of its 2011-06-06 Technical Support Document. https://www.regulations.gov/document/EERE-2011-BT-STD-0011-0012

impact shapes vary by measure and can vary across customer segments within measures (e.g., air-source heat pump impacts are different for single-family versus multifamily buildings). The load impacts also have different input parameterizations. For example, weather dependent measures (solar and building electrification) have full 8,760 load shapes associated with hourly weather patterns, and measures that have diurnal patterns (e.g., transport) have 24-hour daily shapes. In both cases, AdopDER translates these input shapes into 8,760 hourly forecasts that account for the forecast year and use typical meteorological year (TMYx) weather. This section uses illustrations to describe the data processing steps within the load impact module; the sources and segmentation for each load impact are described in the following sections.

Step 1: Assign Load Impact Shape

The load impact module first assigns a load impact shape to each adopter for each measure. AdopDER allows load impact shapes to vary by customer segment. For example, AdopDER can assign unique direct current fast-charging (DCFC) electric vehicle charger profiles to charging stations for heavy-duty vehicles at warehouses and schools, as shown in Figure 6.

Figure 6. Illustration of Load Impact Segmentation for Heavy-Duty Electric Vehicle Chargers



Note: Warehouse load impact represents utilization for heavy-duty long-haul trucks based on available literature and data. The shape—two prominent peaks separated by a valley—is influenced by the trend of early and late long-haul departures.

Step 2: Calendarize Input Shapes

After assigning load impact segments, the load impact module calendarizes the input shapes. AdopDER allows the parameterization of each load impact shape to vary by equipment type though the interpretation of each shape is consistent: hourly impact (in kWh per hour) per unit size of equipment adoption. Figure 7 and Figure 9 show parameterizations of load impact shapes. Figure 7 shows an example of a rooftop solar impact shape where an 8,760-hour time series is necessary because solar generation varies along a diurnal pattern and throughout the year. In this case, AdopDER copies the 8,760-hour input shape to each year in the forecast horizon.[2]

Figure 7. Illustration of Hourly Load Impacts for Solar PV, July 1-7

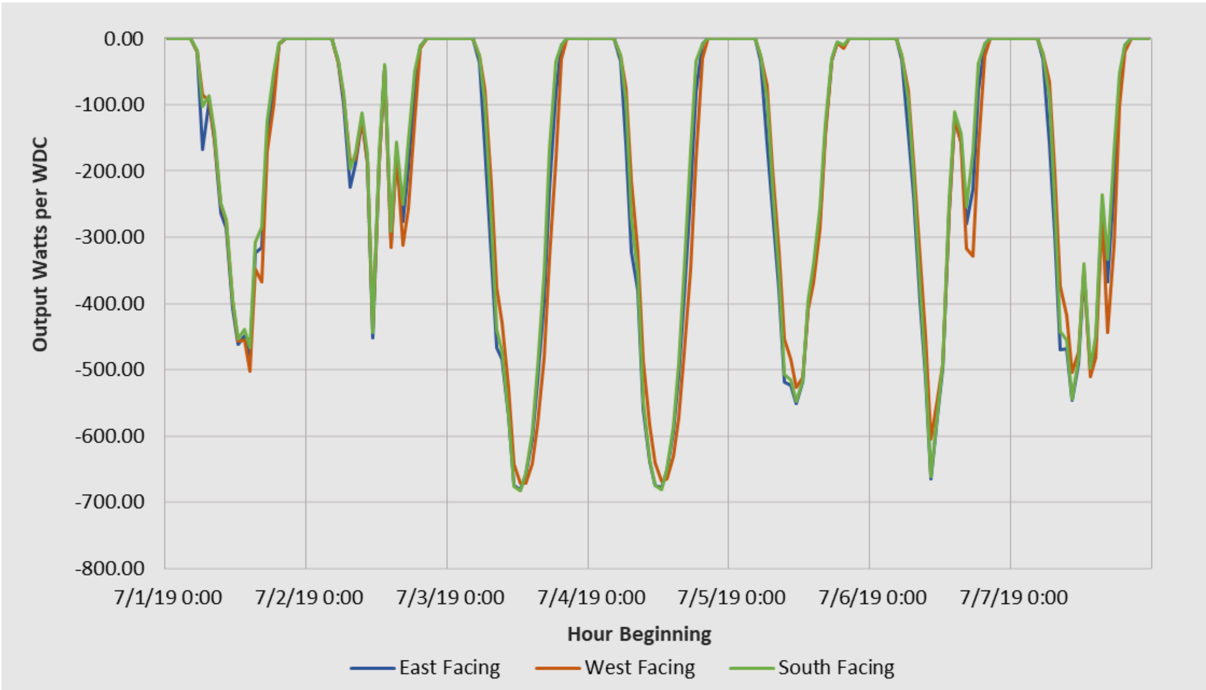


Figure 8 further shows the average daily impacts of rooftop solar systems by sector and season. This information was generated using an average residential solar project of 7 kW-DC and an average commercial solar project of 25 kW-DC with DC-AC ratios of 1.15.

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[2] For leap years, AdopDER creates an 8,784 hourly shape by copying the February 28 hourly shape and applying it to February 29.

Figure 8. Average Hourly Impacts of Rooftop Solar Systems by Season

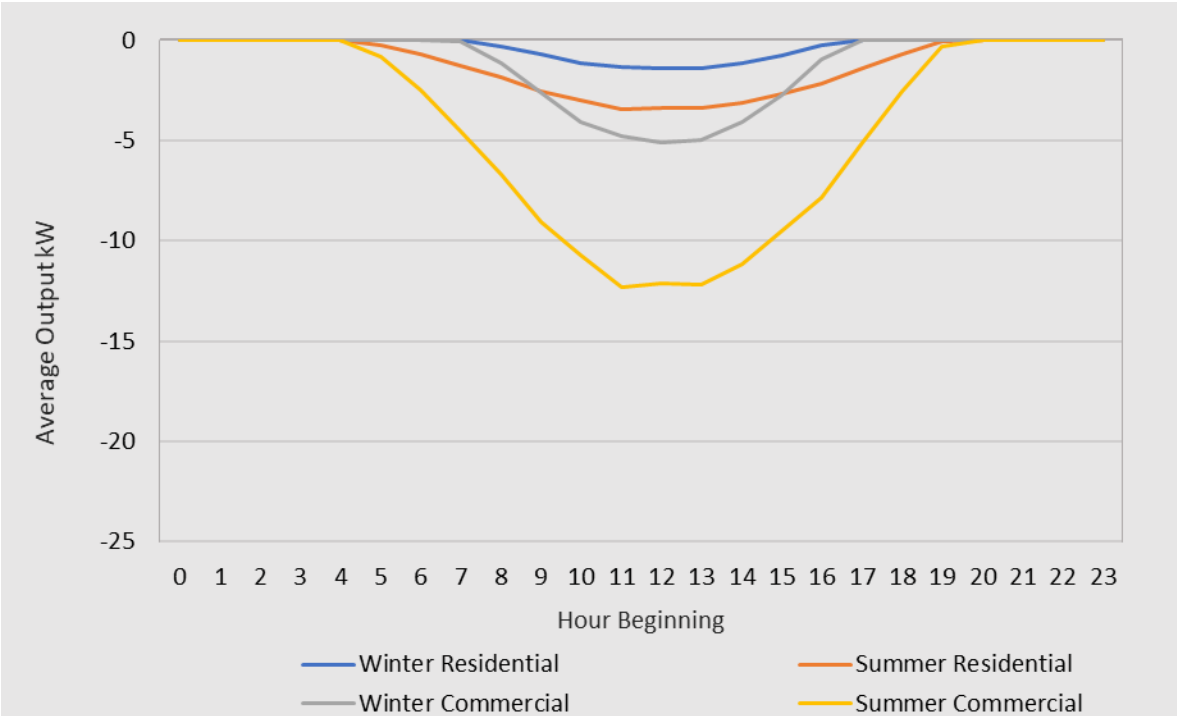
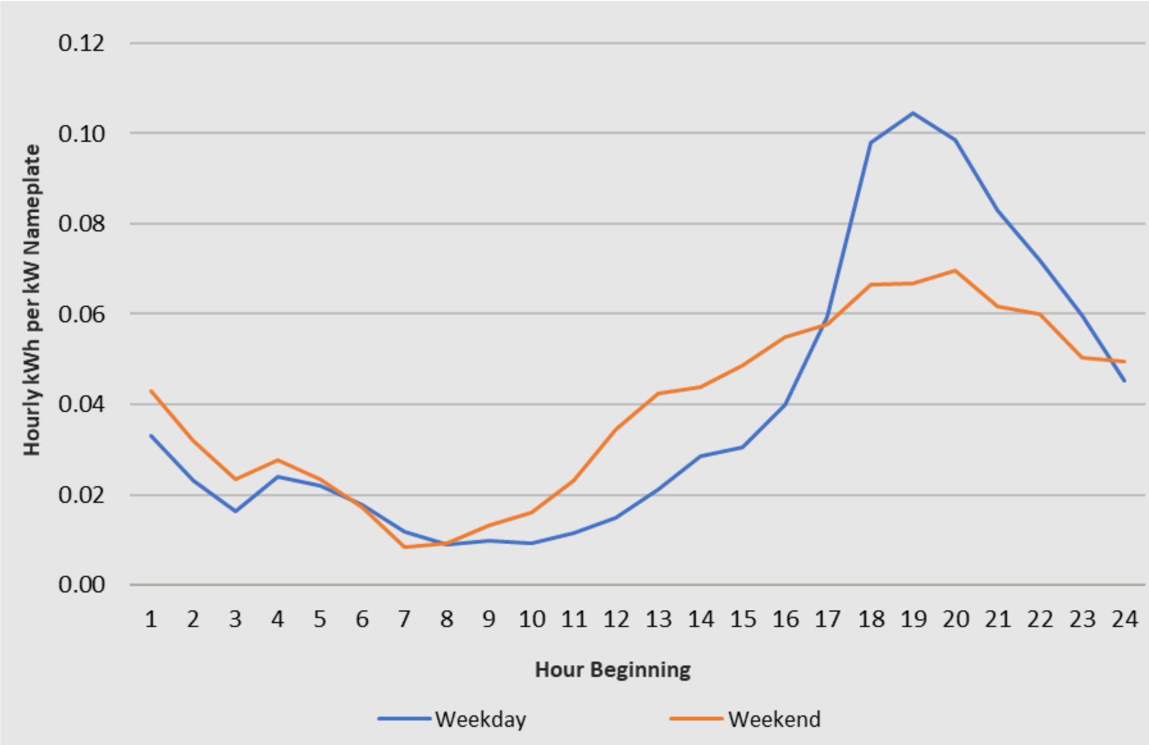


Figure 9 shows an example of a residential Level 2 EV charger load impact shape, where the diurnal usage patterns vary by day of week. In this example, AdopDER constructs an 8,760 shape for each year in the forecast horizon by applying the 24-hour weekday and weekend shapes appropriately to each day for each year in the forecast horizon.

Figure 9. Illustration of Hourly Load Impacts for Residential Electric Vehicle Chargers



Step 3: Hourly Forecast

In this final step, AdopDER combines the adoption and unit sizes created in the stock assessment module with the calendarized, 8,760 hourly load impacts to create an 8,760 hourly forecast of the load impacts for each feeder and each measure for the entire forecast horizon. Equation 1 shows the formula AdopDER uses to generate this forecast, where the hourly kWh for a feeder is the sum of its hourly baseline load (i.e., the kWh without the adoption of any of the measures in this study) and the hourly load impact from measures.

Equation 1. AdopDER 8,760 Forecasting Formula

$$Feeder\ kWh_{fyh} = \sum_{Rate\ Class\ r} C_y * Baseline\ kWh_{rfyh} + \sum_{Segment\ s} Adoption_{smfy} * Size\ Units_{smfy} * Load\ Impact_{smfyh}$$

Where:

- *r* = represents a rate class (residential, small commercial, and large commercial)
- *f* = represents each feeder within Tacoma Power's service territory
- *m* = represents each measure
- *s* = represents the load impact segment for measure *d*

- y = represents each year in the forecast horizon
- h = represents the hour within each year

For residential and small commercial rate classes, in which consumption profiles are typically homogenous, AdopDER estimates baseline kWh for each combination of feeder and rate class as its average 8,760 hourly load profile multiplied by the number of premises. For large commercial premises, AdopDER estimates the load profile on a per-premise basis. For all rate classes, AdopDER uses OpenEEMeter's implementation of CalTRACK methods for normalized metered energy consumption to express baseline kWh as a function of TMYx weather, calendar (day of week, month of year), and hour of day.[3] The C_y term in Equation 1 refers to a calibration constant that aligns AdopDER's bottom-up, feeder-level baseline kWh estimates with Tacoma Power's corporate load forecast.

Demand Response Dispatch and Peak Impact Calculations

AdopDER estimates load impacts for each of the 8,760 hours of the year; however, demand response measures are not applicable for all 8,760 hours. Thus, for this project, the study simulated the dispatch of demand response measures in six annual events, with each event lasting three hours.

To determine the dispatch schedule, the study analyzed its baseline kWh forecast described above and systematically determined event periods that coincided with monthly system peaks in summer and winter. As an illustration, Table 3 shows the six events in 2032. In other years, the specific date of each event may vary with the annual calendar so the event is on a weekday rather than weekend.

Table 3. Demand Response Event Calendar, Year 2032

Event Number	Event Season	Event Time Period	Event Date	Event Start Time[a]
1	Winter	AM	2032-01-02	6:00 AM
2	Winter	PM	2032-01-02	4:00 PM
3	Summer	PM	2032-07-16	3:00 PM
4	Summer	PM	2032-08-27	3:00 PM
5	Winter	AM	2032-12-06	6:00 AM
6	Winter	PM	2032-12-06	4:00 PM

[a] The time listed is hour-starting, in local time

[3] OpenEEMeter. "CalTRACK Public Repository." Accessed October 25, 2023 at https://github.com/openeemeter.

As described above, AdopDER estimates 8,760 hourly energy consumption. For reporting the seasonal peaks, the study defined the peak MW for each measure (i.e., building electrification, energy efficiency, transportation electrification, solar PV) as follows:

- Winter AM peak MW is the largest hourly, equipment-level load impact within the event hours in the winter AM events (Events 1 and 5 in Table 3). [4]
- Winter PM peak MW is the largest hourly, measure-level load impact within the event hours in the winter PM events (Events 2 and 6 in Table 3).
- Summer PM peak MW is the largest hourly, measure-level load impact within the event hours in the summer PM events (Events 3 and 4 in Table 3).

Under this definition, the measure peak MW is based on the equipment loads during the peak periods. As such, the peak MW of each measure depends on its specific load shape; heating and cooling end-use load shapes may not coincide with Tacoma Power's typical system peaks.

Residential and Commercial Model Inputs

This section provides details on how this study developed the primary model inputs for the residential and commercial building sectors, including the base year stock assessment and the measures, scenario descriptions, and methodology for creating adoption forecasts and load shapes for each class of customer equipment and program choices.

Base Year Stock Assessment

The study's base year stock assessment included two primary components: building stock characteristics and vehicle stock characteristics. Each component leveraged separate data sources and assessment methodologies, which are described below.

Base Year Building Stock Assessment

For the base year building stock assessment, the study primarily relied on Tacoma Power's CPA database, which includes attributes of each customer's building. These attributes include location (geographic coordinates, corresponding electric distribution feeder, equity zone, and address), age, square footage, number of stories, heating system type and fuel, and occupancy status (owner *versus* renter-occupied). The study used these building characteristics as the foundation for modeling the impacts of customer adoption of electric equipment, rooftop solar, and storage systems and for estimating participation in demand response programs.

The Tacoma Power CPA database does not contain all the data necessary to characterize the building stock at the level this study required. To supplement the CPA database, the study simulated premise-level equipment conditions using equipment saturations from the Northwest Energy Efficiency Alliance

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4 For measures with load additions (i.e., building electrification and transportation electrification), this is the largest load addition. For measures with load reductions (i.e., demand response, solar PV, and energy efficiency), this is the largest load reduction. For rooftop solar the study selected the minimum load in the winter periods, as solar systems are unlikely to produce energy during winter peaks.

(NEEA) Residential and Commercial Building Stock Assessments (RBSA II and CBSA II)[5] to inform heat pump type, water heater type and fuel, clothes washer saturation, clothes dryer saturation and fuel, cooking equipment fuel, and commercial building controls. The study subset RBSA II and CBSA II saturation data to the western slope of Washington (to maintain a high sample size) and estimated the electric panel size for residential buildings based on contractor survey data from Puget Sound Energy.[6] Tacoma Power's CPA residential customer database includes over 168,000 single-family, multifamily, and manufactured homes premises. As shown in Table 4 most of these premises are heated with electricity.

Table 4. Baseline Stock Distribution of Heating Fuel and Heating Systems in Tacoma Power Residential Premises (Counts and Distribution)

	Heating Fuel		Heating System Type					
	Electric	Fossil Fuel	Dual-Fuel Heat Pump	Electric Baseboard/Wall	Electric Furnace	Heat Pump	Gas Boiler	Gas Furnace
Single-Family	71,300	46,500	4,800	26,900	33,600	6,100	1,500	45,000
Multifamily	26,700	17,200	1,100	15,800	9,000	800	1,400	15,800
Manufactured Home	5,100	1,300	200	800	3,700	400	-	1,300
All Building Types	**103,100**	**65,100**	**6,100**	**43,500**	**46,300**	**7,300**	**2,900**	**62,100**
Single-Family	42%	28%	3%	16%	20%	4%	1%	27%
Multifamily	16%	10%	1%	9%	5%	0%	1%	9%
Manufactured Home	3%	1%	0%	1%	2%	0%	0%	1%
All Building Types	**61%**	**39%**	**4%**	**26%**	**28%**	**4%**	**2%**	**37%**

The commercial customer database includes over 16,000 commercial premises. As shown in Table 5, commercial premises are heated primarily with fossil fuels, and the most prevalent heating systems are gas rooftop units[7]. For electric systems, the Tacoma Power CPA data indicates that heat pumps (e.g., air source heat pumps [split and single], package heat pumps, and geothermal heat pumps) are the most prevalent system type.

5 Northwest Energy Efficiency Alliance. 2016-2017. "Residential Building Stock Assessment." https://neea.org/data/residential-building-stock-assessment (RBSA II).

Northwest Energy Efficiency Alliance. 2019. "Commercial Building Stock Assessment." Northwest Energy Efficiency Alliance (NEEA) | Commercial Building... (CBSA II).

6 Puget Sound Energy. 2023. *Integrated Resource Plan Progress Report*. (PSE 2023).

7 The table does not show 16,000 systems because some of the premises in the CPA data did not include complete heating fuel or system data. For these premises the study extrapolated heating fuel and systems based on the distributions in the table.

Table 5. Baseline Stock Distribution of Heating Fuel in Tacoma Power Commercial Premises (Counts and Distribution)

	Heating Fuel		Heating System Type				
	Electric	Fossil Fuel	Electric Furnace	Electric Baseboard/Wall	Heat Pump	Gas Boiler	Gas Rooftop Unit
Lodging	330	470	100	20	40	430	10
Office	1,180	2,050	50	70	600	1450	80
Other	1,290	2,530	160	710	120	2380	290
Retail	770	2,850	50	110	210	2620	100
School	250	370	170	10	140	230	10
Storage/Warehouse	1,460	730	50	1,300	60	670	440
All Building Types	**5,280**	**9,000**	**580**	**2,220**	**1,170**	**7,780**	**930**
Lodging	2%	3%	1%	0%	1%	0%	3%
Office	8%	14%	0%	0%	7%	4%	10%
Other	9%	18%	1%	5%	3%	1%	17%
Retail	5%	20%	0%	1%	4%	1%	18%
School	2%	3%	1%	0%	0%	1%	2%
Storage/Warehouse	10%	5%	0%	9%	1%	0%	5%
All Building Types	**37%**	**63%**	**4%**	**15%**	**17%**	**8%**	**54%**

Base Year Vehicle and Electric Vehicle Charger Stock Assessment

The study characterized the base year residential vehicle stock within Tacoma using Pierce County vehicle registration data from 2022 from Washington State's Department of Licensing (DOL) database. Because Washington State requires that residents renew vehicle registrations annually, this data provided a comprehensive understanding of the number and locations of residential vehicles within Tacoma and Pierce Counties. The study mapped individual vehicles to specific customer premises in Tacoma Power's customer database according to their census tract, the lowest common geographical level, in Tacoma Power's service territory. To ensure the accuracy of the data, the study used American Community Survey (ACS) data from the Census Bureau to cross check the distribution of vehicle ownership across residential housing segments, shown in Table 6. In total, around 320,000 vehicles of the roughly 700,000 located in Pierce County shared census tracts with Tacoma Power customers and fell inside its service territory, making them eligible for the study's analysis.

Table 6. Vehicle Ownership Distribution in Tacoma Power Service Territory by Residential Segment

Residential Segment	Vehicle Ownership			
	0 vehicles	1 vehicle	2 vehicles	3+ vehicles
Single-Family	3%	18%	31%	25%
Multifamily	3%	11%	6%	1%
Manufactured Home	0%	2%	1%	0%
All Building Types	**6%**	**31%**	**38%**	**26%**

Source: American Community Survey (ACS), Census Bureau, data.census.gov

The study characterized a portion of the commercial market using the same Pierce County vehicle registration data (2022) from Washington State's DOL database. Commercial entities, especially in a port city, which experiences a high degree of out-of-state traffic, often have vehicles registered out of state. To characterize the remainder of the commercial vehicle stock, the study instituted logic-based assumptions for sizing school, retail, and warehouse fleets, the only commercial segments in this study assumed to be fleet-capable. The study grounded these logic-based assumptions in school size data and retail and warehouse activity data. Together, the registration data and assumption-based fleet assignments generated a total base year commercial stock of roughly 80,000 vehicles in Tacoma Power's territory.

Table 7 displays the base year stock of EV chargers in Tacoma Power's service territory. The study used program data from Tacoma Power to characterize the existing stock of residential EV chargers. Because the quantity of registered residential EVs exceeded the number of ports incented by Tacoma Power programs, the study assigned charging ports to residential premises with an EV. Only 80% of residential premises with an EV also hosted charging ports following industry evidence that roughly 80% of charging occurs at home.[8]

The study determined the population of existing commercial and public EV charging stations through two main sources: Tacoma Power program data and the Alternative Fuels Data Center's (AFDC) Electric Vehicle Charging Station Location database.[9] The absence of EV fleet charging station data in either source paired with information that some commercial customer premises have an EV highlighted the need to assign charging ports to fleets. The study implemented simplifying assumptions, shown in Table 23, to fill this data gap.

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8 ENERGY STAR. 2019. *Building Electric Vehicle-Ready Homes*. https://www.energystar.gov/sites/default/files/asset/document/ENERGY_STAR_Building%20Electric%20Vehicle-Ready%20Homes_OnePager.pdf

Joint Office of Energy and Transportation 2023. *Electric Vehicle Charging Solutions for Multifamily Housing, Market Scan*. https://driveelectric.gov/files/webinar-2023-04-25-community-charging-market-scan.pdf

National Renewable Energy Laboratory. 2021. *Incorporating Residential Smart Electric Vehicle Charging in Home Energy Management Systems*. https://www.nrel.gov/docs/fy21osti/78540.pdf

7 U.S. Department of Energy. 2023. "Alternative Fuels Data Center." Alternative Fuels Data Center: Electric Vehicle Charging Station Locations (energy.gov) (DOE 2023).

Table 7. Base Year Residential and Commercial Electric Vehicle Charging Port Stock

Charging Level	Residential Ports	Public/Workplace Ports	Fleet Ports
Level 1	43	N/A	N/A
Level 2	1,817	74	71
DCFC	N/A	27	8

Base Year Rooftop Solar and Battery Storage Stock Assessment

The study characterized the base year stock of rooftop solar and battery storage systems using program participation data from Tacoma Power. Table 8 shows the base year inventory of rooftop solar and battery storage across residential and commercial premises in Tacoma.

Table 8. Base Year Residential and Commercial Rooftop Solar and Storage Stock

Sector	Rooftop Solar		Energy Storage	
	Total Systems	Total Capacity (kW)	Total Systems	Total Capacity (kW)
Residential	1,977	12,617	24	241
Commercial	54	1,333	2	20

Building Electrification and Energy Efficiency

The building electrification and energy efficiency impacts analysis focused on the installation of electric space, water, and cooking equipment in existing residential and commercial buildings and new construction. This study included only electric equipment in the analysis and defined equipment installations as “electrification” when installed in buildings with existing fossil fuel equipment, as “energy efficiency” in buildings with existing electric equipment, and as “new construction” in newly constructed buildings.

This section provides a description of the building and energy efficiency scenarios, equipment, and model inputs, including the methodology for developing the equipment load shapes and adoption curves.

Building Energy Efficiency and Electrification Scenarios

Table 9 shows the building electrification and energy efficiency scenario design. As shown in the table, each scenario focuses on policy such as buildings codes and Washington State Clean Building Performance Standards (CBPS) and policy drivers like Inflation Reduction Act (IRA) tax credits and Washington Climate Commitment Act (CCA) investments. The *Building Energy Efficiency and Electrification Model Inputs* section below describes how this study translated these scenario descriptions into equipment adoption rates.

Table 9. Building Electrification and Energy Efficiency Scenarios

Current Landscape	• **Codes:** Building code progresses to and achieves 70% energy use intensity (EUI) reduction target by 2030 (no further stepdown); ~50% of new residential and ~60% of new commercial continue to use natural gas

	• **Existing Equipment:** Increase in adoption of electric appliances in residential sector due to IRA (over next five years), limited adoption in multifamily; adoption of electric appliances in commercial limited to historical adoption rates; limited adoption in non-owner-occupied buildings • **CBPS:** ~15% EUI reduction has limited impact on electrification in Tier 1 or Tier 2 buildings (e.g., ~5% to 10% of buildings consider electrification to achieve compliance), no further rulemaking beyond existing 2028 compliance for Tier 1 • Some non-cost-effective adoption driven by desire to add cooling/amenities; barriers to electrification from electrical infrastructure
Anticipated Electrification	• **Codes:** Building code accelerates toward 70% by 2030 target with net zero ready code by 2027 for residential and 2036 for commercial buildings; EUI goals further constrain use of natural gas to commercial applications after 2033 (~25% of new residential and ~35% of new commercial continue to use natural gas) • **Existing Equipment:** Increase in adoption of electric appliances in residential sector driven by IRA and redirection of CCA funding; increased commercial and multifamily adoption from CCA funding and more aggressive CBPS compliance; adoption of some equipment still constrained in non-owner-occupied buildings • **CBPS:** Phase 2 of EUI reduction targets announced by 2028 with compliance by 2036, with deeper EUI targets (e.g., 25%) for Tier 1 and Tier 2; Phase 3 announced by 2036 with compliance by 2043 (e.g., 40% target); new phases with steeper fines encourage further electrification (e.g., ~25% of buildings consider electrification to achieve compliance in Phase 2, 40% in Phase 3) • Increasing share of adoption is not cost-effective; reduced barriers to electrification from electrical infrastructure
Expansive Policy	• **Codes:** Building code accelerates beyond Anticipated Electrification scenario with net zero ready by 2027 and full net zero required by 2036; EUI goals eliminate possibility of using natural gas in residential by 2027 and commercial by 2033, supported by law banning new gas connections by 2035 • **Existing Equipment:** Accelerated adoption of electric appliances due to further incentives beyond IRA/CCA/utility; mandates drive further electrification: all residential central ACs must be heat pumps by 2028; no new gas equipment may be installed by 2040; mandates address many split incentive issues • **CBPS:** Same as Anticipated Electrification scenario but more aggressive EUI targets (e.g., 50% target in Phase 3) and fines, T2 buildings expanded to include 10,000+ single-family buildings; majority of buildings must electrify to achieve compliance • Mandates require adoption that may not be cost-effective, though regulated transition away from PSE gas infrastructure increases costs of natural gas and assumes increasing incentives to electrify; on-site electrical infrastructure does not constrain adoption
Policy Regression	• **Codes:** Building code progresses to and achieves 70% EUI reduction target by 2030 but with increased exemptions for natural gas in commercial (e.g., cooking, hospitals) and assumed difficulty for residential buildings to meet EUI reduction targets; ~60% of new residential and ~70% of new commercial buildings continue to use natural gas • **Existing Equipment:** Same as Current Landscape scenario but with greater share of dual-fuel appliances • **CBPS:** Same as Current Landscape scenario
Anticipated Electrification with Mitigation	• Same as Current Landscape scenario
Expansive Policy with Mitigation	• Same as Expansive Policy scenario with the following changes: ▪ **Codes:** Exemptions made for renewable natural gas and hydrogen within EUI calculations ▪ **Existing Equipment/CBPS:** Approximately 20% of Tier 1 buildings use renewable natural gas or green hydrogen as opposed to electrifying

Building Energy Efficiency and Electrification Equipment

Table 10 shows the types of equipment for which this study estimated electrification and energy efficiency load impacts. The table shows how equipment applies to different building types and installation types (electrification, energy efficiency, or new construction) that the study considered. Notes following the table further classify the heating equipment by specifying whether installation requires the building to have ducts and explaining assumptions about air conditioning in existing buildings. The study further segmented building equipment according to ownership status and income level (i.e., if it was installed in rented buildings and occupied by low-income residents).

Table 10. Building Electrification and Energy Efficiency Equipment

Equipment Type	Building Type	Installation Type
Air Source Heat Pumps[a]	Single-Family, Multifamily, Manufactured Home, Commercial	Existing buildings electrification and energy efficiency New construction
Ductless Heat Pumps[a]		
Variable Refrigerant Flow[b]	Single-Family, Multifamily, Commercial	
Dual Fuel Air Source Heat Pump[c]	Single-Family, Multifamily, Manufactured Home	Existing buildings electrification
Electric Furnace[c]		
Electric Baseboard		
Ground Source Heat Pump[d]	Commercial	New construction
Heat Pump Water Heater	Single-Family, Multifamily, Manufactured Home	Existing buildings electrification and energy efficiency New construction
	Commercial	Existing buildings electrification New construction
Electric Resistance Water Heater	Single-Family, Multifamily, Manufactured Home, Commercial	Existing buildings electrification
Electric Cooking Equipment	Single-Family, Multifamily, Manufactured Home, Commercial	Existing buildings electrification New construction
Electric Dryer	Single-Family, Multifamily, Manufactured Home	Existing buildings electrification New construction

[a] Air source heat pumps in buildings with existing ductwork; ductless heat pumps in buildings without ductwork. Assumes residential buildings split between existing and no air conditioning. All existing commercial buildings have air conditioning.

[b] Applies to all building types, assumes existing buildings have air conditioning.

[c] In buildings with existing ductwork. Assumes residential buildings split between existing air conditioning and no air conditioning

[d] Study assumes high barriers, limited installation

Building Energy Efficiency and Electrification Model Inputs

Two primary inputs determine the building electrification and energy efficiency impacts: equipment load shapes and adoption curves. This section describes the methodology for developing each.

Load Shapes

This study produced 167 load shapes for the equipment types described in Table 10. For this study, these load shapes represent the kW energy use for each equipment type per unit (e.g., building square foot or dwelling unit). Thus, the building square footage and number of buildings from Tacoma Power's CPA database are critical inputs for calculating building electrification and energy efficiency impacts.

To develop equipment load shapes, the study calibrated end-use heating and cooling load shapes from the National Renewable Energy Laboratory's (NREL) ResStock and ComStock load shape database[10] to Tacoma Power equipment energy consumption data from its CPA database.

The process for calibrating the load shapes to Tacoma Power equipment consumption followed these steps:

1. Because NREL load shapes are an aggregate of multiple buildings and the distribution of these buildings do not align with the distribution of a Tacoma Power building, this study scaled the NREL end use load shapes to reflect realistic building stock, including matching the percentage of homes with electric heat or gas heat.[11]
2. The study calibrated the load shapes to reflect equipment consumption from Tacoma Power's CPA using equipment energy consumption estimates provided by Tacoma Power.
3. After calibrating the load shapes to Tacoma Power's energy consumption (i.e., space heating, space cooling, or water heating energy needs), the study converted the energy estimates to electric power by applying equipment-specific coefficients of performance (COP) to each load shape. To determine the heat pump profile at given temperature and COP, Cadmus used field data from Massachusetts and New York[12] and then applied a COP verses temperature correlation calculation from these studies to determine hourly heat pump load shapes for Tacoma Power's service area.
4. The study then scaled the load shapes to building square footage (or dwelling units) by dividing the load shape consumption by the building square footage (or dwelling units).

For example, to create a load shape for an air source heat pump installed in a single-family home without existing air conditioning, the study downloaded NREL data for a single-family home. NREL estimates 46% of homes in the dataset use electricity for heat generation; the others use natural gas. The study used this metadata to scale the consumption data so it would represent the standard electric consumption of a single-family home. The study then observed that in the CPA database, the average usage of electric heating equipment is 9,069 kWh while the NREL data estimated 11,665 kWh; the study

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10 National Renewable Energy Laboratory. 2021. ResStock End Use Savings Shapes. AMY2018. Residential: AWS S3 Explorer for the Open Energy Data Initiative (openei.org)

National Renewable Energy Laboratory. 2021. ComStock End Use Savings Shapes. AMY2018. Commercial: AWS S3 Explorer for the Open Energy Data Initiative (openei.org)

11 For the "Other" commercial buildings segment, the study used load shapes from the Northwest Power and Conservation Council because NREL did not have load shapes for this building type.

12 Cadmus. April 22, 2022. "Residential ccASHP Building Electrification Study." PowerPoint presentation. https://e4thefuture.org/wp-content/uploads/2022/06/Residential-ccASHP-Building-Electrification_060322.pdf

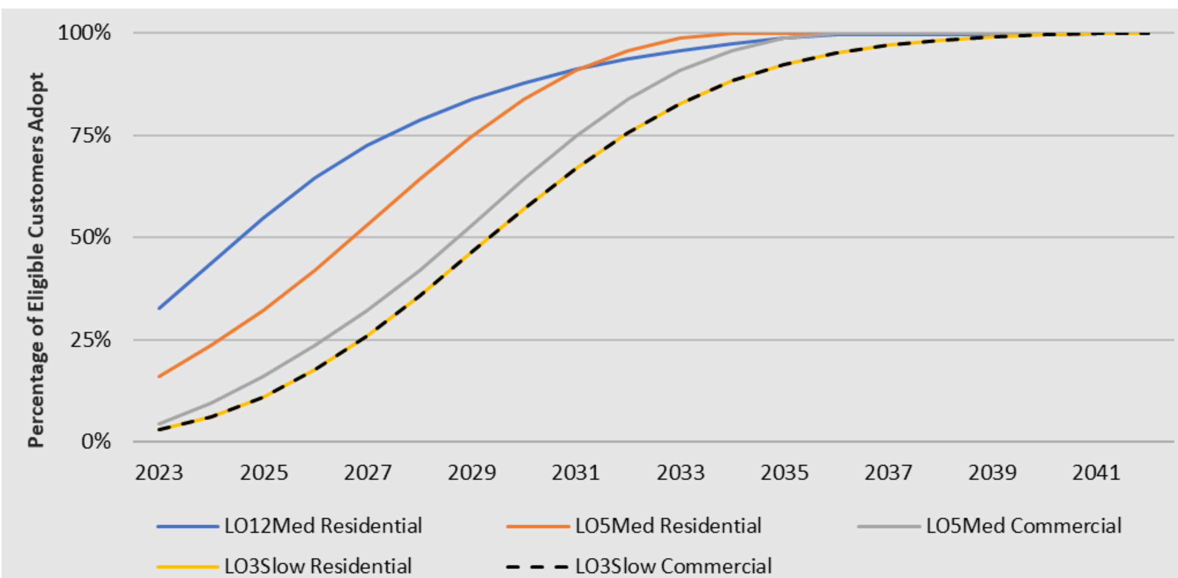
used the calibration factor of 0.78 of the hourly NREL data to make the consumption data more representative of Tacoma's existing building stock.

The study used heat pump field data to estimate a COP verses temperature correlation calculation and then applied to Tacoma area outdoor temperature data (NREL data) to determine the load shape for a heat pump (electric replacement and non-electric replacement heat pump profiles). Since the existing home does not have cooling, the study added electric cooling load as part of the heat pump profile. For the homes with existing non-electric heating, the heat pump load shape presented added load. For homes with existing electric heating, the study then subtracted the original electric heating consumption from the total to create (negative) hourly load impact. The results are then divided by the average square footage of a single-family home from Tacoma's CPA database (e.g., 1,784 sq ft) to get an hourly kWh/square foot load shape.

Adoption Rates

This study used equipment adoption rates from the 2021 Northwest Power Plan (Power Plan)[13] as the basis and starting point for its equipment adoption rates (the Power Plan refers to these adoption curves as ramp rates). The study mapped the Power Plan's adoption rates to specific equipment types, then further modified the adoption curves to account for variables reflected in the scenario design. Figure 10 shows the unmodified equipment adoption rates to represent the starting point before electrification scenario adjustments are applied. All energy efficiency (electric to electric equipment upgrades) used the Power Plan ramp rates without adjustment other than the maximum applicability factor (85%) consistent with the Power Plan.

Figure 10. Northwest Power Plan Adoption Curves Applied to Study Equipment



13 Northwest Power and Conservation Council. 2021. *Northwest Power Plan*. https://www.nwcouncil.org/2021-northwest-power-plan/

Table 11 shows equipment types that the study mapped to individual Power Plan adoption rates, as the basis for making scenario-specific adjustments. The study followed the ramp rate adoption found in the Power Plan. The Power Plan ramp rates are developed for the adoption of energy efficiency measures and not necessarily electrification adoption. Considering this, the study further adjusted Power Plan ramp rates to account for electrification barriers, policies, and potential funding under each scenario.

Table 11. Study Building Equipment to Power Plan Mapping

Study Building Equipment Type	Base Power Plan Adoption Rate
Heat Pump	LO5Med
Water Heater	LO5Med
Cooking Oven	LO3Slow
Cooking Range	LO3Slow
Dryer	LO12Med

Table 12 shows factors applied to the Power Plan adoption rates for the residential Current Landscape, Anticipated Electrification, and Expansive Policy scenario adoption curves. As stated above, the study did not adjust adoption curves from the Current Landscape scenario assumptions for electric-to-electric equipment with existing end uses of electric furnaces, baseboards heaters, or electric resistance water heaters.

The study designed the adjustment factors to reflect the variables that influence equipment adoption, such as incentives, income-level, renter status, and market barriers. Table 12 shows the adjustment factors for heat pumps. Adjustment factors for other equipment types vary.

Table 12. Residential Building Equipment Adoption Curve Adjustment Factors for Heat Pumps

<table>
<tr><th>Impact Type</th><th>Current Landscape</th><th>Anticipated Electrification</th><th>Expansive Policy</th><th>Notes</th></tr>
<tr><td>Decreased adoption to account for rental property</td><td colspan="3">50%</td><td>Applies only to rented buildings. This factor accounts for the barrier of rental customers in participating in electrification equipment adoption. Inferred from PSE 2023 IRP Customer and Contractor Heat Pump Survey findings on market barriers.[a]</td></tr>
<tr><td>Decreased adoption factor to account for property type</td><td colspan="3">68%</td><td>Applies only to multifamily buildings. This factor accounts for the barrier of multifamily customers participating in electrification equipment adoption. Inferred from PSE 2023 IRP Customer and Contractor Heat Pump Survey findings.[a]</td></tr>
<tr><td>Increased demand for air conditioning</td><td colspan="3">15%</td><td>Applies only to buildings without air conditioning. This factor accounts for the difference between customers’ willingness to adopt electric heat pumps that have existing cooling compared to those who do not have existing cooling. Customers are more likely to participate in heat pump adoption if they do not have existing cooling (and would like cooling). Inferred from PSE 2023 IRP Customer and Contractor Heat Pump Survey findings.[a]</td></tr>
</table>

Impact Type	Current Landscape	Anticipated Electrification	Expansive Policy	Notes
IRA funding for non-low-income buildings	Annual percentage factor of 2%	Annual percentage factor of 3%	Annual percentage factor of 4%	Applies only to buildings not occupied by low-income residents. IRA funding impact proportional to number of homes in the state and Tacoma customers.
IRA funding low-income impact	Annual percentage factor of 0.6%	Annual percentage factor of 0.9%	Annual percentage factor of 1.2%	Applies only to buildings occupied by low-income residents. IRA funding impact proportional to number of homes in the state and Tacoma customers.
Increased applicable adoption based on state codes	50%	75%	75%, increase to 100% in 2027	Applies only to new construction. This factor accounts for building code progress over the study period. The factor is derived from assumptions stated in the scenario description.
Maximum scenario equipment applicability	35%	50% (increase to 53% for multifamily buildings from 2032)	75% (increase 79% for multifamily buildings from 2032)	Applies only to existing buildings. This factor accounts for the customer's willingness to install electrification equipment (heat pump) based on incentives covering 50% of cost of conversion. Inferred from PSE 2023 IRP Customer and Contractor Heat Pump Survey findings.[a] Adjustment for multifamily buildings account for scenario changes to CBPS.
Maximum electric to electric equipment conversion applicability	85%			Applies only to buildings with existing electric equipment. This factor estimates the maximum achievability factor for customer adoption. Factor and approach are consistent with Power Plan methodology for energy efficiency measures.
Barriers to electrification installation (electrical panel requirements)	90%	95%	100%	Applies only to fuel-switch equipment. Applies to all buildings. Factor accounts for customer barriers to install due to electric panel and wiring requirements to convert. An increase in the factor increases the adoption rate.

[a] Puget Sound Energy. Conservation Potential Assessment Appendix C, 2023 Gas Utility Integrated Resource Plan. Inferred from figures and data in Appendix A Heat Pump Market Research Findings (page A8, Slide 15). Link: https://www.pse.com/-/media/PDFs/IRP/2023/gas/appendix/09_IRP23_AppC_Final.pdf?modified=20230331213553

For the Policy Regression, Anticipated Electrification with Mitigation, and Expansive Policy with Mitigation scenarios, this study made the following adjustments:

- **Policy Regression:** Increased the base adoption rate for dual fuel heat pumps to the LO50Fast Rate in Power Plan (see Figure 10)
- **Anticipated Electrification with Mitigation:** No changes compared with Anticipated Electrification due to scenario design
- **Expansive Policy with Mitigation:** No changes compared with Expansive Policy because there are no scenario modifications

The IRA federal initiative includes rebates and tax incentives to help homeowners make decisions about their energy use that will encourage them to adopt more-efficient appliances and systems within their homes. These monetary and regulatory incentives are expected to drive changes within the energy industry and other sectors pursuing building decarbonization. This study accounted for the effects of rebates and incentives by increasing adoption rates based on the available funding for Tacoma Power customers.

The High Efficiency Electric Homes Rebates Act (HEEHRA) within the IRA is largely focused on providing rebates to income-eligible consumers for electric equipment upgrades and electrification projects. The Home Energy Performance-Based, Whole-House Rebates (HOMES) program provides rebates for homeowners based on whole-house energy retrofits. States will apply to the U.S. DOE for funding to implement HEEHRA and the HOMES program through their respective state agencies ($166 million is available to Washington state). According to the Washington State Department of Commerce, funding for both programs will be available in the middle of 2024. Expanded tax credits (25C) are also available through the IRA as of January 2023, which will mainly benefit homeowners who have sufficient tax liability and the financial flexibility to purchase eligible products before they receive the benefits from these programs as part of their tax returns.

In this study, IRA funding was assumed to start in mid-2024 and end in 2032, lasting 8 years. The study capped the funding for a given year at the available amount for that year. The study modeled IRA and non-IRA impacts using the ratio of number of households in Washington[14] to number of households in Tacoma Power service area to estimate the total IRA funding available in Tacoma Power's service area through the HOMES Rebate program and HEEHRA. This resulted in 5.8% of all funding available in Washington to be allocated to Tacoma Power customers. The study used a similar process to estimate the funding available through the 25C tax credit with a ratio of the available funding to the number households. This study assumed that 25% of program all funding goes to non-electrification upgrades and administrative costs for state energy offices.

While the IRA will be beneficial in funding electrification, the funding available is limited and will only impact a subset of Tacoma Power's customers. The study estimated roughly 8% of households will participate in the rebate and incentive programs and receive the available funding under the Current Landscape scenario.

Table 13 shows factors that this study applied to the Power Plan adoption rates for the commercial Current Landscape, Anticipated Electrification, and Expansive Policy scenario adoption curves.

[14] There are 2,931,841 households in Washington (Source: United States Census Bureau. Accessed November 2023. "QuickFacts: Washington." https://www.census.gov/quickfacts/WA).

Table 13. Commercial Building Equipment Adoption Curve Adjustment Factors for Heat Pumps

Impact Type	Current Landscape	Anticipated Electrification	Expansive Policy	Notes
Increased applicable adoption of electric equipment based on state codes and existing policies	40%	65%	65%, increased to 100% in 2035	Applies to new construction. This factor accounts for building code progress over the study period. The factor is derived from assumptions stated in the scenario description.
Maximum scenario equipment applicability	35%	50%, increased to 56% in 2036	70%, increased to 79% in 2036	Applies only to existing buildings where fuel switching occurs. This factor accounts for existing construction policy changes. The factor is derived from assumptions stated in the scenario description.
Maximum electric to electric equipment conversion applicability	85%			Applies only to buildings with existing electric equipment. This factor estimates the maximum achievability factor for customer adoption. Factor and approach are consistent with Power Plan methodology for energy efficiency measures.

For the Policy Regression, Anticipated Electrification with Mitigation, and Expansive Policy with Mitigation scenarios, this study made the following adjustments in the commercial sector:

- **Policy Regression:** Reduced the factor that accounts for electric equipment in new construction
- **Anticipated Electrification with Mitigation:** No changes compared with Anticipated Electrification scenario
- **Expansive Policy with Mitigation:** Reduced the share of electric equipment in new construction by 20% as per scenario design that buildings use renewable natural gas or green hydrogen as opposed to electrifying.

Rooftop Solar, Battery Storage and Demand Response

Tacoma Power does not currently offer demand response programs to its customers. Thus, this study modeled an option to participate in demand response programs only in the mitigation scenarios. The rooftop solar and demand response analysis focused on the distribution system impacts when customers adopt rooftop solar systems and/or participate in demand response programs. This section provides the scenario design for rooftop solar and demand response and describes the methodology for modeling rooftop solar and demand response impacts. To model impacts from battery storage dispatch demand response programs, this study modeled battery storage adoption and then applied program participation assumptions to the adopted systems.

Rooftop Solar and Demand Response Scenarios

Table 14 presents the rooftop solar and demand response scenario design. As shown in the table, the scenario designs included assumptions about net metering and state and federal incentives.

Table 14. Rooftop Solar and Demand Response Scenarios

Current Landscape	• **Rooftop Solar:** Continued market-driven adoption of rooftop solar up to the net metering cap (not expanded), reduced adoption after reaching net metering cap, Inflation Reduction Act (IRA) extension of tax credits sunset as scheduled; high adoption in new construction due to code (assumed annual new construction rate of adoption equal to total scenario adoption for existing buildings) • **Storage:** Continued limited market-driven adoption of storage, increases after net metering cap is reached, paired with rooftop solar • **Demand Response:** No adoption (lack of current programs)
Anticipated Electrification	• **Rooftop Solar:** Net metering cap is expanded (up to 8% of peak demand) in conjunction with reinstatement of state incentives, reduced adoption after reaching net metering cap; high adoption in new construction due to code (assumed annual new construction rate of adoption equal to total scenario adoption for existing buildings) • **Storage:** Increased market-driven adoption of storage through Tacoma programs supporting demand reduction value, also increases after net metering cap is reached • **Demand Response:** No adoption (lack of current programs)
Expansive Policy	• **Rooftop solar**: Net metering cap is removed in conjunction with reinstatement of higher RESIP (or similar incentive) to accelerate adoption of rooftop solar; assume 75% adoption in technically feasible new construction by 2036 • **Storage:** Same as Anticipated Electrification scenario but assumes more aggressive incentives; building code by 2036 requires storage in commercial buildings • **Demand Response:** No adoption (lack of current programs)
Policy Regression	• Same as Current Landscape scenario
Anticipated Electrification with Mitigation	• Same as Anticipated Electrification scenario for Rooftop Solar, same as Expansive Policy scenario for Storage • **Demand Response:** Tacoma implements modest demand response programs for managed charging, water heater direct load control, and smart thermostats; achieving 20% of demand response and 30% of managed charging participation by 2042.
Expansive Policy with Mitigation	• **Solar:** Same as Expansive Policy scenario • **Storage:** Building code also requires storage in residential buildings by 2036, assumes further incentives to increase share of PV systems with storage • **Demand Response:** More aggressive demand response programs tie incentive delivery to participation in demand response, achieving 20% of demand response and 40% of managed charging participation by 2042.

Rooftop Solar and Battery Storage Equipment

Table 15 displays the characteristics of rooftop solar and battery storage systems included in this study. The study reviewed NREL's annual technology baseline report and Pacific Gas and Electric's distributed generation data to determine battery sizing by off-taker type (residential vs commercial).[15] [16] The commercial battery sizes from the NREL report were much higher than anticipated (and likely more common for industrial purposes), and therefore the study reviewed actual installation data from the

15 National Renewable Energy Laboratory. 2022 *Annual Technology Baseline Report*. https://atb.nrel.gov/electricity/2022/residential_battery_storage

16 Filtered Net Energy Metering Data for commercial battery projects in Pacific Gas and Electric territory. Accessed July 26, 2023. https://www.californiadgstats.ca.gov/downloads/

Northern California utility with some of the highest storage deployment rates across the nation due to climate resiliency trends including public safety power shutoffs. Although these trends are less likely to impact Tacoma Power residential customers' adoption of rooftop solar and battery storage, the battery size of commercial adopters in Tacoma Power territory is likely like that of commercial adopters in northern California due to typical power needs and cost constraints.

Table 15. Rooftop Solar and Energy Storage Equipment

Building Type	Equipment Type	Sizing Details
Single-Family	Rooftop Solar	1.15 DC-AC Ratio
Single-Family	Battery Storage	5 kW/20 kWh
All Commercial	Rooftop Solar	1.15 DC-AC Ratio
All Commercial	Battery Storage	150 kW/250 kWh

Rooftop Solar Model Inputs

The study estimated solar PV load shapes using NREL's System Advisor Model (SAM) tool, selecting TMY weather data for Tacoma to inform the solar resource potential by time of day and season. Next, four orientations (due south, due west, due east, and southwest) were combined with three tilt levels (35, 25, and 15 degrees) to simulate 10 distinct load shapes on a watt per watt-direct current (W/W-DC) basis.[17] The study then scaled the load shapes by the assumed adopter orientation, tilt, and project size to incorporate the forecasted energy impacts to the grid. The study assumed default assumptions from SAM for the DC-AC ratio of 1.15 and the default losses which equate to a total system loss of 14.08%. The study assumed there would be no required curtailment nor interconnection limits for rooftop mounted solar PV systems.

To calculate the total rooftop solar load impacts, the study scaled customer system sizes by the available rooftop area, as per the Tacoma Power CPA customer database.

Rooftop Solar Adoption Rates

This study used dGen, a publicly available forecasting tool developed by NREL, to develop rooftop solar adoption rates corresponding to the study scenario design for existing owner-occupied single-family homes and all existing commercial buildings.[18] The dGen model uses a combination of project economics and market diffusion rates to simulate market adoption over time. This study used Tacoma Power data as the basis for historical adoption trends, which is also an important input to the dGen model.

NREL designed the model to allow for adjustments to model inputs, underlying assumptions, and model logic. The study reviewed the model inputs from the Tacoma Power dataset in detail and adjusted data inputs and model programming as appropriate. Because model inputs can be varied, adoption scenarios

[17] Not every combination of tilt and azimuth values were simulated.

[18] This study assumed that split incentives preclude multifamily buildings and rented homes from participating.

can be generated by changing key inputs. This study adjusted the following inputs: federal tax credits, state incentives and net-metering policy. Table 16 shows the model adjustments for each scenario.

Table 16. Solar Adoption Rate Scenario Variables

<table>
<tr><th>Scenario</th><th>Federal Tax Credit</th><th>State Incentives</th><th>Net Metering Limit</th><th>New Construction</th></tr>
<tr><td>Current Landscape</td><td rowspan="4">30%</td><td>None</td><td>41.5 MW</td><td rowspan="2">Annual new construction rate of adoption equal to total scenario adoption for existing buildings</td></tr>
<tr><td>Anticipated Electrification</td><td>Residential $0.14/kwh
Commercial $0.04/kWh</td><td>83.1 MW</td></tr>
<tr><td>Expansive Policy</td><td>Residential $0.19/kwh
Commercial $0.06/kWh</td><td>No Limit</td><td>75% of new construction adopts solar by 2036</td></tr>
<tr><td>Policy Regression</td><td colspan="3">Same as Current Landscape scenario</td></tr>
</table>

Battery Storage Adoption Rates

Energy storage adoption was modeled via solar PV attachment rates (percentage of new solar PV systems installed that also include energy storage), as this metric is well tracked nationally via the Lawrence Berkeley National Laboratory's Tracking the Sun Report.[19] The adoption rates varied by scenario, with more optimistic scenarios corresponding to jurisdictions with strong adoption trends (e.g. California), and more conservative estimates assuming a business as usual storage deployment rate (current attachment rate of about 2%).

To account for changes to the net metering compensation scheme as well as net metering caps being met, the storage adoption rates were mapped to those of National Grid – Massachusetts' trends where the net metering cap has been met for the past four years. The Massachusetts landscape serves as a pertinent case study to isolate the impact of the net metering cap on energy storage adoption given that the state is split into two large electric utility territories—National Grid and Eversource—which both cover urban, suburban, and rural areas, but Eversource has not yet met its net metering cap whereas National Grid met its cap years ago. One key difference between the two utilities is that Eversource includes the Boston metro area, which likely explains in part why it still has net metering capacity remaining given the city's large demand but lack of relative rooftop space compared with more suburban areas. While solar deployment in National Grid's territory has slowed due to the lack of available net metering, energy storage adoption relative to solar deployment has increased, likely because there is an arbitrage opportunity in storing excess electricity generated by solar PV.

19 Lawrence Berkeley National Laboratory. September 2023. *Tracking the Sun Report*. https://emp.lbl.gov/sites/default/files/5_tracking_the_sun_2023_report.pdf

Energy storage adoption levels are expected to increase over time, and each scenario begins with the attachment levels recently observed in Tacoma Power territory and then grows to the maximum levels as noted in Table 17.

Table 17. Storage Maximum Attachment Rates Assumed by Scenario

Sector	Current Landscape	Anticipated Electrification	Expansive Policy	Policy Regression	Anticipated Electrification with Mitigation	Expansive Policy with Mitigation
Residential	8%	11%	19%	8%	19%	19%
Commercial	6%	10%	20%	6%	20%	20%

Demand Response Programs

Table 18 shows the four potential demand response programs that the study assumed based on the Tacoma Power input that these programs are the most likely programs to be implemented in the future.

Table 18. Demand Response Programs

Sector	Program	Installation Type
Residential and Commercial	Battery Storage Dispatch	Existing Battery Storage System
Residential	Water Heater Direct Load Control	Existing Electric Resistance or Heat Pump Water Heater
	Smart Thermostat	Existing Air Source Heat Pump
	Managed Charging	Existing Level 2 Charger

Demand Response Model Inputs

This section describes the methodology for developing the load shapes and event structure and adoption rates for the study's four demand response programs, which the study only included in the mitigation scenarios.

Battery Storage Load Shapes

The study estimated energy storage dispatch by reviewing dispatch data from demand response programs throughout the country to identify level of dispatch, participation rates, depth of discharge levels, and recharging patterns. A review of demand response performance suggests that suboptimal performance was often due to factors that include batteries not being fully charged ahead of events, depth of discharge limitations of the off-taker for resilience purposes, and battery degradation.

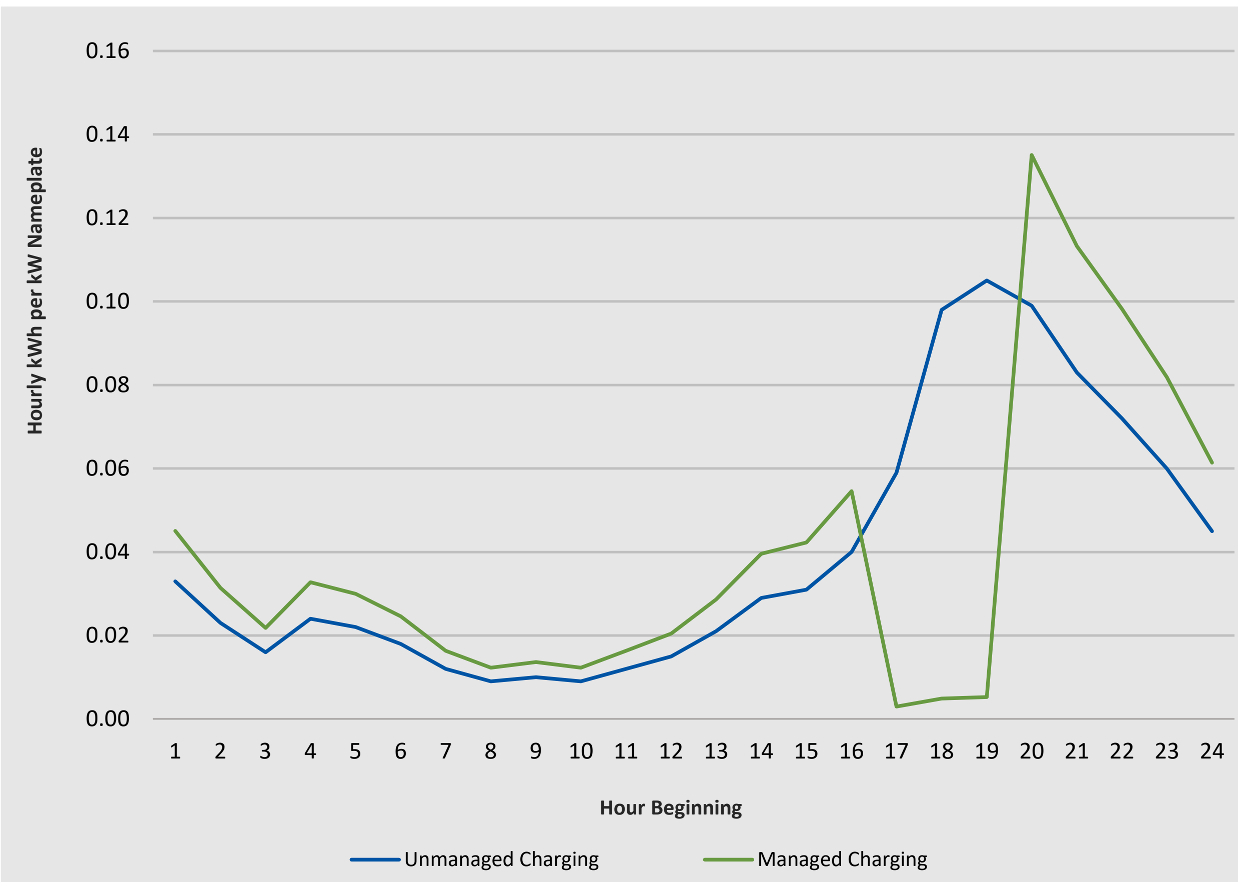
The study also assumes a roundtrip efficiency of 86% to account for system losses attributable to the chemical energy conversion, which impacts the charge and discharge levels. To accommodate resiliency concerns, participation rates, and technical constraints, the study assumed that 60% of the nameplate power would be dispatched in demand response events where feasible and that the battery state of charge would be constrained to between 20% to 90% of its maximum at all times in line with best practices for preserving lithium-ion battery life expectancy. Because the commercial battery modeled was not estimated to store as much energy relative to its power rating, the dispatch tails off in hour three of the event.

Managed Charging Load Shapes/Event Structure

The study manipulated the Level 2 residential load shapes used in the transportation electrification analysis for managed charging, assuming that some portion of the fleet would shift charging away from the peak hours during a demand response events. The load shapes included Level 2 chargers servicing Battery EVs (BEV) and Plug-In Hybrid EVs at (PHEV) residential building types. The study assumed that demand response events would occur on weekdays, that participants would stop charging during the demand response windows, and that charging would be shifted proportionately across other non-peak hours so the total daily energy consumption would be equal to the original load shapes included in the transportation electrification modeling.

Figure 11 compares the two load shapes modeled for a Level 2 charger servicing a BEV on a winter day during one single evening demand response event. The unmanaged charging curve includes charge values during peak hours whereas the managed charging measure zeros out during the evening peak window but is higher in other remaining time periods such that 100% of the daily charging needs are still met.

Figure 11. Effect of Managed Charging on Winter PM Residential Level 2 Charging



Smart Thermostats Load Shapes/Event Structure

This study used Cadmus' previous evaluation work for a utility in the Pacific Northwest to estimate the savings associated with a smart thermostat coupled with a heat pump in the winter season. The study incorporated two years of winter event data and contained thermostats controlling a range of HVAC equipment and both "bring-your-own" and utility direct installed thermostats for the program. This study averaged the savings across events between these two program types given that the study did not define the program at this level. This study translated the benchmarked savings from kW per single family home to kW/sq ft to scale to other segments (e.g., multifamily).

Water Heaters Load Shapes/Event Structure

This study used hourly single family 8,760 data from a similar study conducted for Seattle City Light (SCL) to identify the annual load patterns attributable to water heaters and estimate single-family and multifamily Peak Load Impacts (kW per participant) per event. Random weekdays were selected in January and August to identify load implications of a demand response event from the 8,760 framework. Results were then compared against the pilot program findings for the Tacoma Power study shared.[20]

Demand Response Adoption Rates

The study used adoption rates for managed charging, smart thermostats, and water heaters from the 2021 Northwest Power Plan (Power Plan). While the scenarios defined the actual achievable percentage of adoption as per *Real Reliability: The Value of Virtual Power* 2023 (Brattle Group)[21], the Power Plan rates were used to estimate if and by what year those maximum achievable percentages would be achieved (Table 19).

Table 19. Demand Response Adoption Rates

	Anticipated Electrification with Mitigation	Expansive Policy with Mitigation
Demand Response Adoption	20%	30%
Managed Charging Adoption	20%	40%

Managed Charging

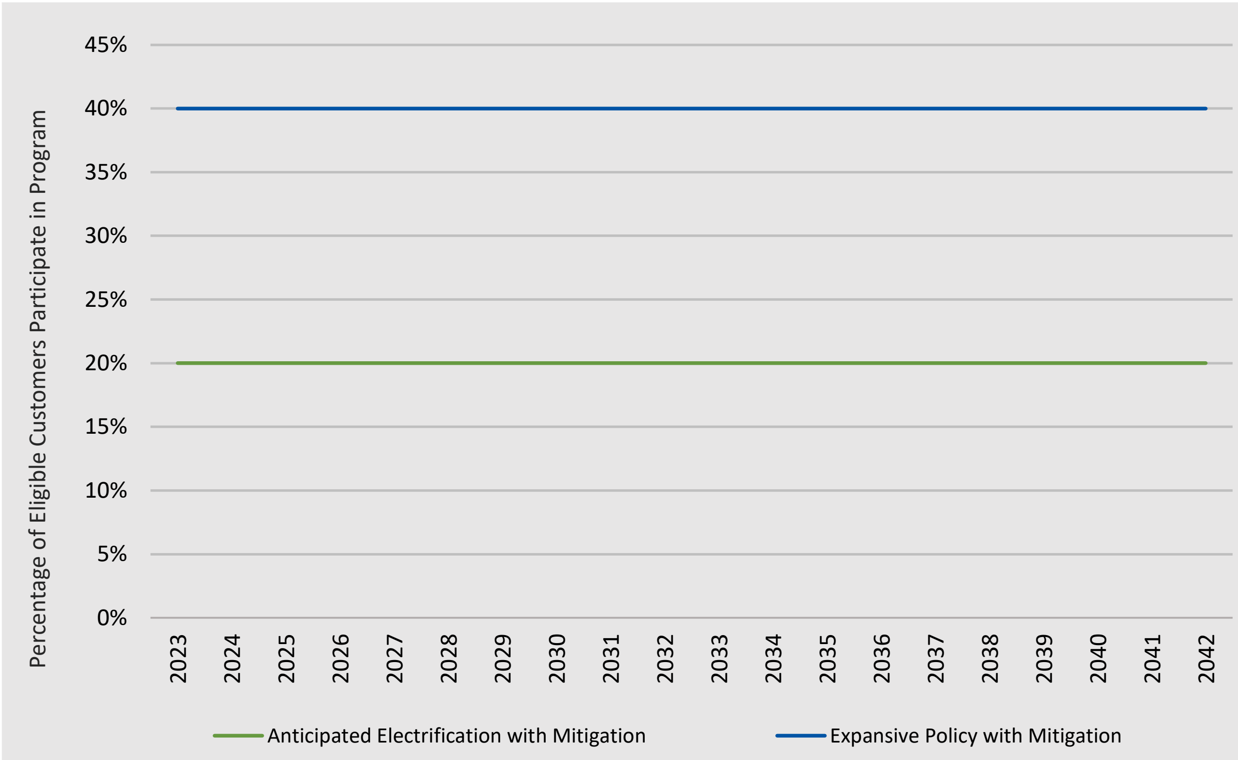
The study assumed that a steady percentage of chargers would enroll in a managed charging program (meaning that participation grows as the number of chargers increases). It assumes a 95% participation rate in demand response events.

Figure 12 shows the participation rates for managed charging programs.

20 Tacoma Power. July 25, 2023. *Water Heater Demand Response Pilot.* (June Results).

21 Brattle Group. May 2023. *Real Reliability: The Value of Virtual Power 2023*. https://www.brattle.com/wp-content/uploads/2023/04/Real-Reliability-The-Value-of-Virtual-Power-Technical-Appendix_5.3.2023.pdf

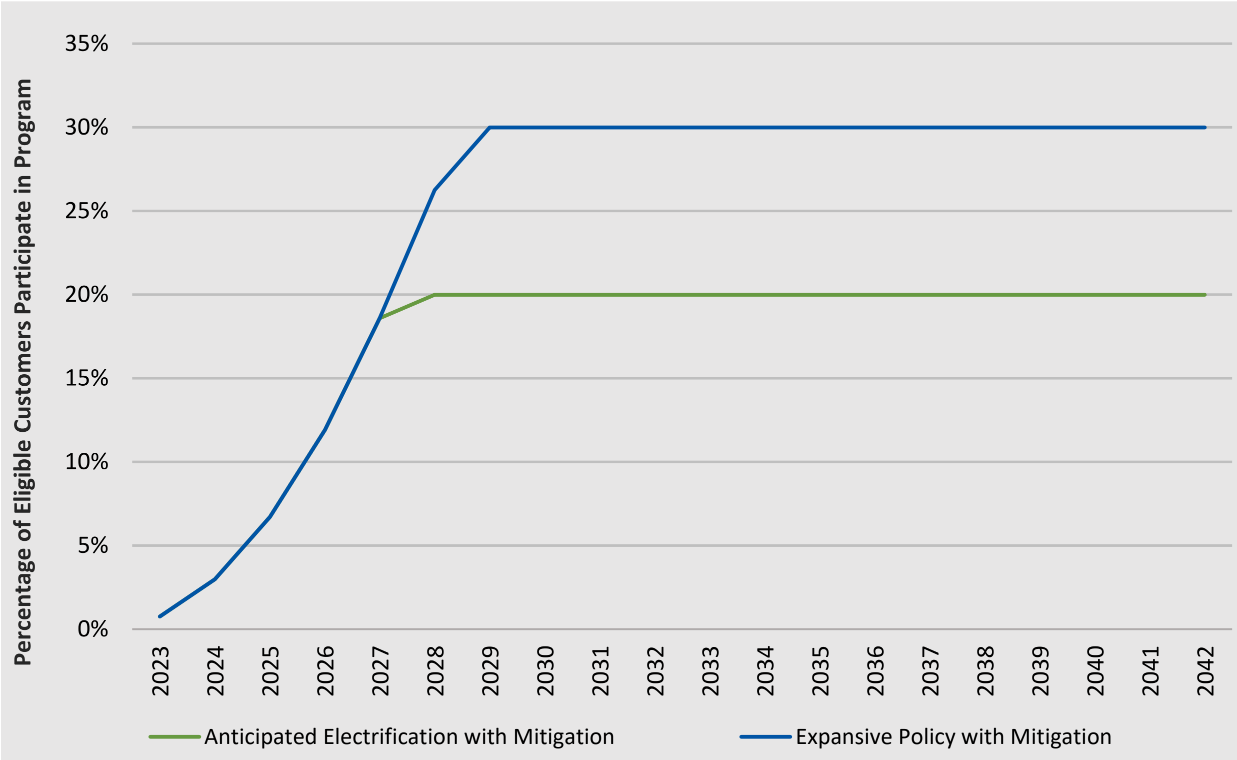
Figure 12. Managed Charger Program Participation Rates by Scenario



Smart Thermostats

Figure 13 shows the adoption rates for smart thermostat demand response. Both scenarios shown feature the same slope but plateau as they meet the maximum penetration percentage.

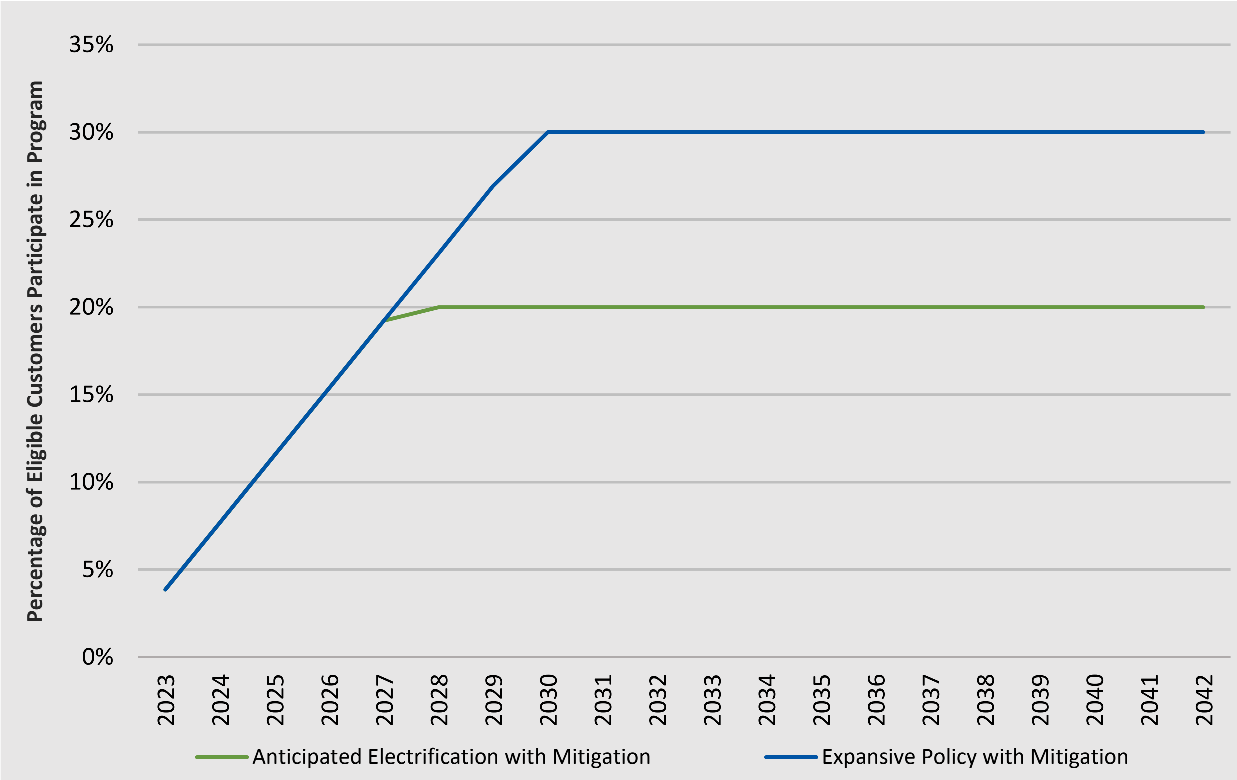
Figure 13. Smart Thermostat Program Participation Rates by Scenario



Water Heaters

The study mapped water heater growth rates directly to the Power Plan assumptions, including a ramp rate of 13 years and event participation rates of 94%. Figure 14 illustrates the adoption rates for the water heater demand response program. Both scenarios feature the same slope but plateau as the maximum penetration percentage by scenario is met.

Figure 14. Water Heater Direct Load Control Program Participation Rates by Scenario



Transportation Electrification

The study's transportation electrification impacts analysis focused on the adoption of residential and fleet EVs, their charging equipment, and the deployment of public charging stations. This section describes the transportation electrification scenarios, equipment, and model inputs, including key assumptions and the methodology for developing EV charging load shapes and adoption rates.

Transportation Electrification Scenarios

Table 20 shows the residential transportation assumptions the study used to design electrification scenarios.

Table 20. Electrification Scenarios' Residential Transportation Assumptions

Current Landscape	Achieves 85% of target for passenger vehicles (100% passenger LDV/MDV zero-emission vehicle [ZEV] sales) by 2035, increases toward 100% over subsequent years; ramps more slowly, below the 35% sales target in 2026
Anticipated Electrification	Achieves 95% of target for passenger vehicles (100% passenger LDV/MDV ZEV sales) by 2035, increases toward 100% over subsequent years, 85% for MDV; achieves 35% sales target by 2026 to ramp more rapidly than Current Landscape scenario
Expansive Policy	Achieves 95% of target for passenger vehicles (100% passenger LDV/MDV ZEV sales) by 2030, increases toward 100% over subsequent years, 90% for MDV (tracking closer to Clean Cars 2030 law); more rapid ramp than Anticipated Electrification scenario
Policy Regression	Fails to achieve 2035 passenger vehicle target, reaching 50% of annual sales by 2035
Anticipated Electrification with Mitigation	Same as Anticipated Electrification scenario
Expansive Policy with Mitigation	Same as Expansive Policy scenario

Table 21 shows the commercial transportation assumptions the study used to design electrification scenarios.

Table 21. Electrification Scenarios' Commercial Transportation Assumptions

Current Landscape	Advanced Clean Trucks Rule and cost of compliance with Heavy-Duty Engine and Vehicle Omnibus Regulation increases sales of HDV, though slow ramp and delayed replacement results in only about 30% to 35% of HDV sales and 40% to 45% of MDV sales by 2035
Anticipated Electrification	Advanced Clean Trucks Rule and cost of compliance Omnibus Regulation increases sales of HDV; combined with CCA funding and increased incentives, achieves goals of about 55% to 60% of sales by 2035
Expansive Policy	Washington State adopts California Advanced Clean Fleets Rule, banning sales of ICE MHDV by 2036 and all trucks on road ZEV by 2045 (95% compliance assumed)
Policy Regression	Limited further advancement and cost compression greatly limits sales, achieving 15% to 20% HDV and 20% to 25% MDV by 2035
Anticipated Electrification with Mitigation	Same as Anticipated Electrification scenario
Expansive Policy with Mitigation	Same as Expansive Policy scenario unless otherwise noted

Transportation Electrification Charging Equipment

The study characterized transportation electrification equipment based on a review of related literature and data. The list of equipment, shown in Table 22, includes the full range of potential electrification and alternative technologies, including battery electric options, across vehicle classes and EV charger types across sectors and use cases.

Table 22. Transportation Electrification Equipment

Equipment Sector	Equipment Type	Equipment Details
Residential	Light-Duty Battery EV (BEV)	Adopted in competition with LDV PHEVs
	Light-Duty Plug-in Hybrid EV (PHEV)	Adopted in competition with LDV BEVs
	Medium-Duty EV	Large pickup trucks and vans. Represents the smallest residential vehicle segment
	Level 1 Charger	1.5 kW nameplate rating
	Level 2 Charger	7 kW nameplate rating
Commercial	Light-Duty BEV	Adopted in competition with LDV PHEVs
	Light-Duty PHEV	Adopted in competition with LDV BEVs
	Medium-Duty EV	Small bus, type A-C school bus, rigid and delivery truck
	Heavy-Duty EV	Long-haul tractor truck, type D school bus, transit bus, and refuse truck
	Public/Workplace Level 2 Charger	7 kW nameplate rating
	Public/Workplace Level 3, DCFC Charger	150 kW nameplate rating
	Fleet Level 2 Charger	22 kW nameplate rating
	Fleet Level 3, DCFC Charger	125 kW nameplate rating

Transportation Electrification Model Inputs

This section describes the methodology for developing the two main modeling inputs for the transportation electrification analysis: vehicle charging load shapes and vehicle-charger adoption rates.

Vehicle Charger Load Shapes

The Electric Vehicle Widescale Analysis for Tomorrow's Transportation Solutions (EV Watts) EVSE and EV Telematics dashboards and databases informed load shape development for most residential and commercial EV charging cases. The base utilization data from EV Watts was specific to the Pacific region, EV charger level, and residential or commercial application (e.g., multifamily Level 2, public DCFC). The study used supplementary sources including the Northwest Power and Conservation Council, Pacific Northwest National Laboratory and California Energy Commission to develop load shapes for certain residential applications, such as Level 2 home charging, and medium- and heavy-duty vehicle types such as heavy-duty long haul and medium-duty delivery trucks. The study determined the average quantity of kilowatt-hours and EV miles these vehicles produced.[22]

Vehicle Charger Adoption Rates

The residential adoption forecast relied on a mix-mode approach that used both top-down and bottom-up modeling methods. The study first established EV sales projections for the forecast years, 2023 to

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[22] U.S. Department of Transportation, Federal Highway Administration. 2021. *Annual Vehicle Distance Traveled in Miles and Related Data by Highway Category and Vehicle Type.* https://www.fhwa.dot.gov/policyinformation/statistics/2021/pdf/vm1.pdf

Washington State Department of Transportation. 2021. "Annual Mileage and Travel Information." https://wsdot.wa.gov/about/transportation-data/travel-data/annual-mileage-and-travel-information

2042, using historical EV adoption data for Washington State and specifically the Tacoma region (i.e., Pierce County) and the study's scenario assumptions, shown in Table 20.

After defining scenario-specific EV sales forecasts, the study employed the bottom-up allocation model, distributing EVs across households according to their unique propensity score for EV ownership. The propensity scoring method, based on McFadden et. al 2019,[23] was adapted according to this study's data and locational (feeder-based) approach. The model assigned each household in Tacoma Power's residential customer database a propensity score based upon the following factors:

- **Income**: Higher income households are more likely to adopt an EV. The study estimated household income using appraised property values from Tacoma Power's residential customer database.
- **Household location (census tract):** Household locations with more historical EV adoption are more likely to adopt an EV (e.g., exposure to and/or prior ownership).
- **Occupancy:** Property owners are more likely than renters to adopt an EV.
- **Dwelling unit**: Single-family households (both attached and unattached single-family residences) are most likely to adopt an EV.

The commercial adoption forecast relied purely on a top-down approach as local and household conditions have little effect on the commercial vehicle market. The study compiled third-party, U.S. EV adoption forecasts for applicable vehicle types from a comprehensive range of established sources such as the International Energy Agency, the International Council on Clean Transportation, and NREL. Depending on the vehicle segment, the study sourced initial adoption of EVs from Washington State's DOL database or the Electric School Bus Initiative's Dataset of U.S. Electric School Bus Adoption. Vehicle types included light-duty vehicles, medium-duty vehicles (Class 3-6) and heavy-duty vehicles (Class 7-8) as described in Table 22.[24]

The study validated these forecasts by their source and methodology and then created averages for each vehicle segment included in the study. The study then weighted the averaged forecasts to closely align with the stated electrification scenarios shown in Table 21.

The study lowered retail and warehouse fleet retirement rates following enactment of the Advanced Clean Fleets Rule, assuming the lifespans of medium- and heavy-duty internal combustion trucks would be extended by operators reluctant to transition to EVs. While adoption forecasting occurred at the vehicle level, the study's location-based approach necessitated that vehicles be translated to stationary EV chargers to estimate feeder-level load impacts. The study achieved this by determining vehicle-to-port and parking space-to-port conversion rates, shown in Table 23.

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23 Electric Power Research Institute. 2019. *Identifying Likely Electric Vehicle Adopters: National Average Results*. https://www.epri.com/research/products/000000003002017550

24 World Resources Institute. 2023. "Dataset of Electric School Bus Adoption in the United States." https://datasets.wri.org/dataset/electric_school_bus_adoption

Table 23. Vehicle-to-Electric Vehicle Charger Relationships

Building Segment	Equipment	Conversion Assumption
Single Family, Manufactured Home	Level 1 Charger	1:1 Electric Vehicle to Port[1]
All Residential	Level 2 Charger	
All Commercial	Public/Workplace Level 2 Charger	4:1 Parking Spaces to Port[3, 4, 5]
All Commercial	Public/Workplace Level 3, DCFC Charger	14:1 Parking Spaces to Port[3, 4, 5]
School, Retail, Warehouse	Fleet Level 2 Charger	1:1 Electric Vehicles to Port[5, 6]
School, Retail, Warehouse	Fleet Level 3, DCFC Charger	4:1 Electric Vehicles to Port[5, 6]

[1] Residential Electric Vehicle-to-Port Assumptions sourced from Plug-in America EV Driver Surveys (2022-2023)

[2] Joint Office of Energy and Transportation. April 2023. 'Electric Vehicle Charging Solutions for Multifamily Housing, Market Scan.'

[3] US Department of Energy, Alternative Fuels Data Center. 2023. Alternative Fueling Station Locator; Database filters (Facility and EVSE Level) contingent upon building segment and equipment.

[4] Google Maps. n.d. Accessed June 2023–August 2023.

[5] Southern California Edison. June 2022. 'Standard Review Projects and AB 1083/1083 Pilots, Evaluation Year 2021.' Cadmus Group, Energetics Incorporated.

[6] US Department of Energy, Alternative Fuels Data Center. 2023. 'Electric Vehicles for Fleets.'

Industrial Electrification

This study did not use AdopDER to model electrification for the industrial sector. Instead, the study used a top-down industrial model to estimate the adoption and load impact from industrial electrification technologies in Tacoma Power's service territory. The primary model development steps included industry classification, industry fuel usage estimation, customer interviews, and equipment characterization. The methods for modeling industrial electrification were consistent across all of Tacoma's industries except the Port of Tacoma, for which the study used the electrification potential developed by the South Harbor Electrification Roadmap (SHERM). Details on how the approach differed for the Port of Tacoma are included below. This industrial customer assessment did not assume any growth in electrification from West Rock given its planned closure.

Industrial Electrification Scenarios

Table 24 shows the industrial electrification scenario design and the different market drivers and barriers to the adoption of key electric equipment. It also explains the adjustments made to the SHERM for the Port of Tacoma for each scenario. The *Industrial Electrification Model* section describes how this study translated these scenario descriptions into electrification potential.

Table 24. Industrial Electrification Scenarios

Current Landscape	• **Port of Tacoma:** NWSA (controls <20% of power usage) on track to achieve 2050 electrification targets, matched by Husky, Pierce County and Washington United Terminals electrify shore power only. Other terminals will not implement Port end-use electrification due to lack of commitments (beyond some fleet electrification in alignment with transportation assumptions) • **Market Drivers**: Gas utility response to Washington Climate Commitment Act (CCA), stable and low electric prices, corporate policies/carbon disclosure requirements, and DOE industrial electrification investments encourages industry to eliminate gas use. Hydrogen competes with electricity as fossil fuel alternative • **Market Barriers:** Conversion costs remain significant. Slow adoption of electric boilers for industries with small- to medium-scale boilers. No electrification of custom/large boilers, CHP, or boilers heated by product or onsite processes. Slow process heating electrification limited to industries with low-temp processes with significant customer willingness/interest in process heating electrification (e,g., customers who signal corporate commitments/targets) • **Electric Forklifts:** Adoption of electric forklifts, driven by operating benefits and I**RA** incentives
Anticipated Electrification	• **Port of Tacoma:** NWSA and Husky on track to achieve 2050 electrification targets. All other terminals implement shore power electrification aligned with SHERM due to expected policy targeting emissions from ship auxiliary engines. All other terminals achieve 50% of SHERM target for on-site vehicles and process equipment • **Market Drivers:** Expanded federal industrial electrification investments, federal incentives/grants, more aggressive carbon disclosure requirements, increased pressure for corporate policies. Tacoma Power actively promotes federal grants and incentives with customers • **Market Barriers**: Conversion costs remain significant. Faster adoption of electric boilers for industries with small- to medium-scale boilers. Slow but widespread process heating electrification for low- to medium-temp processes • **Electric Forklifts**: Faster adoption of electric forklifts, driven by operating benefits and Inflation Reduction Act incentives
Expansive Policy	• **Port of Tacoma:** NWSA and all terminals on track to achieve 2050 electrification targets • **Market Drivers:** Sufficient federal and Tacoma Power incentive expansion to electrify processes that would be extremely difficult/costly to electrify (although still limited by technical feasibility – not including processes where no commercially available technology exists) • **Market Barriers**: Conversion costs remain significant. Faster adoption of electric boilers for industries with small-to-medium scale boilers. Increased adoption of electric boilers in industries with larger-scale boilers near end of study period. Widespread process heating electrification for industries with low- and medium-temp processes • **Electric Forklifts**: Electrification of all forklifts for all capacities where there is commercially available technology
Policy Regression	• **Port of Tacoma:** SHERM and Husky on track to achieve only 2050 electrification targets. Other terminals will not implement Port end-use electrification due to lack of commitments (beyond some fleet electrification in alignment with transportation assumptions) • **Market Drivers:** Development of carbon market that allows for compliance via credits and does not lead to increased electrification • **Market Barriers**: Conversion costs remain significant. Slow adoption of electric boilers for industries with small-to-medium scale boilers. No electrification of custom/large boilers, CHP, or boilers heated by product or onsite processes. Slow process heating electrification limited to industries with low-temp processes with significant customer willingness/interest in process heating electrification (e.g., customers who signal corporate commitments/targets) • **Electric Forklifts**: Adoption of electric forklifts, driven by operating benefits and Inflation Reduction Act incentives

Industrial Customer Fuel Usage Estimation

The study classified Tacoma Power's industrial customers into 15 industries based on their North American Industry Classification System (NAICS) code. Because customer gas and other fuel usage data was not available, the study estimated customer fuel usage based on the 2018 Manufacturing Energy Consumption Survey (MECS) results and customer interviews. The MECS results are available at the NAICS code level and broken down by end use (Table 25). By using an industry's known annual electrical load, the study was able to develop initial estimates of fuel usage by end use for each industry.

Table 25. Manufacturing Energy Consumption Survey End Uses

Indirect Uses – Boiler Fuel	Direct Uses – Total Process	Direct Uses – Total Non-Process
Conventional Boiler Use	Process Heating	Facility HVAC (g)
CHP and/or Cogeneration Process	Process Cooling & Refrigeration	Facility Lighting
	Machine Drive	Other Facility Support
	Pumps	Onsite Transportation
	Fans & Blowers	Conventional Electricity Generation
	Compressed Air	Other Non-Process Use
	Refrigeration	
	Material Handling	
	Material Process	
	Other Motors	
	Electro-Chemical Processes	
	Other Process Use	

Industrial Customer Interviews

Leveraging the initial fuel usage estimates by industry and input from Tacoma Power's industrial account executives, the study identified the top energy-consuming industrial customers to interview from each of the ten largest industries in Tacoma. The goal of the customer interviews was two-fold: to adjust the industries' initial fuel usage estimate from MECS based on actual customer facility information and to understand customers' perceptions of, plans for, and barriers to electrification.

For nearly all segments, MECS overestimated customers' fuel usage, and they study adjusted these initial estimates based on industrial customers' information on energy usage at their facilities. Table 26 lists the customers interviewed and adjustments made to the MECS fuel-to-electric ratio. A higher fuel-to-electric ratio indicates more fuel energy used. The study used industrial customers' feedback on their goals and concerns for electrification to determine achievability factors for electrification and refine the list of relevant electrification measures for each industry.

Table 26. Manufacturing Energy Consumption Survey End Uses

Industrial Sector	MECS Fuel to Electric Ratio	Customer Fuel to Electric Ratio
Paper Manufacturing	1.1	1.9
Glass, Nonmetallic Mineral Product Manufacturing	4.6	2.9
Food Manufacturing	5.0	2.5
Miscellaneous Industrial	3.6	3.0
Cement and Concrete Product Manufacturing	4.8	3.8
Chemicals	5.6	4.5
Petroleum and Coal Products Refining	9.7	9.7
Primary Metal Manufacturing	2.0	1.0
Industrial Gases	1.3	0.08
Wood Product Manufacturing	7.3	6.5

Industrial Electrification Equipment

Each industry's estimated fuel usage was broken down by MECS end-use. Table 27 shows gas end uses mapped to the corresponding electric equipment needed to electrify the given end use. Some electrification equipment, such as heat pumps and electric forklifts, were relevant across all industries, whereas others were specific to one industry.

Table 27. Industrial Non-Electric End Uses Mapped to Electric Equipment

Sector	Non-Electric End Use	Electric Equipment
All	Facility HVAC (g)	Heat Pump
All	Conventional Boiler Use	Electric Boiler
All	Onsite Transportation	Electric Forklifts
Food Manufacturing	Facility HVAC (g)	Heat Pump
Wood Product Manufacturing, Paper Manufacturing, Food Manufacturing	Process Heating	Radio Frequency Heating
Plastics, Glass and Nonmetallic Mineral Product Manufacturing, Fabricated Metals, Chemicals, Miscellaneous Industrial	Process Heating	Electric Infrared Heaters
Primary Metal Manufacturing	Process Heating	Electric Arc Furnace
Chemicals	Process Heating	Electrochemical Process Change (from thermochemical)
Food Manufacturing	Process Heating	Microwave Heating
Primary Metal Manufacturing, Fabricated Metals	Process Heating	Electric Induction Melting
Cement and Concrete Product Manufacturing	Process Heating	Resistance Heating
Primary Metal Manufacturing	Process Heating	Plasma Melting
Primary Metal Manufacturing	Process Heating	Electrolytic Reduction
Port and Harbor Operations	Onsite Transportation	Electric Cargo Handling Equipment (CHE)
Port and Harbor Operations	Other Process Use	Shore Power
Port and Harbor Operations	Process Cooling & Refrigeration	Electric Reefers

Industrial Electrification Model

The study modeled the impact of industrial electrification on electrical load and peak demand from 2023-2042 under four different electrification scenarios. Table 28 presents key inputs in the electrification potential model with modeling steps. Note that the methods outlined are for all Tacoma industries except the Port of Tacoma. Details on how the approach differed for the Port of Tacoma are presented at the end of each modeling section.

Table 28. Key Industrial Modeling Inputs

Non-Electric End Use Efficiency	Input in the calculation to determine the electric energy required if a given non-electric end use was electrified
Electric End-Use Efficiency	Input in the calculation to determine the electric energy required if a given non-electric end use was electrified
Technical Feasibility	Percentage of end-use load that **can** be electrified based on commercially available technology. Informed by literature review, SMEs, and process temperature ranges typical for sector. Static for all scenarios but varies by electric equipment and industry
Achievability Factor	Percentage that reflects customers' willingness to adopt. Informed by interviews and literature review. Varies by scenario, electric equipment, and industry
Ramp Rate	Defines the rate of adoption of the electrification equipment from 2023 through 2042. Varies by scenario and equipment
Industrial Load Profile	Input in the demand impact calculations. Defines the typical electric energy use load profile for an industry

End-Use Electric Energy Calculations

Based on the estimated fuel usage for non-electric end-uses by industry, the study calculated the electrical energy required to electrify the given end use by considering the non-electric process efficiency and the corresponding electric equipment efficiency. The study estimated the efficiency of gas and electric end-uses based on a variety of sources, including white papers and interviews with Tacoma Power industrial customers, study team Subject Matter Experts, and Washington code requirements.

Table 29 is an example the inputs required to convert a conventional boiler to an electric boiler based on the estimated fuel usage for the conventional boiler, the conventional boiler efficiency, and the electric boiler efficiency. In this case the non-electric energy is converted to electric energy by applying first a non-electric efficiency factor, followed by the electric efficiency factor.

Table 29. Example End Use Energy Calculation

Sector	Non-Electric End Use	Electric Equipment	Non-Electric Energy (BBTU)	Non-Electric Efficiency	Energy Load (BBTU)	Electric Efficiency	Electric Energy (BBTU)
Food Manufacturing	Conventional Boiler Use	Electric Boiler	302	75%	226	99%	228

Note that the study did not perform the above end use electric energy calculations for the Port of Tacoma. For the Port of Tacoma, the study used electrification potential developed by the South Harbor Electrification Roadmap and therefore did not need to perform this intermediary calculation.

Technical Feasibility

The calculation to determine the electric energy required to electrify the various industries' non-electric end uses assumed that 100% of the gas end use could be electrified with the given electric equipment. The technical feasibility factor is introduced to correct this assumption and account for the non-electric end uses that cannot be electrified using commercially available technology.

The technical feasibility factors varied by electrification measure and industry and were based on literature reviews and customer interviews. For example, current electric forklift technology is available for loads up to 20,000 lbs. For many industries, all forklifts are under 20,000 lbs capacity and the technical feasibility of electric forklifts is therefore 100%. However, the largest customers from the Cement Manufacturing Industry, the Primary Metal Industry, and the Glass and Nonmetallic Manufacturing Industry reported that a portion of their forklifts and on-site transportation equipment are used for loads over 20,000 lbs. Therefore, the technical feasibility of electric forklifts for each of these industries was set to only model the electrification of the portion of their lighter capacity forklifts.

As noted earlier, for the Port of Tacoma, Cadmus used electrification potential developed by the South Harbor Electrification Roadmap. Therefore, the Port's end uses were not assigned technical feasibility factors.

Adoption Rates

All modeling steps through the technical feasibility were scenario-agnostic, meaning the inputs and outputs were the same for all electrification scenarios. The scenarios have different electrification potential results because the achievability factors and ramp rates introduced in the model are scenario specific as well as electrification equipment and industry specific.

The achievability factor accounts for customers' willingness to adopt and was highly informed by interviews. The ramp rates set the pace at which a given electrification measure for an industry will be adopted. The ramp rates enable estimating the electrification potential annually for the period from 2023 to 2042. The study used planning ramp rates from the 2021 Northwest Power and Conservation Council (NWPCC) Power Plan as the basis for the electrification adoption forecast for electric boilers and electric process heating equipment.

The conservative Low1Slow ramp rate was used for adoption of all electric boiler and electric process heating equipment in all scenarios, although the achievability factors changed. The conservative ramp rates for boilers and process heating equipment were used across all scenarios due to the high capital cost and manufacturing downtime impacts to changing out this type of equipment. Even under an Expansive Policy scenario, the study anticipates that boiler and process heating electrification will be challenging and have slower adoption.

A custom ramp rate accounting for IRA incentives for heat pumps and electric forklifts was used for heat pump and electric forklift adoption. This ramp rate has adoption ramping quickly until 2032 when IRA incentives expire. Figure 15 shows the NWPCC Power Plan ramp rate and the Custom IRA ramp rate.

Figure 15. Industrial Electrification Ramp Rates

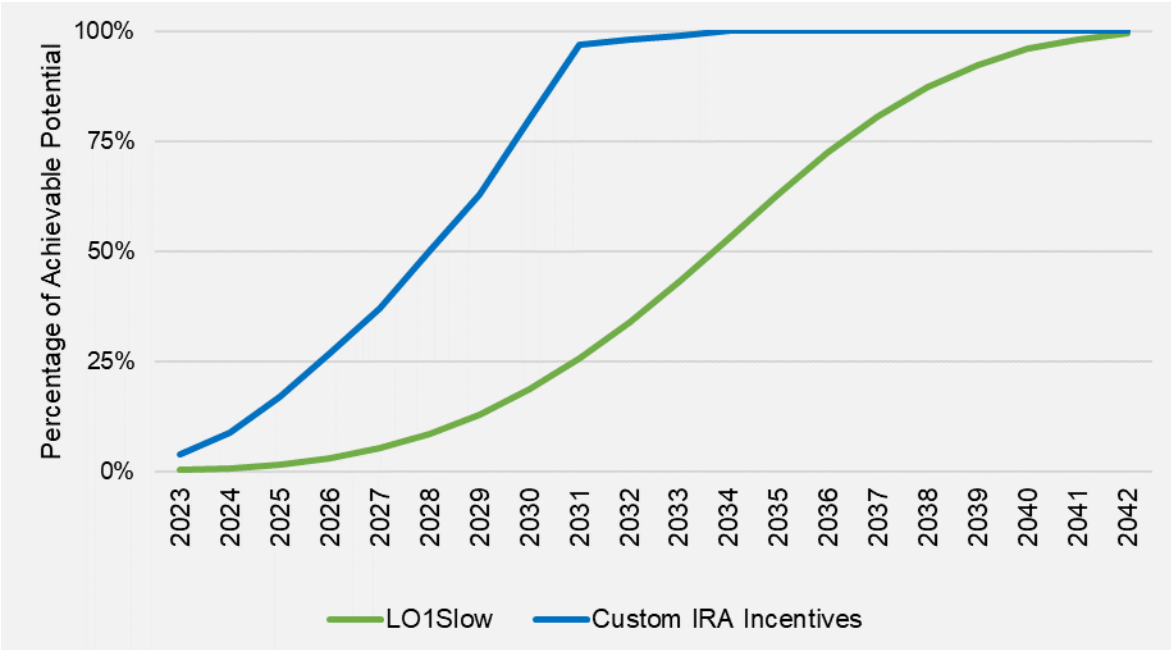


Table 30 shows the achievability factors and ramp rates applied to electric equipment for various Tacoma industries.

Table 30. Example End-Use Energy Calculation

Scenario	Non-Electric End Use	Electric Equipment	Sector	Achievability Factor	Ramp Rate
Current Landscape	Conventional Boiler Use	Electric Boiler	*All others	15%	Low1Slow
			Paper Manufacturing	0%	Low1Slow
			Petroleum and Coal Products Refining	0%	Low1Slow
	Facility HVAC	Heat Pump	All	40%	Custom5HVAC
	Onsite Transportation	Electric Forklifts	All	50%	Custom5Transit
	Process Heating	Multiple	All others	25%	Low1Slow
		Electric Arc Furnace	Primary Metal Manufacturing	60%	Low1Slow
		Radio Frequency Heating	Paper Manufacturing	0%	Low1Slow
Anticipated Electrification	Conventional Boiler Use	Electric Boiler	All others	20%	Low1Slow
			Paper Manufacturing	0%	Low1Slow
			Petroleum and Coal Products Refining	0%	Low1Slow
	Facility HVAC (g)	Heat Pump	All	65%	Custom5HVAC
	Onsite Transportation	Electric Forklifts	All	75%	Custom5Transit
	Process Heating	Multiple	All others	50%	Low1Slow

Scenario	Non-Electric End Use	Electric Equipment	Sector	Achievability Factor	Ramp Rate
		Electric Arc Furnace	Primary Metal Manufacturing	100%	Low1Slow
		Radio Frequency Heating	Paper Manufacturing	0%	Low1Slow
		Resistance Heating	Cement and Concrete Product Manufacturing	40%	Low1Slow
Expansive Policy	Conventional Boiler Use	Electric Boiler	All others	35%	Low1Slow
			Paper Manufacturing	10%	Low1Slow
			Petroleum and Coal Products Refining	10%	Low1Slow
	Facility HVAC (g)	Heat Pump	All	100%	Custom5HVAC
	Onsite Transportation	Electric Forklifts	All	100%	Custom5Transit
	Process Heating	Multiple	All others	75%	Low1Slow
		Electric Arc Furnace	Primary Metal Manufacturing	100%	Low1Slow
		Radio Frequency Heating	Paper Manufacturing	10%	Low1Slow
		Resistance Heating	Cement and Concrete Product Manufacturing	50%	Low1Slow
Policy Regression	Conventional Boiler Use	Electric Boiler	All others	5%	Low1Slow
			Paper Manufacturing	0%	Low1Slow
			Petroleum and Coal Products Refining	0%	Low1Slow
	Facility HVAC (g)	Heat Pump	All	30%	Low1Slow
	Onsite Transportation	Electric Forklifts	All	25%	Low1Slow
	Process Heating	Multiple	All	0%	Low1Slow

For the Port of Tacoma, the electrification potential in the South Harbor Electrification Roadmap was adjusted for the Current Landscape, Anticipated Electrification, and Policy Regression scenarios. The Expansive Policy scenario achieved 100% of the roadmap's electrification potential with no adjustments. The adjustments for the other scenarios differed for Port Owned and Operated and the Port's different tenants to account for their varying levels of commitment to follow the electrification roadmap based on Tacoma Power's feedback. The ramp rates in the South Harbor Electrification Roadmap were not adjusted for any scenarios. However, the roadmap showed electrification potential for only every fifth year from 2025 through 2050 so the study performed linear interpolation between roadmap years to derive values for electrification potential for all years from 2023-2042.

Demand Impact

The study estimated the demand impacts of industrial electrification by applying summer and winter peak industrial load coincidence factors to the scenarios' annual industrial electrical load forecasts. The winter and summer peak factors are based on NWPCC Load Profile Data.

Table 31 shows the summer and winter peak factors for the two load profiles used for Industrial customers. Note the winter peak factor is the same for the morning and evening peaks.

Table 31. Industrial Summer and Winter Peak Factors

Load Profile	Winter Peak Factor	Summer Peak Factor	Definition
IndShift3	0.000132835	0.000131544	24-7 operations; used for Paper Manufacturing, Food Manufacturing, Petroleum Manufacturing, and Glass & Nonmetallic Manufacturing
IndShift2	0.000143465	0.000186821	Two-shift operation; used for all other sectors

Electrification Scenario Impacts

This findings section shows the impacts on Tacoma Power's electric sales and peak energy demand from adoption of the study's building electrification, transportation electrification, rooftop solar, and industrial electrification equipment. The study also reports the impacts from customer participation in potential demand response programs, which Tacoma Power may decide to offer in the future. While this study also includes an analysis of the impacts of heat pumps installed to replace existing electric equipment (energy efficiency), only the Building Electrification section reports those impacts because Tacoma Power already accounts for energy efficiency in its load forecasts.

This study provides electrification and rooftop solar energy sales and peak demand impacts in five sections. The first section, Cross Sector Results, shows impacts across the Tacoma Service territory for building electrification, transportation electrification, rooftop solar, demand response, and industrial electrification together. Additional report sections provide further information on each of these equipment categories.

Cross Sector Peak Demand and Energy Sales Impacts

According to the adoption scenarios of this study, Tacoma Power's winter PM peak demand will experience a net increase of 21% to 41% from 2023 to 2042, when compared to its current peak. The winter AM and summer PM peak demand impacts are less pronounced because of two primary factors: First, daily usage patterns of EV charging is more energy intense in the afternoon and evening than in the morning. Second, rooftop solar offsets a significant portion of summer PM peak demand.

This study predicts significant net increases in summer PM peak demand from combined impacts of rooftop solar, building, transportation, and industrial electrification only after 2027. This is because the estimated adoption trajectories of rooftop solar and building electrification run in opposite directions: rooftop solar has low barriers to adoption, a mature market, and strong existing financial incentives with net metering. Thus, it has an initially strong adoption curve that levels over time. Building electrification has higher barriers to adoption and a slower adoption curve that ramps up over time. Estimates of summer PM peak load increase include additional energy demands from heat pump cooling loads (as well as the other equipment types included in this study), but not additional cooling loads from customer adoption of stand-alone air conditioners.

While this study included building energy efficiency equipment, it does not show the impacts of these systems on peak demand and energy sales in this report section. While the *Building Electrification Results* section discusses the significant load reduction potential energy efficiency, the figures and tables in the cross sector sections do not show energy efficiency impacts.

Cross Sector Peak Demand Impacts

Figure 16 shows the summer PM, winter AM, and winter PM peak energy impacts for the study's scenarios. Generally peak demand impacts are highest in the winter PM peak period, which are especially pronounced in 2042.

Figure 16. Additional Peak Demand from Building Electrification, Electric Vehicle Chargers, and Rooftop Solar (MW)

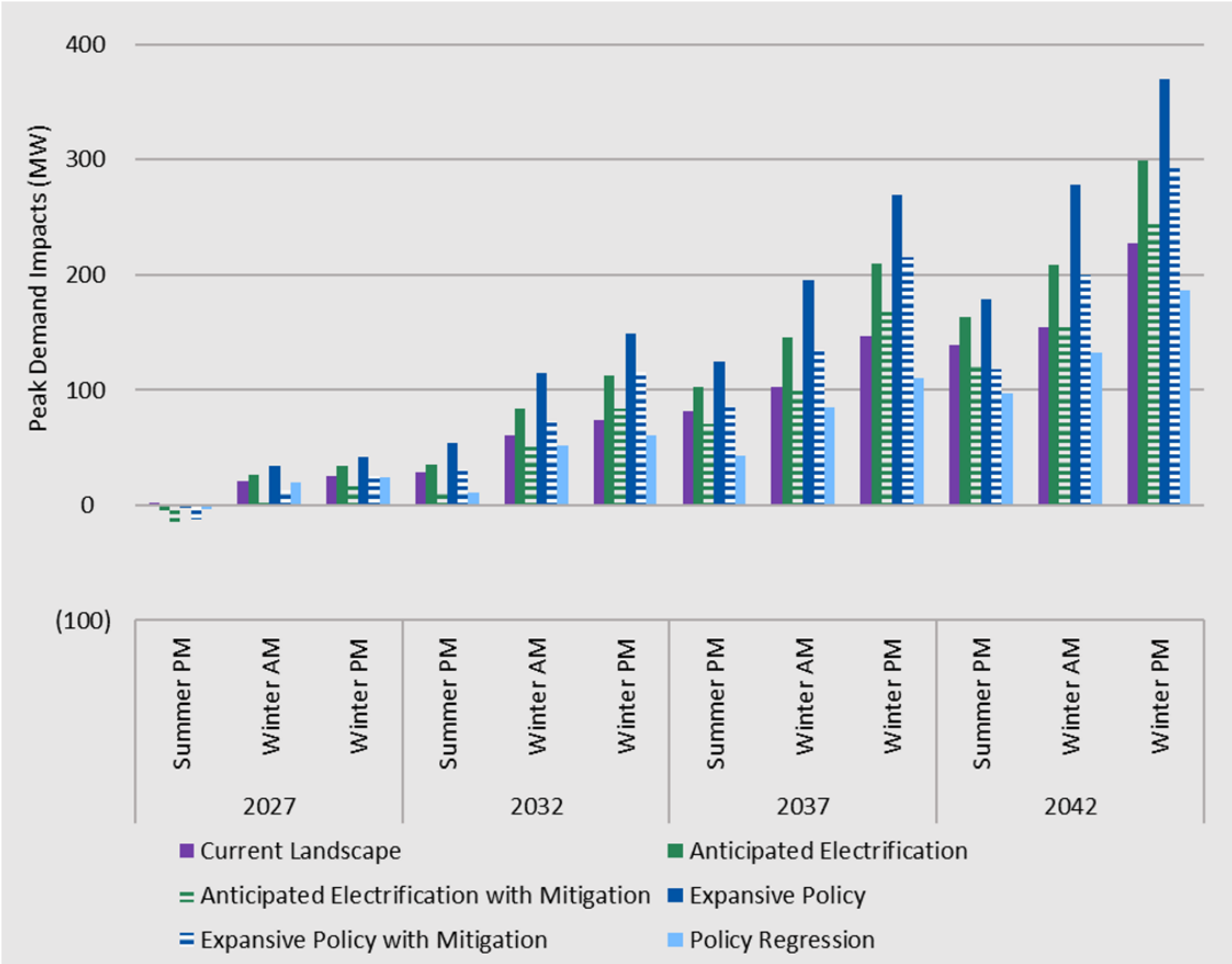


Table 32 shows the summer PM, winter AM, and winter PM peak load impacts by sector. The table also includes the impacts of demand response programs in the mitigation scenarios (these impacts are not additive to the scenario total, as they are already included in the sector level impacts). In the residential and commercial sectors peak load impacts are primarily driven by transportation electrification, whereas in the industrial sector port electrification and boiler conversions (for non-port industries) drive peak impacts.

Table 32. Additional Peak Demand from Building Electrification, EVs Chargers, and Rooftop Solar Adoption by Sector (MW)

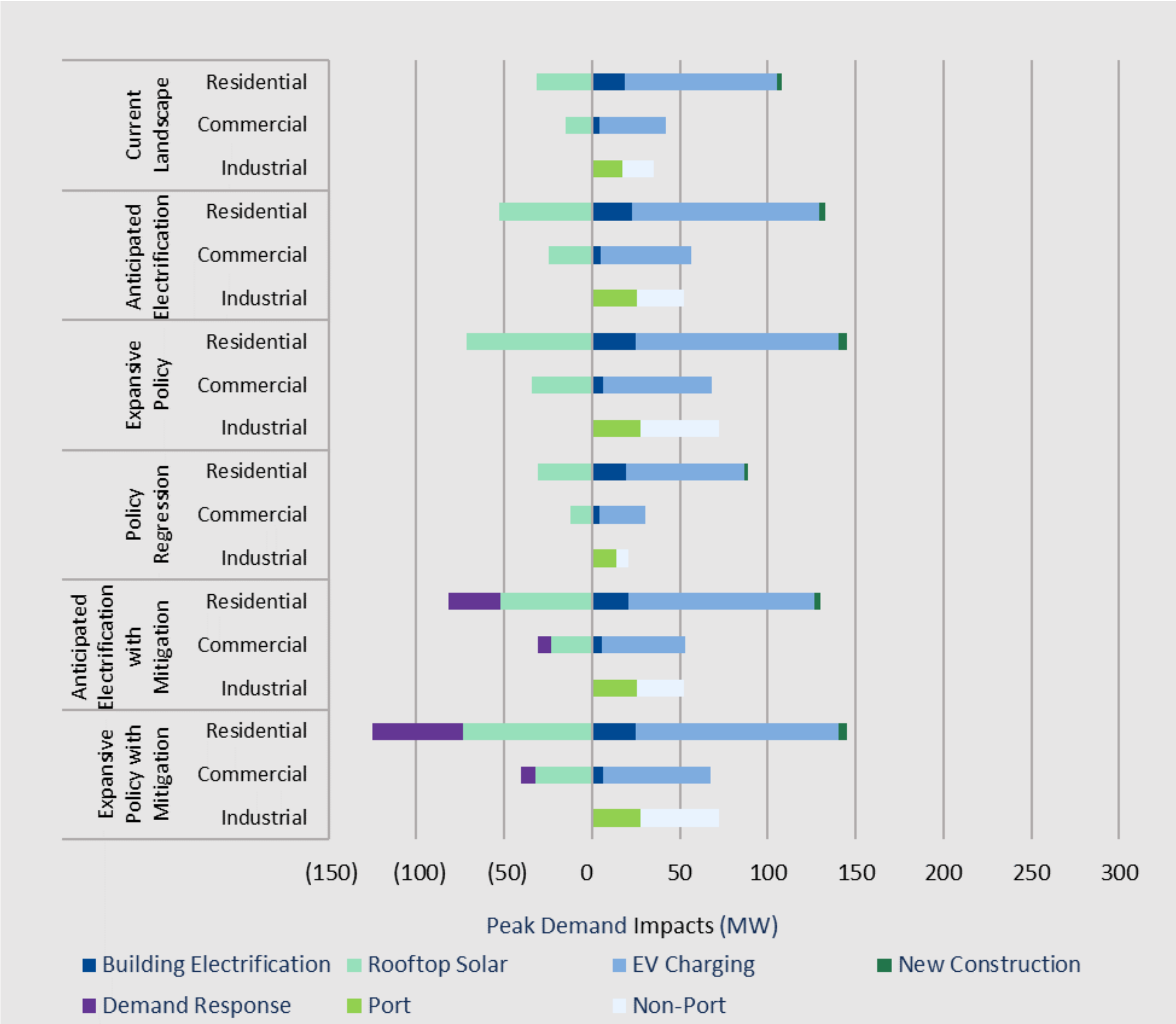
Scenario[1]	Sector	2027			2032			2037			2042		
		Summer PM	Winter AM	Winter PM	Summer PM	Winter AM	Winter PM	Summer PM	Winter AM	Winter PM	Summer PM	Winter AM	Winter PM
Current Landscape	Residential	(7)	7	14	3	23	40	35	39	86	77	66	144
	Commercial	1	6	5	6	22	18	16	40	37	27	61	55
	Industrial	8	7	7	20	16	16	30	24	24	24	28	28
Scenario Total		**2**	**20**	**26**	**29**	**61**	**73**	**81**	**103**	**146**	**127**	**154**	**227**
Anticipated Electrification	Residential	(15)	11	20	1	34	67	41	55	123	80	86	182
	Commercial	1	7	6	7	29	25	19	57	53	32	81	76
	Industrial	10	8	8	27	21	21	42	34	34	52	42	42
Scenario Total		**(4)**	**26**	**34**	**35**	**84**	**112**	**102**	**146**	**209**	**164**	**209**	**299**
Expansive Policy	Residential	(15)	15	24	7	50	88	43	75	153	73	112	216
	Commercial	1	10	8	12	37	33	23	75	69	33	109	97
	Industrial	12	10	10	35	28	28	58	47	47	72	58	58
Scenario Total		**(2)**	**34**	**42**	**54**	**115**	**149**	**125**	**196**	**269**	**179**	**279**	**370**
Policy Regression	Residential	(7)	10	16	(2)	26	38	18	40	70	58	65	126
	Commercial	(1)	6	5	2	18	14	9	32	27	18	50	43
	Industrial	5	4	4	11	8	8	17	13	13	21	16	16
Scenario Total		**(3)**	**20**	**24**	**10**	**52**	**60**	**43**	**85**	**111**	**97**	**132**	**186**
Anticipated Electrification with Mitigation	Residential	(26)	(10)	4	(16)	4	42	18	18	91	49	42	139
	Commercial	0	7	6	3	26	21	11	50	45	22	72	65
	Demand Response[a]	(11)	(21)	(16)	(19)	(31)	(25)	(27)	(38)	(34)	(36)	(45)	(44)
	Industrial	10	8	8	27	21	21	42	34	34	52	42	42
Scenario Total		**(16)**	**5**	**18**	**13**	**51**	**84**	**70**	**101**	**169**	**123**	**156**	**245**
Expansive Policy with Mitigation	Residential	(26)	(6)	8	(14)	10	57	9	20	105	20	42	146
	Commercial	0	9	8	9	34	31	19	68	63	27	101	88
	Demand Response[a]	(11)	(21)	(16)	(22)	(41)	(32)	(39)	(58)	(52)	(60)	(76)	(76)
	Industrial	12	10	10	35	28	28	58	47	47	72	58	58
Scenario Total		**(13)**	**13**	**26**	**31**	**72**	**116**	**86**	**135**	**215**	**119**	**200**	**292**

[a]The demand response figures in the mitigation scenarios are included in the sector-level results. Only the residential, commercial, and industrial figures sum to the scenario total.

As the table shows, even without demand response in most core scenarios the residential sector is not projected to have a summer PM peak demand impact until after 2027, whereas the study projects peak demand increases in winter from 2027 onwards. The industrial sector contributes significant peak demand impacts starting in 2027, which are more evenly distributed across seasons given the relatively less time-variable load of the industrial sector. The figure also shows that demand response programs can play a significant role in mitigating peak demand impacts in all seasons, although they have the most significant impact, especially in the early years of the study, in the winter season.

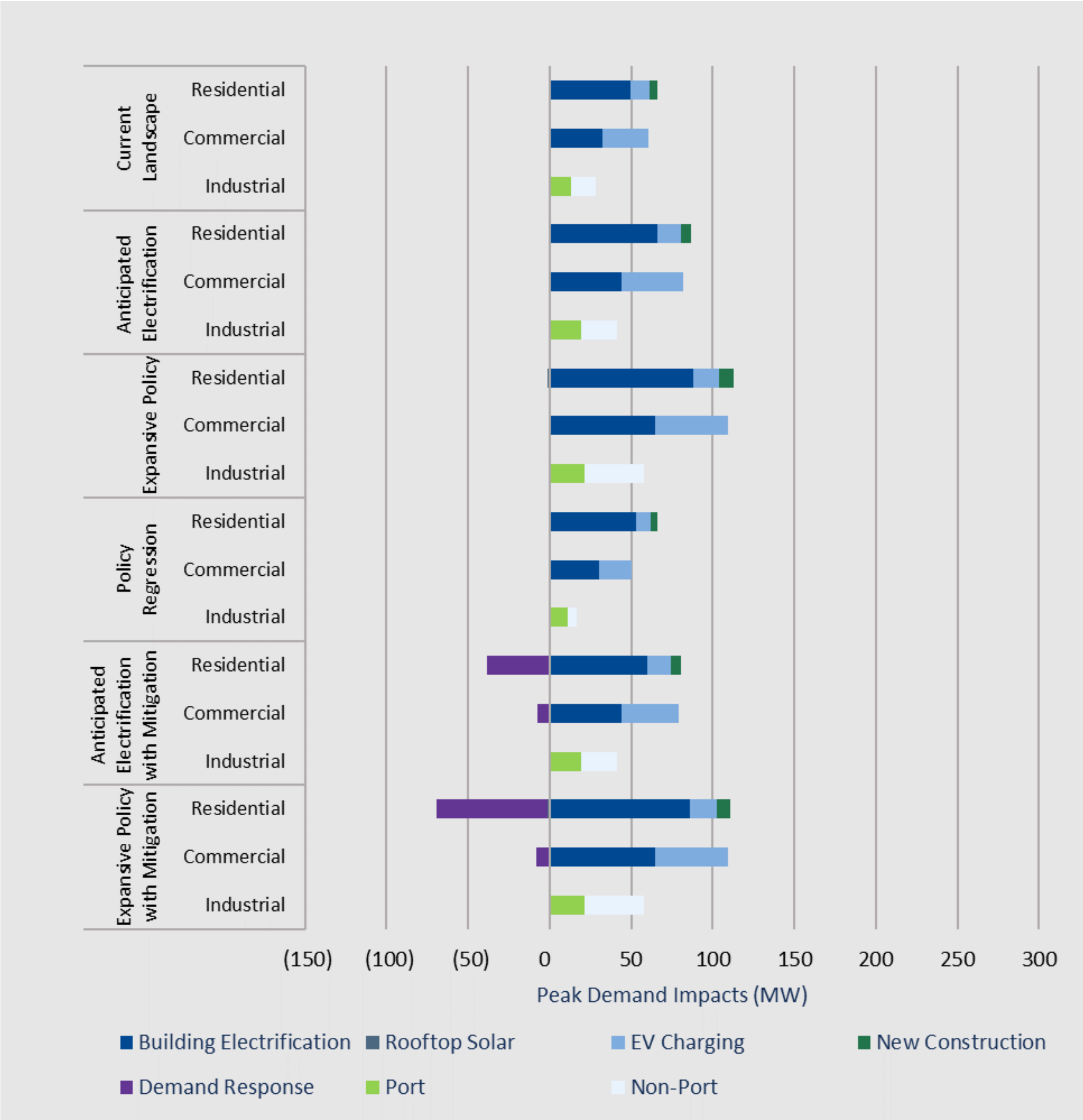
This study broke residential and commercial energy and demand impacts into four equipment categories: building electrification, rooftop solar, EV charging, and new construction. As illustrated in Figure 17, in 2042 rooftop solar mitigates summer PM peak demand while EV charging adds the most peak demand, especially in the residential sector. Building electrification and heat pumps installed in new construction add comparatively less peak demand during the summer PM peak demand period. The figure also shows the peak impacts in the industrial sector, breaking out impacts from port electrification from other industries.

Figure 17. 2042 Summer PM Peak Demand Impact by Equipment Type and Sector (MW)



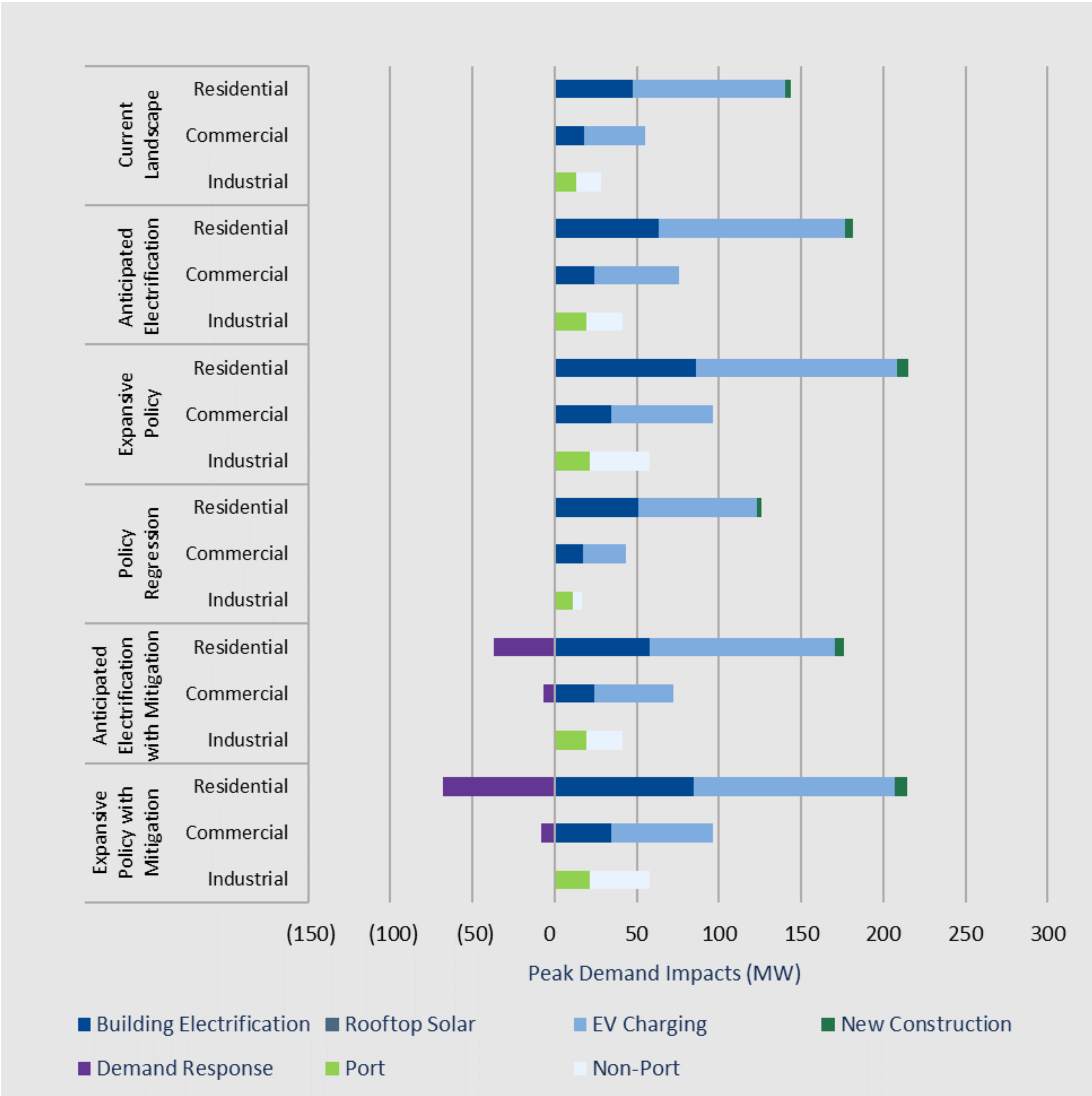
For the winter AM peak, the mitigating impacts from rooftop solar systems are absent, and only demand response programs serve to reduce peak demand. At the same time, relative to the summer PM period, the peak demand impacts from building electrification are more pronounced. Additionally, the peak contribution from EV charging is smaller compared to summer PM peak period. Figure 18 shows the winter AM peak impacts by equipment type in the residential and commercial sectors, as well as industrial peak impacts.

Figure 18. 2042 Winter AM Peak Demand Impact by Equipment Type and Sector (MW)



For the winter PM period, illustrated in Figure 19, the peak reduction contributions from demand response programs in the mitigation scenarios are like those in the winter AM peak period. However, while the peak contributions from building electrification are higher for winter AM peak periods and the peak contribution from EV charging is higher in the winter PM peak period.

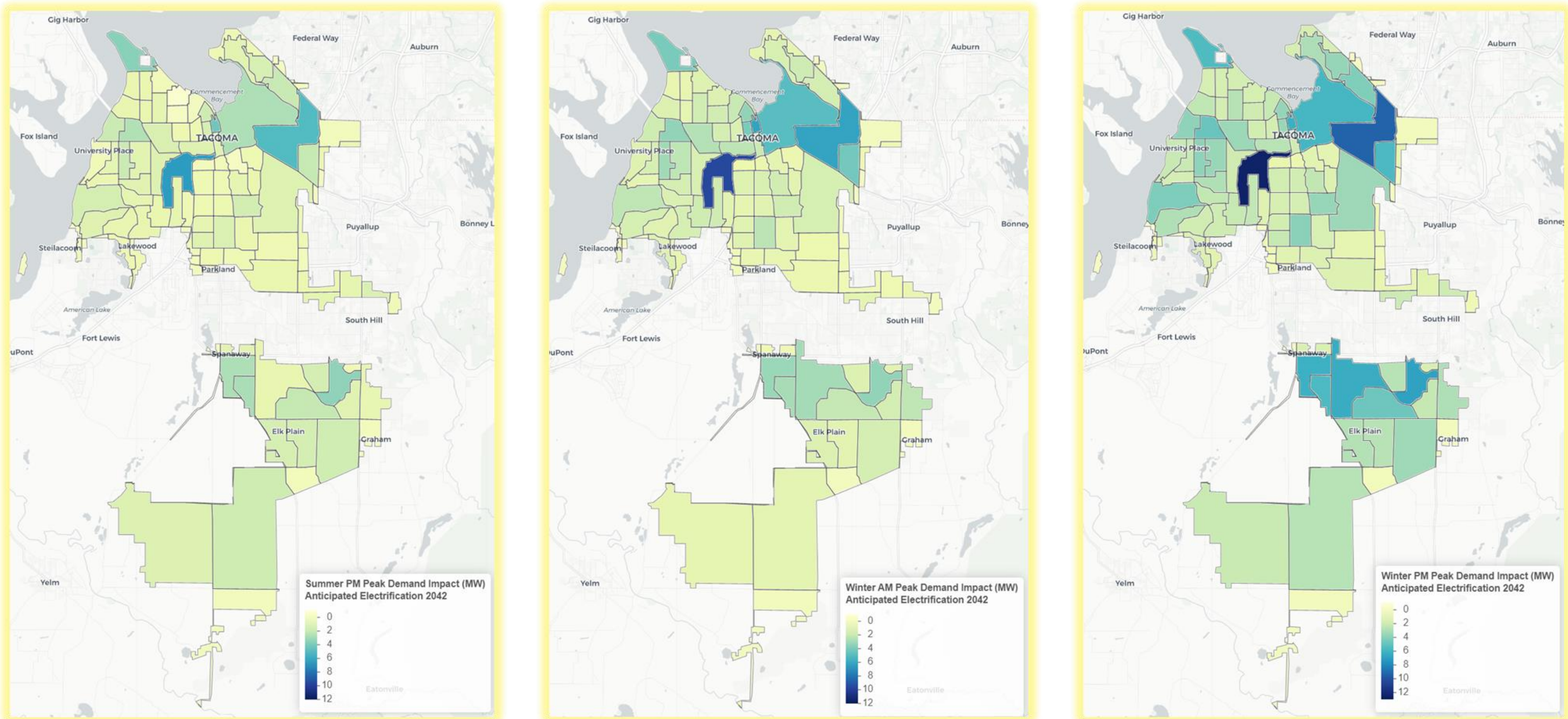
Figure 19. 2042 Winter PM Peak Demand Impact by Equipment Type and Sector (MW)



The peak impacts from building electrification are not evenly distributed across Tacoma Power service territory. The distribution and density of the building stock, as well as the space and water heating, and space cooling configurations of these buildings are the determinants of the geographic distribution of peak demand impacts. Because Tacoma Power has mapped each of the buildings that it services to a 2010 census tract, this study mapped the summer PM, winter AM, and winter PM load increases in the residential and commercial sectors; accounting for building electrification, rooftop solar, and EV charging.

As illustrated in Figure 20, the study estimates that the peak demand impacts are concentrated in the central and northeastern parts of Tacoma Power's service area. In both areas the drivers of peak increases primarily come from vehicle chargers in commercial buildings.

Figure 20. 2042 Peak Demand Impacts from Building and Transportation Electrification, and Rooftop Solar by 2010 Census Tract in Tacoma Power Service Territory (MW)



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This study also estimated the average hourly impacts of building and transportation electrification, and rooftop solar. Figure 21 and Figure 22 show this analysis for the Anticipated Electrification scenario in 2042. The figures show the average hourly load for summer and winter respectively and provide an indication of how the various equipment types contribute to peak load over the course of a typical day. For this analysis summer is defined as the months of June, July, and August, and winter as the months of December, January, and February.

Because the figures represent these impacts as hourly averages over the course of three summer and three winter months, they do not necessarily show the systems' behavior at the summer PM, winter AM, or winter PM peak. For example, Figure 16 above shows a peak demand impact of 164 MW in the Anticipated Electrification scenario in 2042. However, Figure 21 shows that in summer between 3 pm and 6 pm (hour starting 15 to hour starting 18) the maximum net demand impact is approximately 70 MW. The difference between the two estimates is due to the study peak demand impacts being calculated in terms of impacts during times of maximum load versus average impacts distributed across three months. Nonetheless, Figure 21 and Figure 22 show the time variant impacts of the equipment types over the course of an average summer and winter day in 2042 in the Anticipated Electrification scenario.

Figure 21. Average Summer Hourly Demand from Building and Transportation Electrification and Rooftop Solar in 2042 in the Anticipated Electrification Scenario (MW)

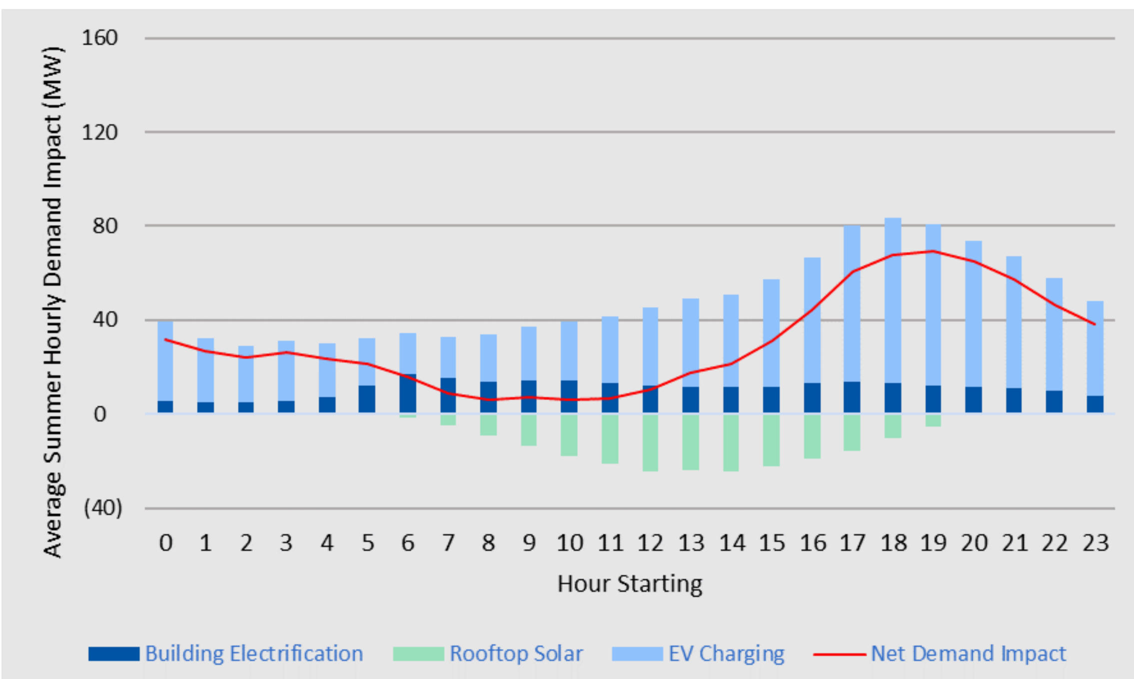
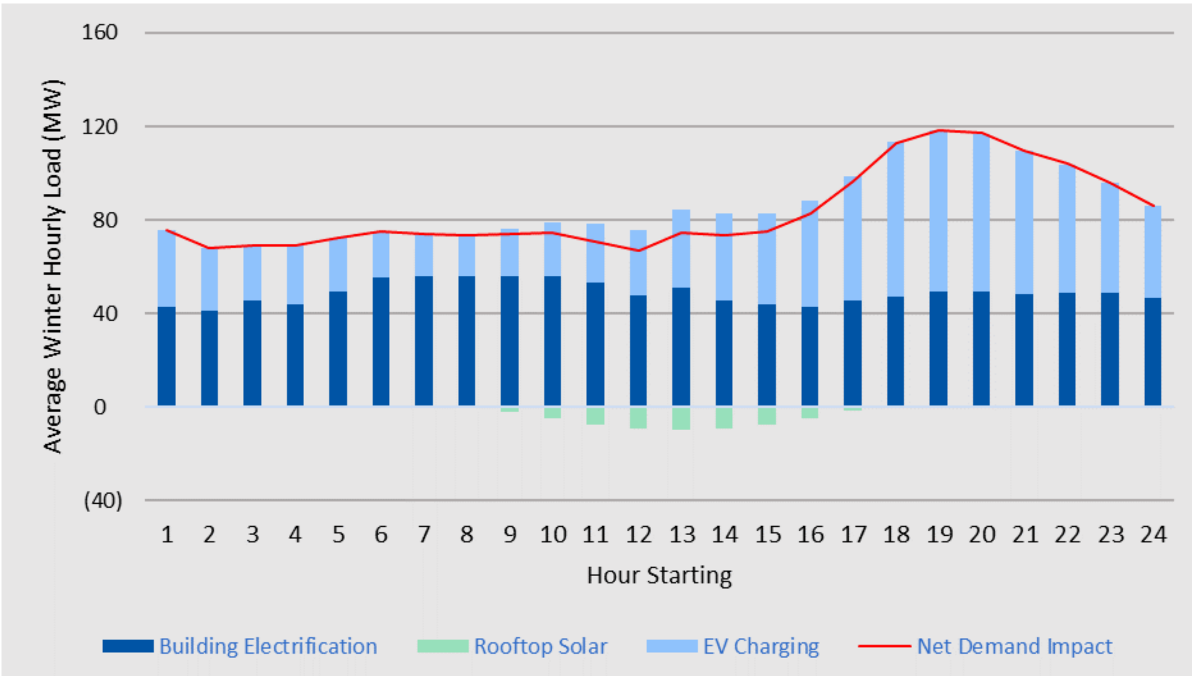


Figure 22 shows the average hourly demand impacts in winter in 2042 in the Anticipated Electrification scenario. Compared with the figure showing the average hourly demand in summer, this figure demonstrates significantly less rooftop solar production during peak periods in the morning and afternoon, significantly higher building electrification impacts, and relatively consistent transportation electrification impacts.

Figure 22. Average Winter Hourly Demand from Building and Transportation Electrification and Rooftop Solar in 2042 in the Anticipated Electrification Scenario (MW)



Cross Sector Energy Sales Impacts

This study also estimated the impacts of rooftop solar, and building, transportation, and industrial electrification on Tacoma Power electric sales. As illustrated in Figure 23, and similar to peak energy demand impacts, the cross sector estimates of this report section do not include the effects of customers installing energy efficient equipment. This study estimates that Tacoma Power's electric sales will increase between 16% and 33% compared to 2023 sales due to building, transportation and industrial electrification, and accounting for reduced sales from rooftop solar installations. The figure does not show the mitigation scenarios, since these scenarios primarily impact peak demand. Gas sales in Tacoma Power service territory in 2022 were approximately 11,000 billion British thermal units (BBtu). The 2042 electric sales impact in the expansive policy scenario is approximately 5,000 BBtu.

Figure 23. Additional Electric Sales from Building Electrification, Electric Vehicle Chargers, and Rooftop Solar Adoption (MWh)

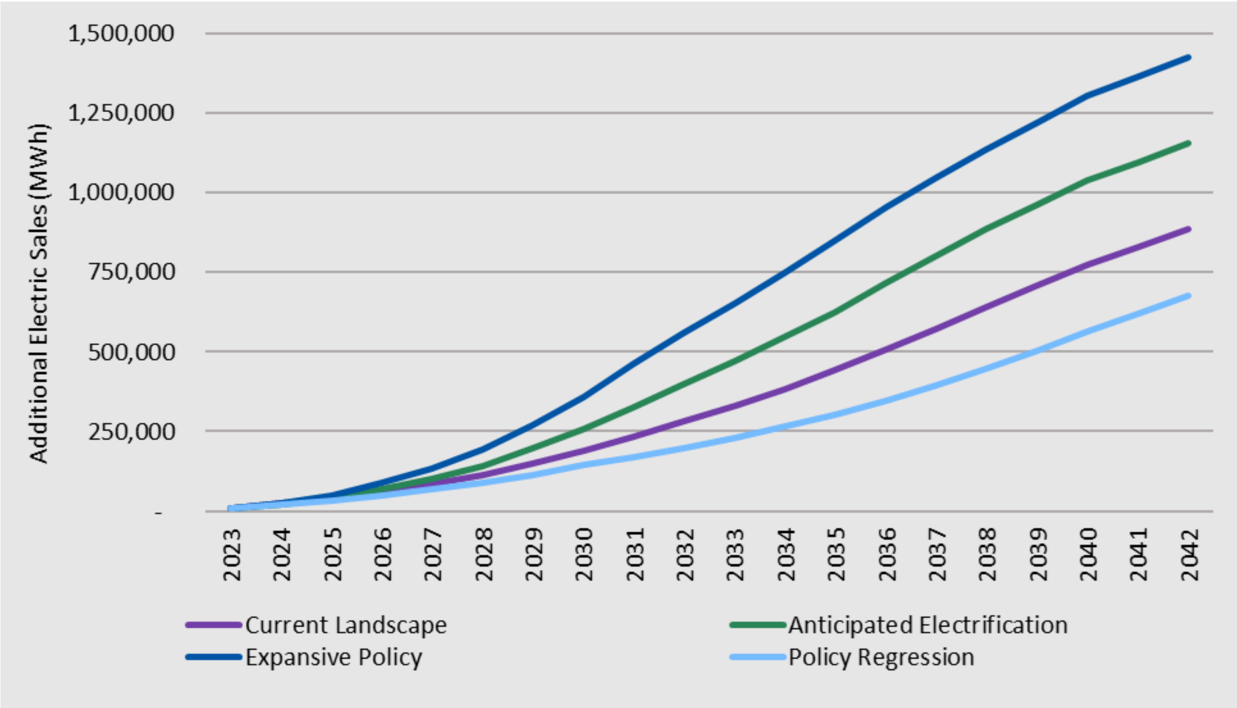


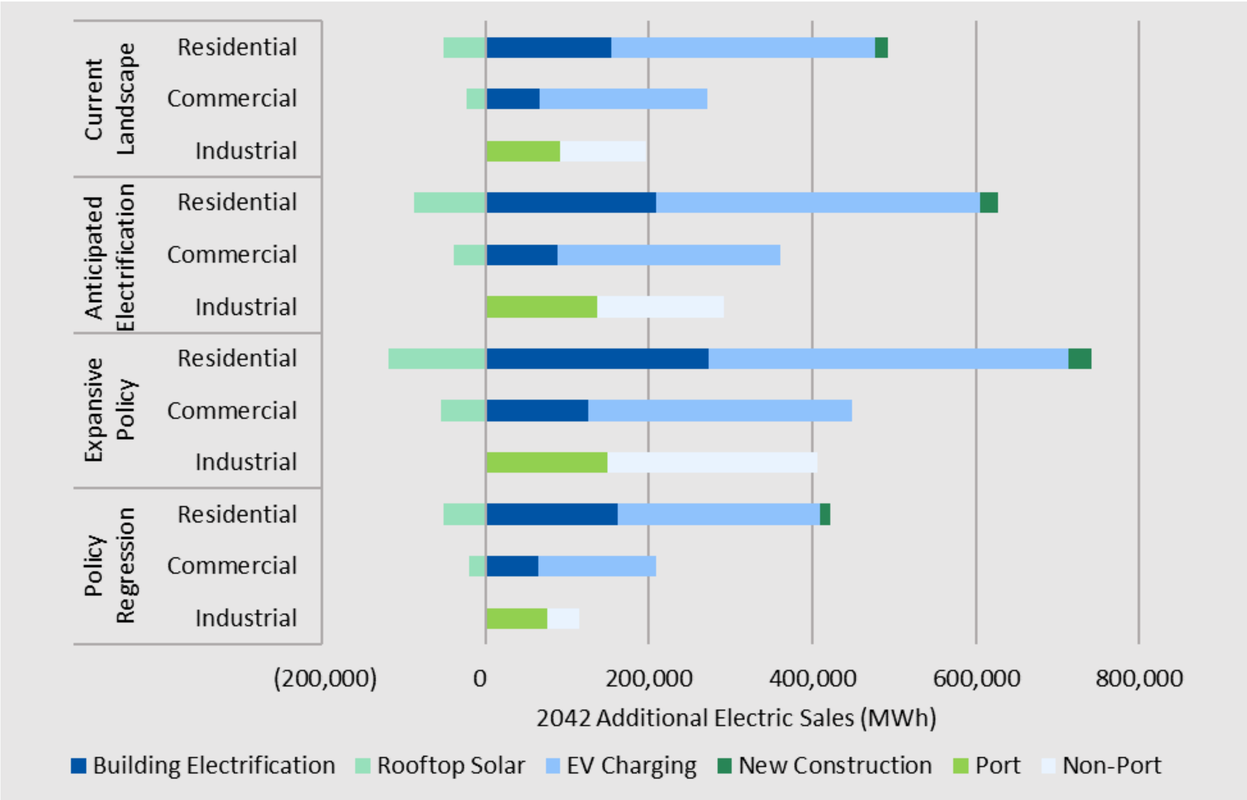
Table 33 shows the study's estimated sector additional sales from building, transportation, and industrial electrification, accounting for the lost electric sales from rooftop solar systems. The table shows that all sectors contribute significantly to additional electric energy demand, with the industrial sector making a proportionally large contribution in the study's early years, particularly in the Port of Tacoma. By 2042, however, the residential sector makes to strongest contribution to additional electric sales under every scenario. In the residential sector the largest impacts on additional load are from vehicle electrification. For example, in 2024 in the anticipated electrification scenario, EV chargers installed in single and multifamily homes account for almost 400 MWh of additional electric sales, while residential building electrification makes up only approximately 200 MWh of additional electric sales.

Table 33. Additional Electric Sales from Building Electrification, Electric Vehicle Chargers, and Rooftop Solar Adoption by Scenario and Sector (MWh)

Scenario	Sector	2027	2032	2037	2042
Current Landscape	Residential	18,100	92,800	248,900	440,600
	Commercial	21,000	75,500	157,800	248,600
	Industrial Port	31,500	57,300	74,600	91,300
	Industrial Non-Port	15,000	54,800	91,134	105,677
Scenario Total		**85,700**	**280,300**	**572,300**	**886,200**
Anticipated Electrification	Residential	19,500	148,500	346,800	540,000
	Commercial	26,300	102,700	217,800	322,200
	Industrial Port	33,300	66,000	102,000	137,100
	Industrial Non-Port	22,800	82,000	134,300	155,200
Scenario Total		**101,900**	**399,100**	**801,000**	**1,154,500**
Expansive Policy	Residential	31,100	218,300	434,300	623,000
	Commercial	32,100	142,200	281,900	395,100
	Industrial Port	34,700	69,700	109,600	149,200
	Industrial Non-Port	34,400	129,200	220,800	257,500
Scenario Total		**132,300**	**559,300**	**1,046,600**	**1,424,800**
Policy Regression	Residential	24,700	84,800	189,600	370,800
	Commercial	16,900	55,900	113,000	189,600
	Industrial Port	23,900	44,800	59,900	75,400
	Industrial Non-Port	2,100	13,300	31,700	39,100
Scenario Total		**67,600**	**198,900**	**394,200**	**675,000**

Figure 24 shows additional electric sales from building and transportation electrification, as well as sales reductions from rooftop solar projects in the residential and commercial sectors. The figure shows that in 2042 EV charging is biggest driver of additional electric sales in both sectors, with a greater impact in residential buildings. Heat pumps installed in new construction, have a minimal impact on electric sales.

Figure 24. Additional 2042 Electric Sales from Building Electrification, Electric Vehicle Chargers, and Rooftop Solar Adoption (MWh)

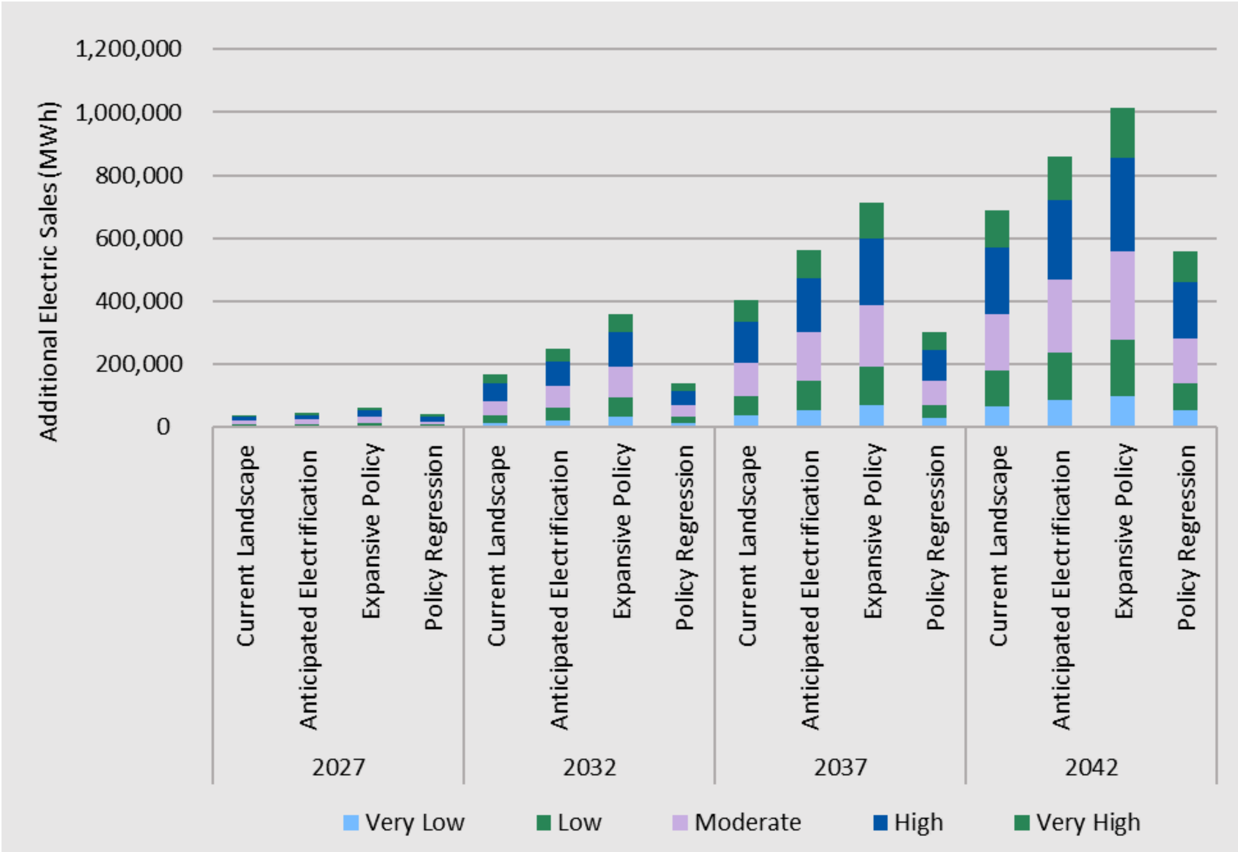


The City of Tacoma has developed an equity index to guide city policy.[25] The equity index includes the following indicators: very high, high, moderate, low, and very low. The equity index is geographically defined, and because Tacoma Power has mapped each of its customers to an equity index, this study estimated additional electric sales from building and transportation electrification, and accounting for rooftop solar system impacts on sales, for each equity indicator.

As illustrated in Figure 25, this study found that most of the electric energy impacts are concentrated in areas with moderate and high equity indicators, roughly proportional to the number of residential premises in those equity zones in 2022. The increased electric sales shown in the figure do not represent impacts on customer net energy costs, as this study's scope did not include calculating the avoided fossil fuel costs from electrification. This study did not have the data necessary to map industrial energy impacts to equity indicators. Because the CPA database did not map all premises to an equity index, the totals below do not exactly match the totals elsewhere in this report.

25 City of Tacoma. Accessed November 2023. "Realizing Equity in Tacoma." https://www.cityoftacoma.org/cms/One.aspx?portalId=169&pageId=175030

Figure 25. Additional Electric Sales from Residential and Commercial Building Electrification, Electric Vehicles Chargers, and Rooftop Solar Adoption by Equity Indicator (MWh)



This study also estimated electric sales impacts by building type for the residential and commercial sectors. Figure 26 shows the energy sales impacts for single family, multifamily, and manufactured homes buildings. As illustrated in the figure, the energy sales impacts are primarily focused on single family homes, despite this study not considering rooftop solar for multifamily buildings and manufactured homes. This study estimates that manufactured homes have relatively little electrification impacts, given their relatively small number in Tacoma Power service area. According to the Tacoma Power CPA customer database its service territory includes over 117,000 single family homes, over 43,000 multifamily premises, and only 6,450 manufactured homes. In multifamily buildings increased electric sales come primarily from installing EV chargers: approximately 80% of 2042 total additional electric sales in the anticipated electrification scenario.

While vehicle transportation also accounts for most of the increased electric sales in single family buildings, the share of the additional sales from EV chargers is lower compared to multifamily buildings. In single family buildings approximately 65% of 2042 total additional electric sales in the anticipated electrification scenario come from EV chargers, with almost all the remaining additional load coming from building electrification.

Figure 26. Additional Residential Electric Sales from Building Electrification, Electric Vehicles Chargers, and Rooftop Solar Adoption by Building Type (MWh)

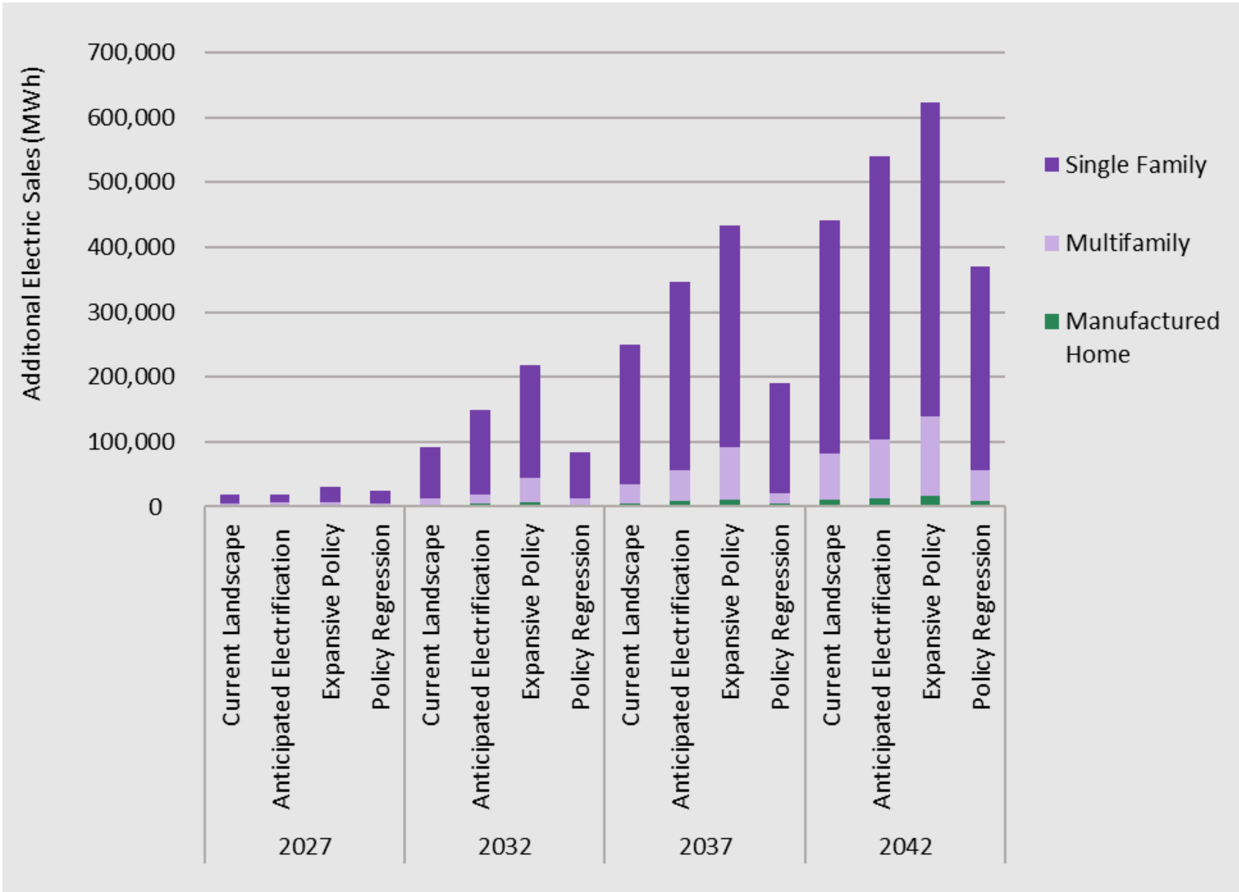
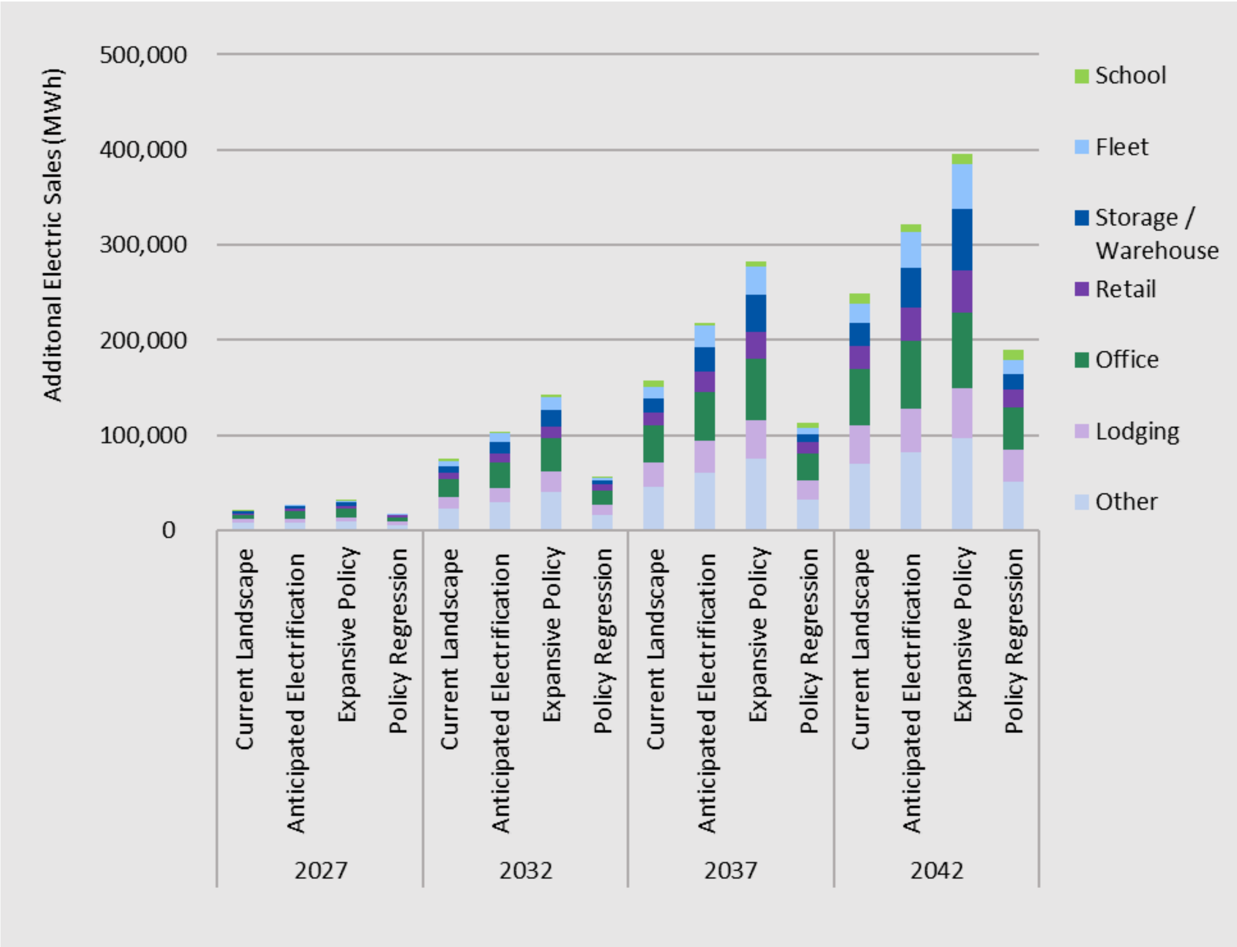


Figure 27 shows the shows the energy sales impacts for each of the commercial sectors' building types. As illustrated in the figure, other buildings, offices, and storage spaces and warehouses contributed the most to additional electric sales. Other buildings include 36 business types, including buildings such as parking lots and garages, radio stations, historical sites, religious organizations, sports centers, and others. As in the residential sector, electrification impacts are primarily driven by adoption of EV chargers.

Figure 27. Additional Commercial Electric Sales from Building Electrification, Electric Vehicle Chargers, and Rooftop Solar Adoption by Building Type (MWh)



Building Electrification Results

This section describes the peak demand and energy sales impacts from building electrification, which includes a comparative analysis of building energy efficiency. Building energy efficiency impacts are not reported in the cross-sector results. As with the cross-sector section, this section presents the peak demand impacts and energy sales impacts separately. This section also shows the number of equipment units that the study estimated would be adopted by Tacoma Power customers over the study period according to the relevant scenarios.

The following factors contribute to the additional load from building electrification measures:

The total area affected by equipment. The study calculated affected area using the Tacoma Power CPA database, which has unique data for each premise.

Existing space or water heating fuel type. If existing equipment uses fossil fuel, upgrading to electric equipment reduces the fossil fuel load and increases the electric load (this study does not calculate or factor in the decrease in fossil fuel load). If existing equipment uses electricity, an upgrade results in reduced electric load only (energy efficiency).

Existing buildings space cooling. For buildings with air conditioning, equipment upgrades reduce the cooling load; if buildings don't have space cooling the upgrades add to the building's space heating load.

Energy intensity of the equipment and building stock. Energy consumption estimates for equipment vary by building and equipment type. This study created a unique load profile for each equipment type depending on where it was installed.

All four factors together drive the study peak energy demand and electric sales impacts. For example, a single-family home that is heated with fossil fuel and does not have air conditioning will see an electric load increase in the summer and winter if a heat pump is installed. A single-family home that is heated with electricity and does not have air conditioning will see an electric load increase in the summer and an electric load decrease in the winter if a heat pump is installed. Finally, a home that is heated with electricity and has air conditioning will see a summer and winter load reduction if a heat pump is installed. According to the Tacoma Power CPA database, the residential housing stock comprises of a wide variety of heating and cooling system combinations.

The energy consumption of the installed heat pumps compared with energy consumption of existing equipment determines the magnitude of the impact. For example, a heat pump water heater adds approximately 1,100 kWh of load per year per single-family home when it replaces a fossil fuel water heater. However, it saves approximately 1,900 KWh per year per home when replacing an existing inefficient electric water heater.

For the commercial sector, the study assumed that all existing buildings had space cooling. Table 34 lists the overall building stock assumptions.

Table 34. Distribution of Space Heating Fuel and Space Conditioning in Residential and Commercial Buildings

Sector	Percentage of Building Area with Electric Heat	Percentage of Building Area with Air Conditioning
Single-family	61%	39%
Multifamily	80%	14%
Manufactured Homes	61%	40%
Commercial	44%	100%

Building Electrification Peak Demand Impacts

The peak load additions from residential and commercial building electrification equipment are primarily concentrated in the winter peak periods, especially in the residential sector. In 2042 the residential sector does see some summer PM peak demand impacts, but these impacts are relatively small compared with winter AM and winter PM load additions. In the residential sector especially, the impacts of energy efficiency are significantly greater in winter than the impacts of electrification.

Figure 28 shows the peak load impacts from electrification and energy efficiency from the study's equipment types. The negative and patterned bars show the impacts from energy efficient equipment, such as heat pumps installed in homes with existing electric heat.

Figure 28. Additional Peak Demand Impacts from Building Electrification and Energy Efficiency Equipment in 2032 and 2042 by Sector (MW)

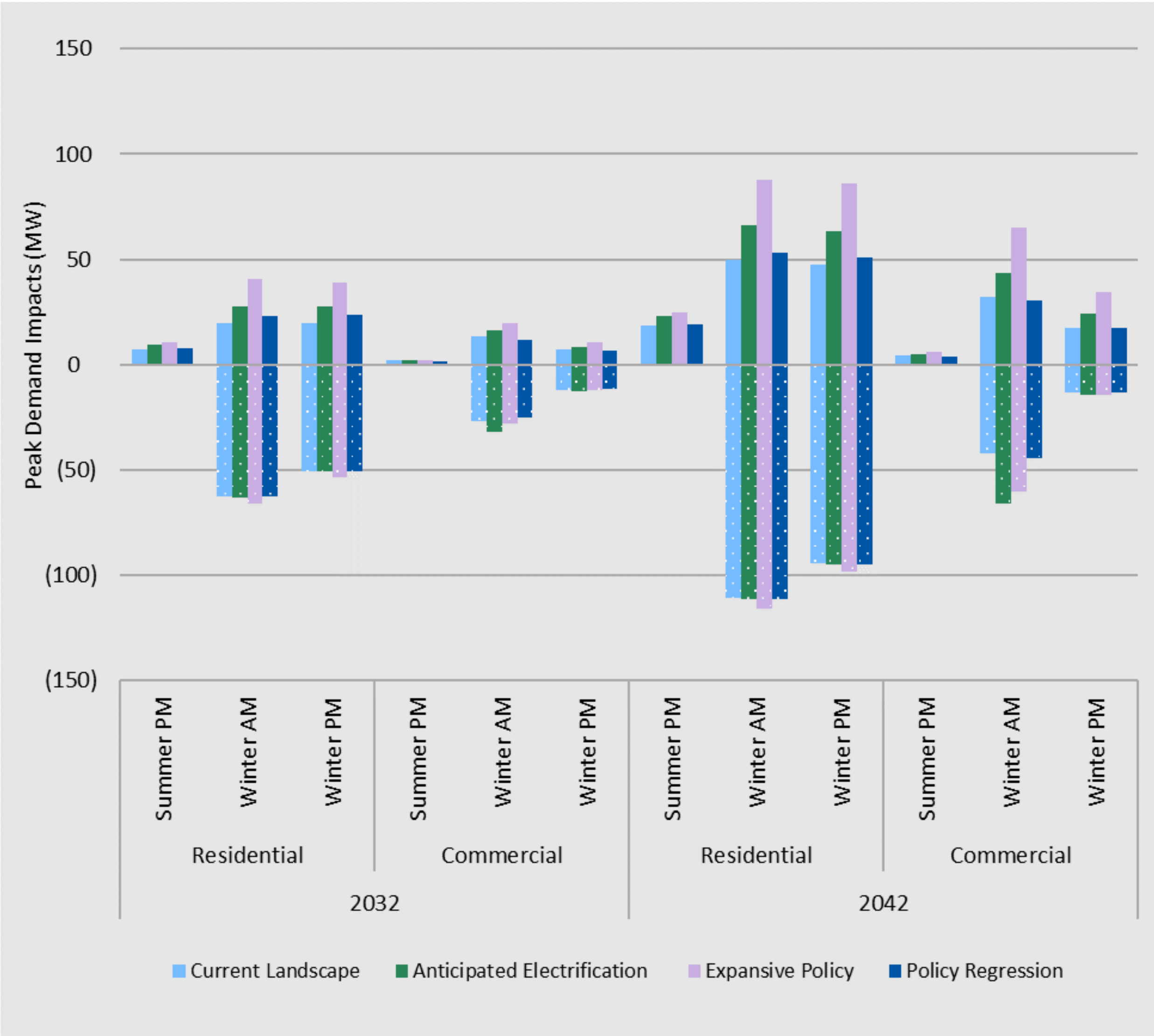


Table 35 shows the peak load impacts in 2042 by equipment type. As shown in the table, space and water heating heat pumps are the primary contributors to increased peak energy demand, although the energy efficiency potential of that equipment is greater than the increased load impact.

Table 35. Additional Peak Demand Impacts from Building Electrification and Energy Efficiency Equipment in 2042 by Sector and Equipment Type (MW)

Scenario	Equipment Type	Building Electrification						Building Energy Efficiency					
		Residential			Commercial			Residential			Commercial		
		Summer PM	Winter AM	Winter PM	Summer PM	Winter AM	Winter PM	Summer PM	Winter AM	Winter PM	Summer PM	Winter AM	Winter PM
Current Landscape	Heat Pump	5	26	27	1	24	11	16	(89)	(73)	(0)	(42)	(13)
	Water Heater	4	6	5	2	2	2	(14)	(20)	(20)	0	0	0
	Electric Furnace / Baseboard		8	6									
	Electric Dryer	8	8	8									
	Electric Cooking	2	1	1	1	1	1						
	VRF		0	0	0	5	4		(2)	(2)	0	0	0
Scenario Total		**18**	**50**	**48**	**4**	**32**	**18**	**2**	**(111)**	**(94)**	**(0)**	**(42)**	**(13)**
Anticipated Electrification	Heat Pump	7	39	39	2	33	16	16	(90)	(73)	(0)	(66)	(15)
	Water Heater	5	10	8	2	2	2	(14)	(20)	(20)	0	0	0
	Electric Furnace / Baseboard		8	7									
	Electric Dryer	8	8	8									
	Electric Cooking	2	1	2	1	1	1						
	VRF		0	0	0	7	5		(2)	(2)	0	0	0
Scenario Total		**23**	**66**	**64**	**5**	**44**	**24**	**2**	**(111)**	**(95)**	**(0)**	**(66)**	**(15)**
Expansive Policy	Heat Pump	10	61	62	2	50	23	16	(94)	(77)	(0)	(60)	(14)
	Water Heater	4	8	7	2	3	3	(14)	(20)	(20)	0	0	0
	Electric Furnace / Baseboard		9	7									
	Electric Dryer	9	8	8									
	Electric Cooking	2	1	2	1	1	1						
	VRF		0	0	0	11	7		(2)	(2)	0	0	0
Scenario Total		**25**	**88**	**86**	**6**	**65**	**35**	**3**	**(116)**	**(98)**	**(0)**	**(60)**	**(14)**
Policy Regression	Heat Pump	6	30	30	1	22	11	16	(90)	(73)	(0)	(44)	(13)
	Water Heater	4	7	6	2	2	2	(14)	(20)	(20)	0	0	0
	Electric Furnace / Baseboard		8	6									
	Electric Dryer	8	8	8									
	Electric Cooking	2	1	1	1	1	1						
	VRF		0	0	0	5	3		(2)	(2)			
Scenario Total		**19**	**53**	**51**	**4**	**30**	**17**	**2**	**(111)**	**(95)**	**(0)**	**(44)**	**(13)**

Note: Shaded cells indicate that the peak demand impact is not applicable to the equipment type.

Building Electrification Energy Sales Impacts

As with peak energy demand impacts, annual electric sales increase each year, but the potential from building energy efficiency is greater than the electrification impacts for both sectors, for each scenario, and in every year. Table 36 shows sales impacts from building electrification and energy efficiency for each scenario in 2027, 2032, 2037, and 2042.

Table 36. Additional Energy Sales from Building Electrification and Energy Efficiency Equipment in 2027, 2032, 2037 and 2042 by Sector (MWh)

Year	Scenario	Residential		Commercial	
		Building Electrification	Building Energy Efficiency	Building Electrification	Building Energy Efficiency
2027	Current Landscape	20,700	(84,200)	8,300	(38,100)
	Anticipated Electrification	29,200	(84,000)	9,400	(41,400)
	Expansive Policy	38,600	(86,200)	12,900	(38,700)
	Policy Regression	29,500	(83,400)	8,200	(37,400)
2032	Current Landscape	64,400	(178,300)	26,000	(45,000)
	Anticipated Electrification	90,700	(179,200)	31,200	(51,200)
	Expansive Policy	124,400	(186,600)	37,700	(46,500)
	Policy Regression	75,300	(178,700)	23,300	(42,400)
2037	Current Landscape	110,400	(265,600)	45,200	(50,400)
	Anticipated Electrification	154,100	(267,000)	60,600	(66,600)
	Expansive Policy	203,100	(274,000)	77,600	(63,200)
	Policy Regression	120,900	(266,100)	40,500	(50,800)
2042	Current Landscape	153,400	(330,500)	66,500	(57,800)
	Anticipated Electrification	208,900	(332,600)	87,700	(80,900)
	Expansive Policy	272,600	(343,100)	126,500	(75,800)
	Policy Regression	162,700	(332,200)	64,200	(60,600)

Figure 29 further illustrates the impacts from building electrification and energy efficiency equipment in the residential sector. As illustrated in Figure 29, space heat pumps are the primary contributor to increased electric sales, while at the same time providing a significant opportunity for load reduction when installed with existing heating equipment. While efficient water heaters provide some additional energy load when replacing fossil fuel water heaters, they have a significantly higher load reduction opportunity because they typically replace inefficient electric water heaters. Electric dryers, and electric cooking equipment only make minor additions to electric load.

Figure 29. Residential Electric Sales Impacts from Building Electrification and Energy Efficiency Equipment by Equipment Type (MWh)

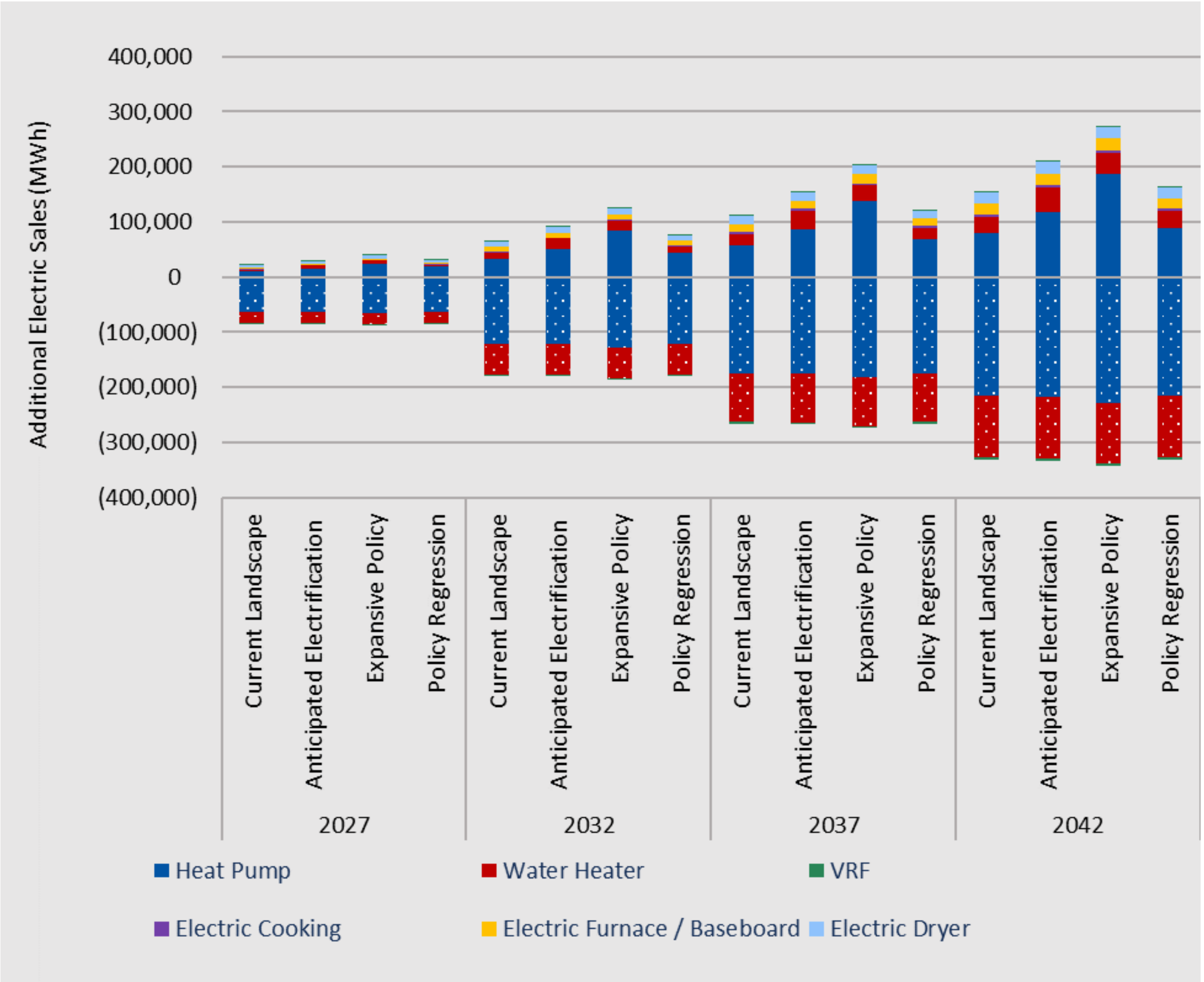
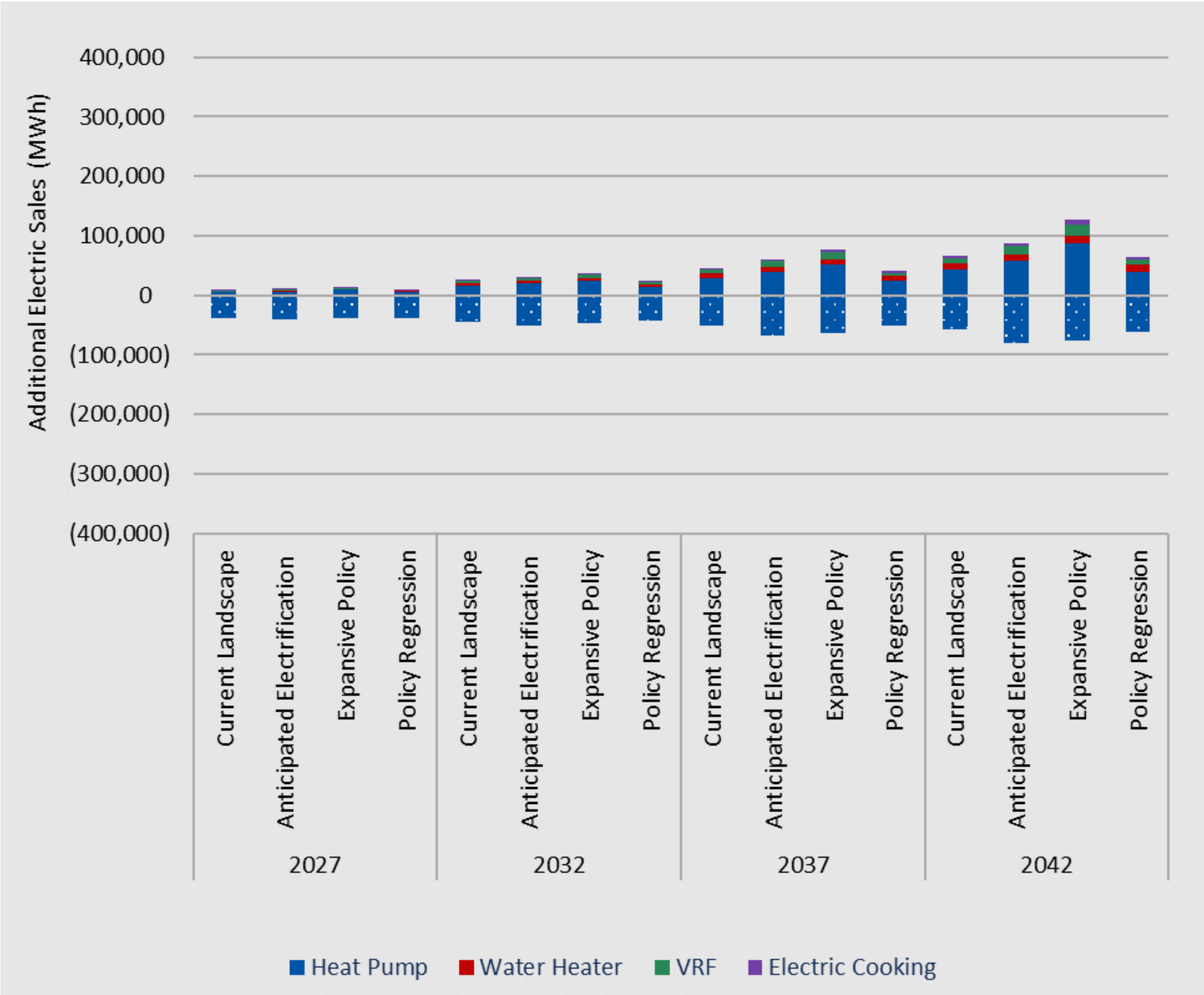


Figure 30 shows the study's estimated impacts of building electrification and energy efficiency in the commercial sector. Compared to the residential sector, the relative and absolute impacts of VRFs are greater. Similar to the residential sector, the energy sales impacts are primarily due to heat pump installations.

Figure 30. Commercial Electric Sales Impacts from Building Electrification and Energy Efficiency Equipment by Equipment Type (MWh)



Building Electrification Equipment Adoption

This study based its estimates of electrification impacts on peak energy demand and energy sales on a number of factors, including the total quantity of equipment adopted by Tacoma Power customers. Table 37 shows the number of pieces of building electrification equipment that the study projected to be adopted through 2042. The number of systems reflect cumulative stock in the Tacoma Power service area, beginning with the approximate 2022 equipment saturations, as per the Tacoma Power CPA database. As illustrated in the table, the study estimates that the number of space heat pumps will increase by a factor of approximately four in the Expansive Policy scenario in 2042 and a factor of five for the commercial sector. For other equipment types the magnitude of the change is less pronounced.

Table 37. Residential and Commercial Building Electrification and Energy Efficiency Equipment Stock (Cumulative Units)

Year	Scenario	Heat Pumps		Heat Pump Water Heaters		Electric Resistance Water Heaters		Electric Cooking[a]		VRF		Electric Furnaces[a]	Baseboards[a]	Electric Dryers[a]
		Residential	Commercial	Residential	Commercial	Residential	Commercial	Residential	Commercial	Residential	Commercial	Residential		
2022	Approximate Base Equipment Stock	24,600	2,200	15,200	20	105,900	4,000	127,400	6,100	300	-	46,100	44,200	158,400
2027	Current Landscape	23,600	2,900	15,300	200	105,700	5,100	127,500	7,400	300	30	46,000	44,200	158,500
	Anticipated Electrification	24,900	3,200	17,100	300	106,000	5,100	128,000	7,500	300	60	46,000	44,100	158,900
	Expansive Policy	27,400	3,200	18,000	400	105,300	5,100	128,300	7,500	300	70	46,000	44,100	159,100
	Policy Regression	24,600	2,900	15,200	200	105,900	5,100	127,400	7,400	300	30	46,100	44,200	158,400
2032	Current Landscape	44,400	3,900	43,800	700	110,600	5,800	134,500	7,800	900	120	47,300	45,900	165,800
	Anticipated Electrification	48,300	4,600	48,000	1,100	111,400	5,800	135,200	7,800	900	170	47,200	45,800	166,300
	Expansive Policy	57,000	4,900	51,500	1,400	108,800	5,800	135,900	7,900	1,000	220	47,300	45,700	166,600
	Policy Regression	45,700	3,900	43,300	700	111,000	5,800	134,200	7,800	900	90	47,300	45,900	165,600
2037	Current Landscape	65,200	5,200	70,900	1,500	114,900	6,600	141,600	8,100	1,500	230	48,500	47,400	172,500
	Anticipated Electrification	71,500	6,400	77,200	2,100	116,300	6,600	142,800	8,300	1,600	320	48,400	47,300	173,100
	Expansive Policy	84,300	7,300	83,100	2,700	111,700	6,600	144,000	8,400	1,700	430	48,500	47,200	173,600
	Policy Regression	66,300	5,100	69,900	1,400	115,700	6,600	141,200	8,100	1,500	190	48,500	47,500	172,200
2042	Current Landscape	82,300	6,500	91,900	2,200	118,700	7,400	149,100	8,600	2,000	360	49,600	49,000	179,400
	Anticipated Electrification	90,400	8,400	99,900	3,100	120,300	7,300	150,800	8,700	2,200	500	49,500	48,900	180,000
	Expansive Policy	109,400	10,300	107,700	3,800	114,000	7,300	152,500	8,900	2,300	640	49,600	48,700	180,700
	Policy Regression	83,100	6,500	90,500	2,100	119,800	7,400	148,700	8,500	2,000	300	49,600	49,100	179,100

[a]Adoption figures reflect both electrification and energy efficiency except for those in the categories shown in gray (electric cooking, electric furnaces/baseboards, and electric dryers), which reflect electrification only.

Rooftop Solar and Demand Response

This section shows the study's peak load impacts from rooftop solar adoption in the residential and commercial sectors and the impact from potential demand response programs, as discussed in the mitigation scenarios. As shown in the following figures and charts, rooftop solar reduces Tacoma Power's summer PM load significantly, while demand response programs provide additional winter AM and PM load reductions. The following factors contribute to rooftop solar's peak load impacts:

The study scenarios' rooftop solar growth projections. According to the scenario design, energy produced by solar by 2042 is projected to be 130 MW in the Anticipated Electrification scenario and 178 MW in the Expansive Policy scenario.

Rooftop solar's energy production coincidence with Tacoma Power's summer peak period. The study assumed that Tacoma Power's summer peak period occurs on July 16 and August 27 between 3 PM and 6 PM, during this timeframe rooftop solar projects are maximizing their output.

Rooftop Solar and Demand Response Peak Demand Impacts

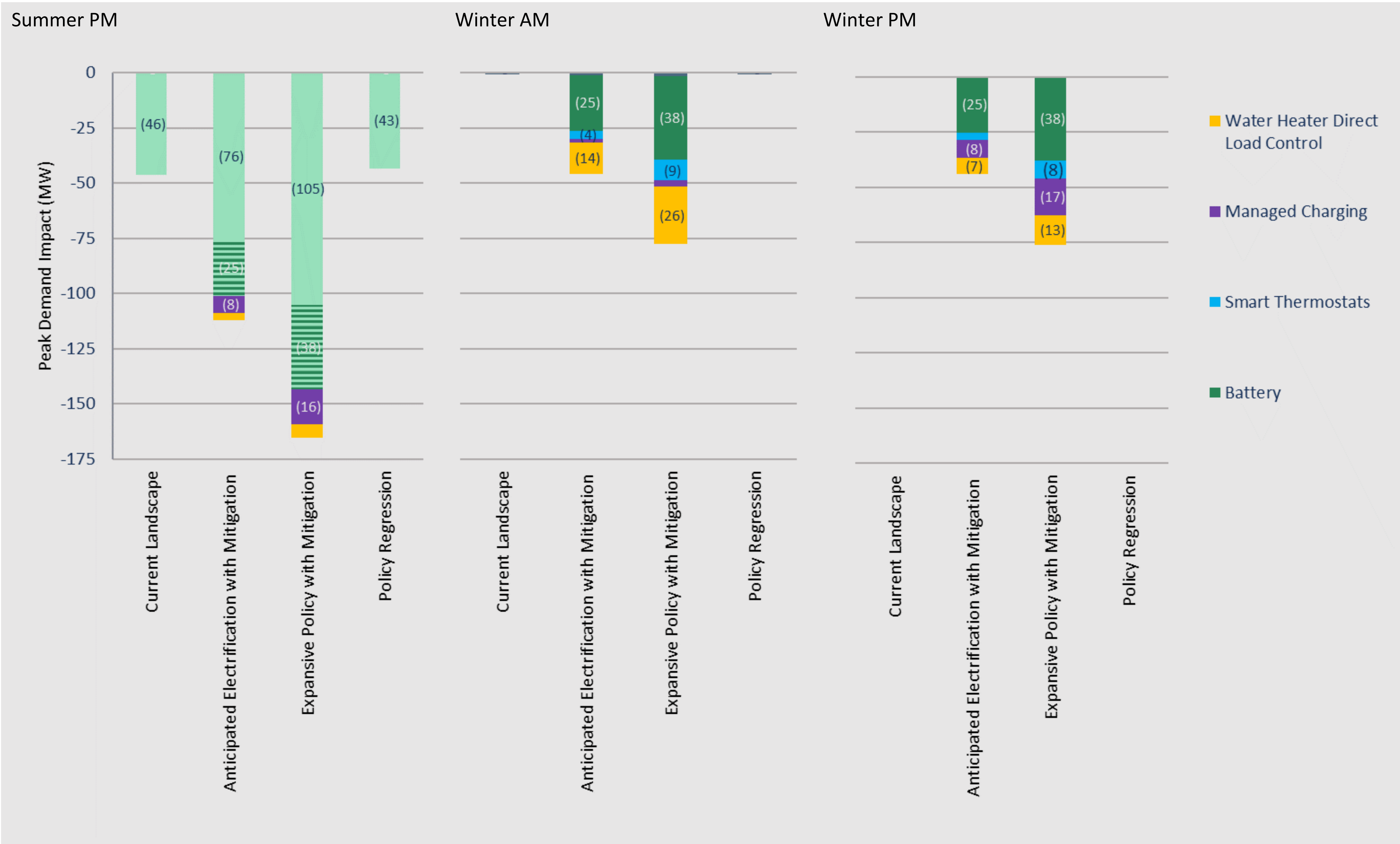
Figure 31 shows the 2042 summer PM, winter AM, and winter PM peak demand impacts from residential and commercial rooftop solar installations, and for the four demand response programs (battery storage dispatch, smart thermostats, water heater direct load control, and managed charging of EVs) included in this study in mitigation scenarios. Demand response impacts occur primarily in the residential sector, as per the study's design; however, battery storage dispatch has some impact in the commercial sector.

This study did not account for batteries charging during peak hours for demand response dispatch, and thus the battery dispatch in summer PM hours would likely not add significantly to peak reduction impacts from rooftop solar systems. Because the study scenarios do not distinguish solar adoption in the mitigation scenarios, Figure 31 does not show the Anticipated Electrification and Expansive Policy scenarios separately from the mitigation scenarios.

The figure illustrates the following:

- Peak impacts from rooftop solar are concentrated during the summer PM peak period, due to coincidence of rooftop solar production with summer PM peak demand.
- Smart thermostats do not provide summer peak demand reduction potential because the program was focused exclusively on space heating demand reduction.
- During the winter AM and PM peak periods, battery storage dispatch provides the greatest demand reduction impacts compared with other demand response programs. This study also estimates that water heater direct load control programs contribute additional peak reductions, although these are higher in the winter PM period than the winter AM period because higher usage amounts in the winter PM must be offset.
- Managed charging provides additional peak demand reduction, primarily in summer and winter PM as most would be unavailable for charging during the morning commute.

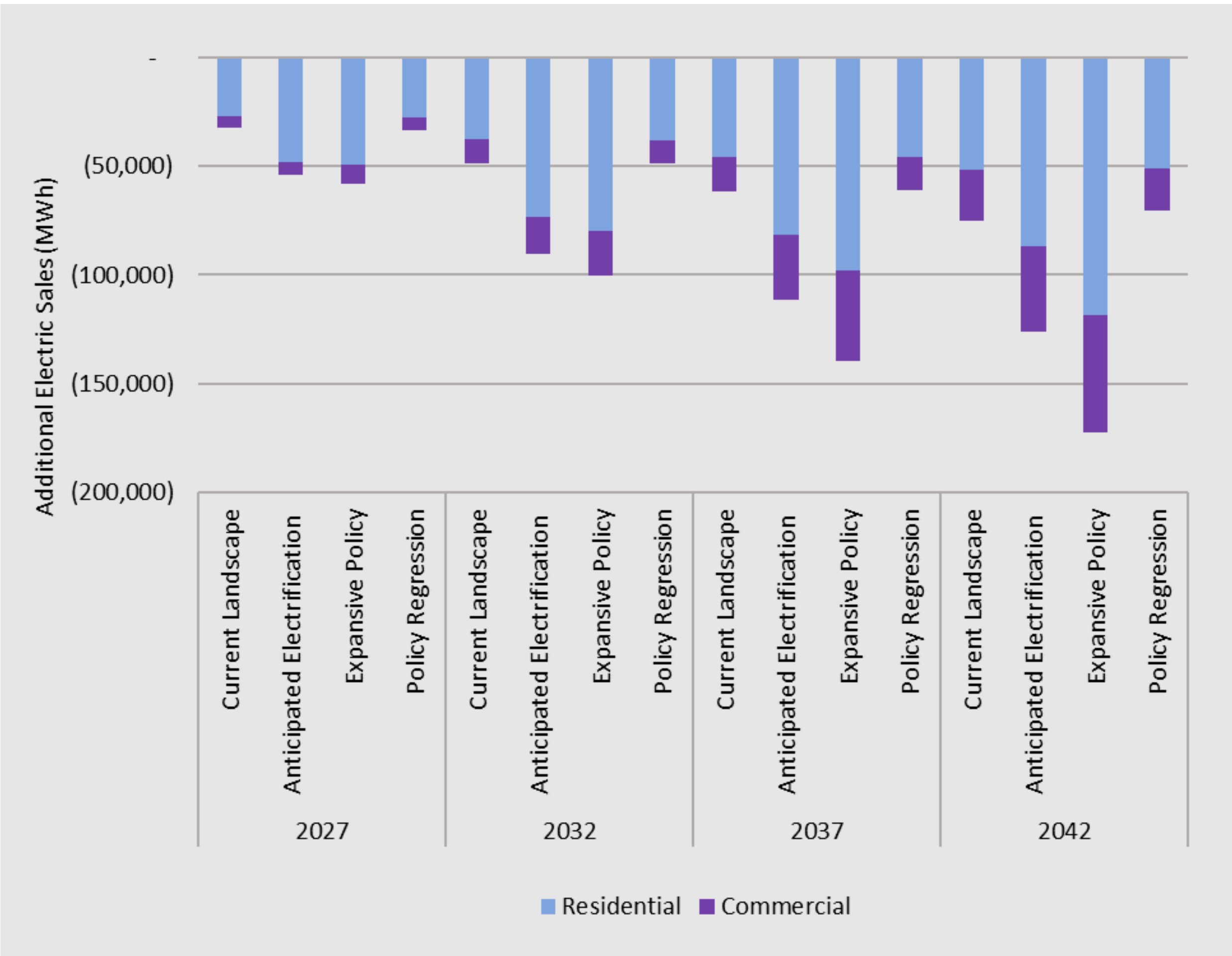
Figure 31. 2042 Peak Demand Impacts from Rooftop Solar and Demand Response Programs (MW)



Rooftop Solar Energy Sales Impacts

Potential demand response programs included in the study's mitigation scenarios would likely be designed to minimize changes in electric consumption, focusing instead on shifting energy use away from periods of peak demand. Thus, this study section focuses on the residential and commercial electric sales impacts from rooftop solar development only, where impacts on electric sales are expected. As shown in Figure 32, the study estimates that the residential sector will account for most of the impacts on electric sales for Tacoma Power.

Figure 32. Electric Sales Impacts from Rooftop Solar by Sector (MWh)



Rooftop Solar System Adoption and Demand Response Program Participation

This section shows the study scenarios' rooftop solar system adoption forecast for the residential and commercial sectors in nameplate capacity, and the projected demand response program participation in the mitigation scenarios in number of participants enrolled in potential programs.

Figure 33 shows the study's projected residential and commercial rooftop solar capacity adoption. For rooftop solar, extensions and removals of net metering limits were an important component of the scenario design. The scenario new construction assumptions add significantly to solar adoption. For example, in 2042 solar installations on new construction account for approximately a third of the total solar capacity.

Figure 33. Residential and Commercial Rooftop Solar Capacity Adoption (Nameplate kW)

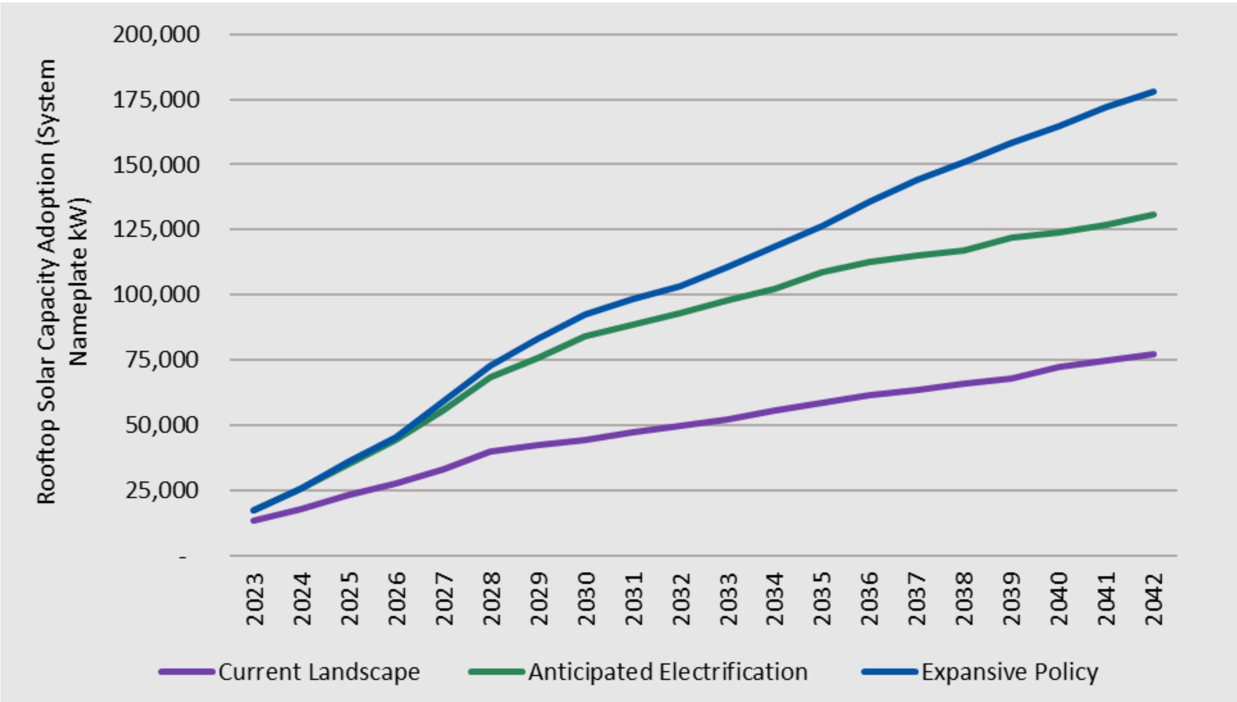


Table 38 shows the number of premises that the study expects to participate in demand response programs in the mitigation scenarios. The large number of participants in the water heater direct load control program can be explained by the high saturation of electric water heaters.

While adoption of battery systems and program participation is low compared with participation in other demand response programs, the net impacts on peak load from battery storage dispatch are relatively high, due to the higher power ratings per unit. The study assumed that residential batteries would contribute 3 kW worth of peak shaving and commercial batteries would contribute 67 kW of peak shaving per event per unit while the other demand response programs would contribute less than 1 kW of peak shavings per event per unit.

Table 38. Residential and Commercial Demand Response Program Participation (Number of Premises)

Year	Demand Response Programs	Anticipated Electrification with Mitigation	Expansive Policy with Mitigation
2032	Battery Storage Dispatch	4,100	4,400
	Managed Charging	2,000	5,400
	Smart Thermostats	3,800	6,800
	Water Heater Direct Load Control	26,000	40,100

Year	Demand Response Programs	Anticipated Electrification with Mitigation	Expansive Policy with Mitigation
2042	Battery Storage Dispatch	5,900	10,000
	Managed Charging	11,200	22,700
	Smart Thermostats	6,200	14,300
	Water Heater Direct Load Control	28,900	52,700

Transportation Electrification Results

This section describes the peak demand and energy impacts from transportation electrification, which includes adoption of residential EV chargers for use in homes and multifamily buildings, publicly accessible chargers, and charging stations for commercial vehicle fleets such as school buses.

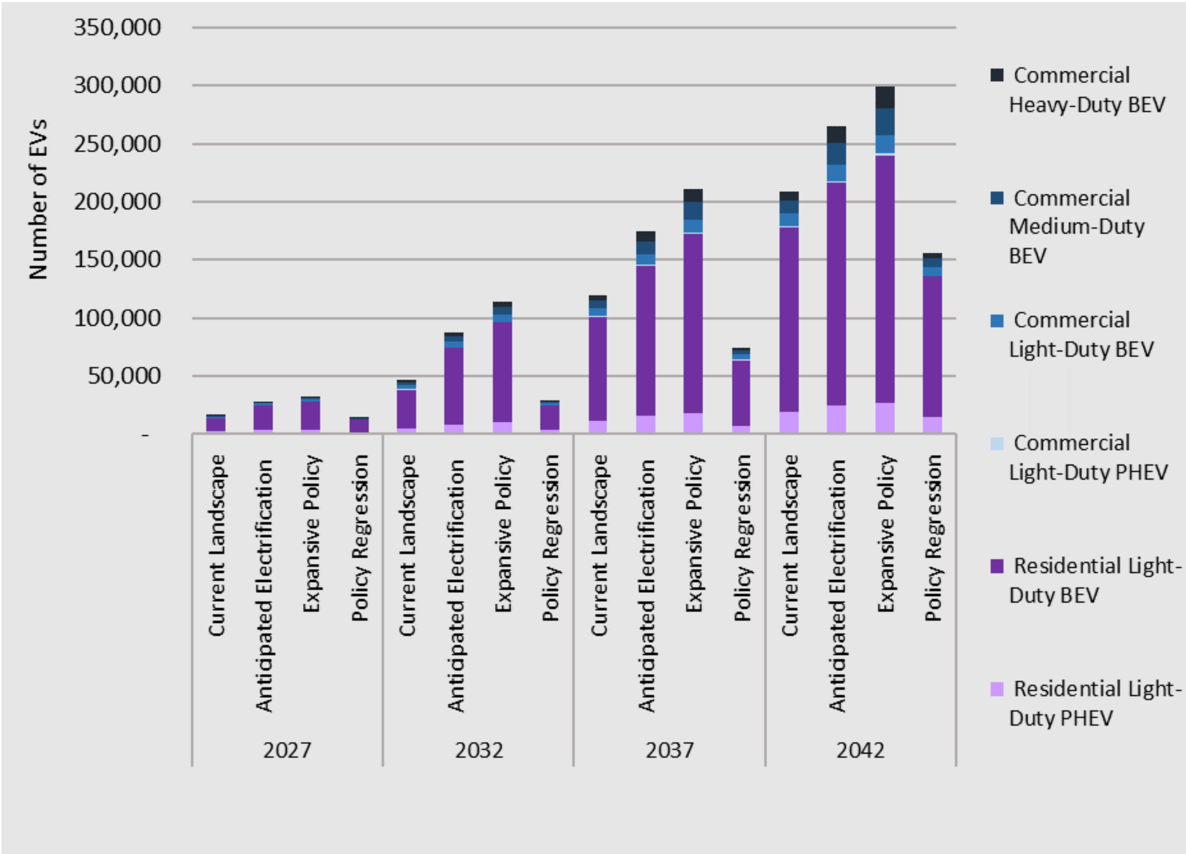
To estimate energy impacts from transportation electrification, this study considered seven types of chargers, listed in Table 39. These charger types serve private BEVs and PHEVs at residential and commercial locations (for this study commercial chargers refer to workplace or public chargers serving both privately owned and business-owned vehicles) and commercial fleet vehicles at schools, retail businesses, and warehouses.

Table 39. Electric Vehicle Charger Types

Charger Type	Building Types	Vehicle Types	Vehicle Use
Residential Level 1	Single-Family, Multifamily, Manufactured Homes	BEV and PHEV	Private Vehicles
Residential Level 2			
Workplace, Public Level 2	All commercial building types	BEV and PHEV	Private and commercial vehicles
Workplace, Public DCFC		BEV only	
Fleet Level 2	Schools, Retail, and Warehouses	BEV and PHEV	Commercial fleets
Fleet DCFC		BEV only	

This study based charger adoption on forecasted EV purchases by households (private vehicles) and businesses (commercial vehicle fleets) over the study period. Figure 34 shows the projected EV adoption by scenario, for each vehicle type.

Figure 34. Electric Vehicle Adoption by Vehicle Type and Scenario (Number of Vehicles)



As described in the *Methodology* section, the number of vehicles does not translate directly into the number of chargers. The study considers factors such as multiple EVs using a single charger and parking availability.

Transportation Electrification Peak Demand Impacts

The peak load additions from residential and commercial EV adoption occur primarily in the summer and winter PM peak periods. This is because most vehicle charging occurs in the late afternoon or early evening. Fleet operators often plug their commercial vehicles into stations to recharge at the end of the workday, and private vehicles arrive home from work and connect to their residential charger for overnight charging. This study's vehicle charging load shapes reflect these trends and the unique duty cycles of school, retail, and warehouse fleets.

Table 40. Additional Peak Demand Impacts from Transportation Electrification by Sector and Charger Type (MW)

Scenario	Charger Type	2027			2032			2037			2042		
		Summer PM	Winter AM	Winter PM	Summer PM	Winter AM	Winter PM	Summer PM	Winter AM	Winter PM	Summer PM	Winter AM	Winter PM
Current Landscape	Residential Level 1	1	0	1	3	0	3	7	1	7	12	1	12
	Residential Level 2	6	1	6	15	2	16	41	5	44	75	11	80
	Commercial Level 2	2	2	2	6	6	6	12	11	11	19	18	18
	Commercial DCFC	1	0	1	2	1	2	4	2	4	5	3	5
	Commercial Level 2 - Fleet	0	0	0	0	0	0	1	1	1	1	1	1
	Commercial DCFC - Fleet	0	0	1	3	1	3	7	4	8	12	7	14
Scenario Total		**9**	**3**	**10**	**28**	**10**	**29**	**72**	**24**	**75**	**125**	**40**	**130**
Anticipated Electrification	Residential Level 1	1	0	1	5	1	5	10	1	10	15	1	15
	Residential Level 2	9	1	9	29	4	31	61	8	65	91	13	98
	Commercial Level 2	2	2	2	8	8	7	17	15	15	23	21	21
	Commercial DCFC	1	0	1	2	1	2	4	2	4	6	3	5
	Commercial Level 2 - Fleet	0	0	0	0	0	0	1	1	1	1	1	1
	Commercial DCFC - Fleet	1	0	1	6	3	6	13	8	14	22	13	24
Scenario Total		**14**	**4**	**15**	**51**	**17**	**53**	**106**	**35**	**110**	**157**	**52**	**165**
Expansive Policy	Residential Level 1	1	0	1	6	1	6	11	1	11	16	2	16
	Residential Level 2	9	1	10	37	5	39	70	10	75	99	15	107
	Commercial Level 2	3	3	3	11	11	11	21	19	19	24	22	22
	Commercial DCFC	1	0	1	3	2	3	5	3	5	6	4	6
	Commercial Level 2 - Fleet	0	0	0	1	1	1	1	1	1	1	1	1
	Commercial DCFC - Fleet	1	1	1	8	5	9	18	11	20	30	18	32
Scenario Total		**16**	**5**	**16**	**66**	**23**	**68**	**127**	**46**	**132**	**176**	**61**	**184**

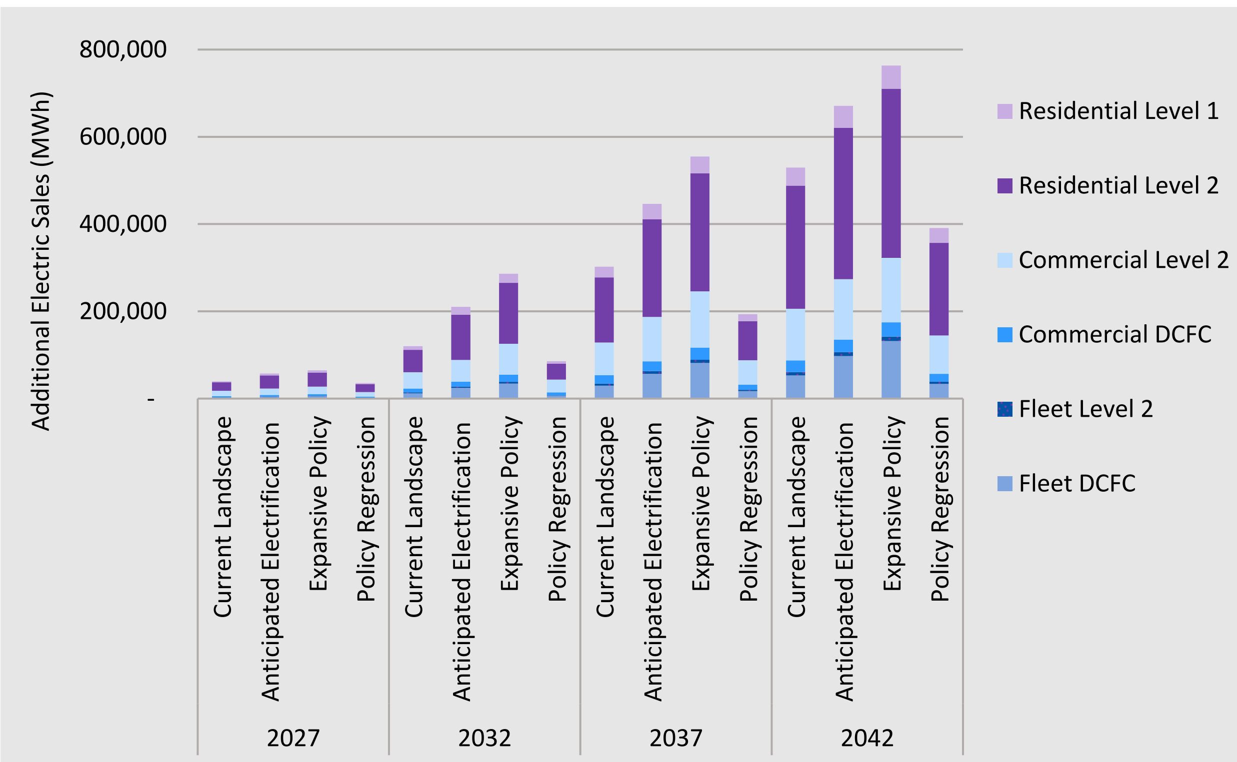
Scenario	Charger Type	2027			2032			2037			2042		
		Summer PM	Winter AM	Winter PM	Summer PM	Winter AM	Winter PM	Summer PM	Winter AM	Winter PM	Summer PM	Winter AM	Winter PM
Policy Regression	Residential Level 1	1	0	1	2	0	2	5	0	5	10	1	10
	Residential Level 2	5	1	6	10	1	11	26	3	28	58	8	62
	Commercial Level 2	2	2	2	5	4	4	9	8	8	14	13	13
	Commercial DCFC	1	0	1	1	1	1	2	1	2	3	2	3
	Commercial Level 2 - Fleet	0	0	0	0	0	0	0	0	0	1	1	1
	Commercial DCFC - Fleet	0	0	0	1	1	2	4	2	4	8	4	9
Scenario Total		**8**	**3**	**9**	**20**	**8**	**20**	**46**	**16**	**48**	**94**	**29**	**98**

Transportation Electrification Energy Sales Impacts

Residential, private-use vehicle adoption is the primary driver of additional electric sales from EV chargers, as shown in Figure 35. The electric sales impacts from transportation electrification are concentrated in Residential Level 2 chargers because residential vehicles dominate Tacoma's overall vehicle stock and the majority of residential charging occurs at home on Level 2 chargers.

Workplace and public charging also contribute additional load from powering residential and some commercial vehicles. Fleet vehicle charging load ramps up the most slowly over time, reflecting the maturity and cost of heavy duty BEV technology, and adds a more modest amount of electric load compared to public and residential charging. Fleet charging is primarily concentrated in DCFCs stationed at warehouses and at Level 2 chargers at schools. Warehouse charging will comprise a significant portion of the total fleet load because, as a port city, Tacoma experiences elevated warehouse and long-haul trucking activity. Because of their significant energy requirements, large batteries, and tight delivery schedules, the study assumes that long-haul trucks will rely on DCFCs. School fleets were one of the earliest commercial fleets targeted for electrification because their buses travel fixed and mostly short routes, they have predictable dwell times, they are situated in residential areas that can benefit from reduced emissions, and they are eligible for government funding set aside for schools.

Figure 35. Additional Electric Sales from Electric Vehicle Charger Adoption by Charger Type and Scenario (MWh)



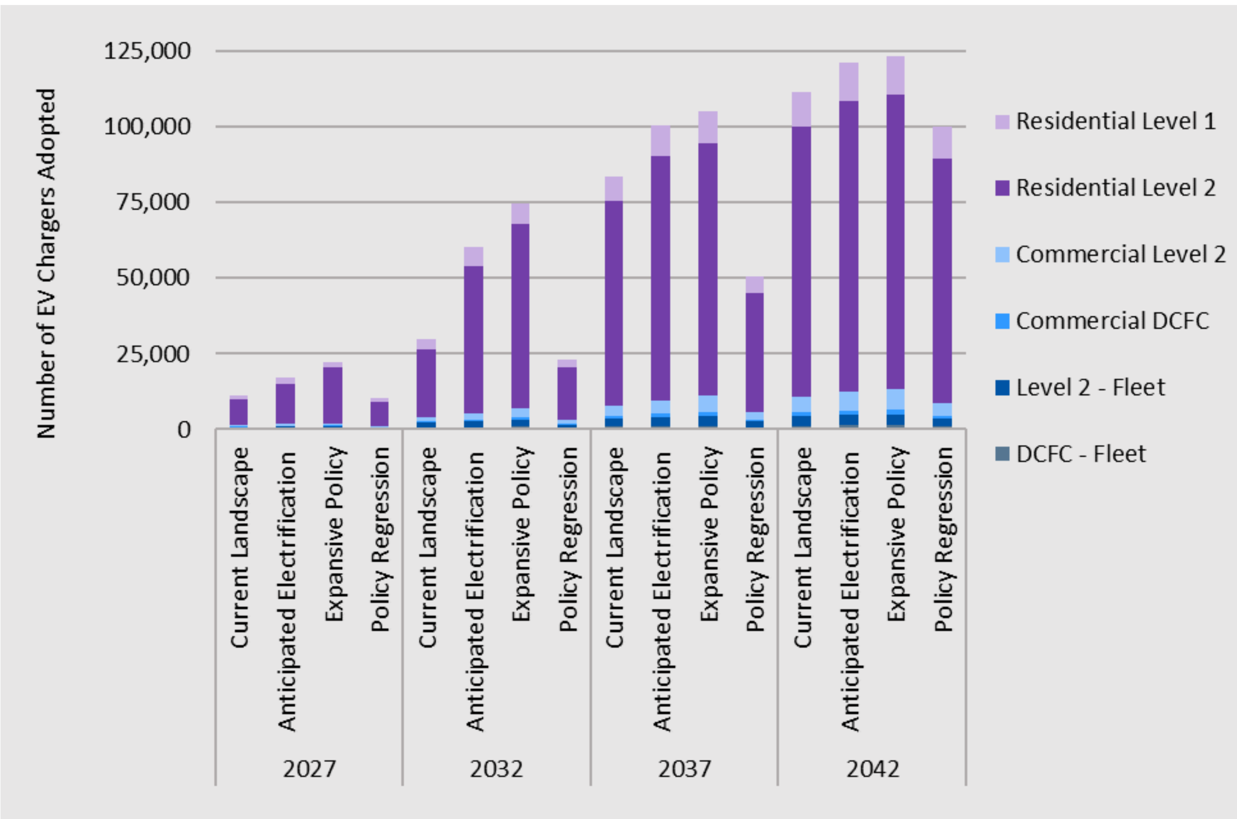
This study projects that residential Level 2 chargers account for just over 50% of added electric sales in 2042; however, these types of chargers comprised almost 80% of the chargers installed that same year.

This is because daily vehicle miles traveled (VMT) and the resulting load requirement for residential vehicles is lower than that of commercial fleet vehicles. Further, in a given 24-hour period, only a single vehicle will connect to a residential charger, whereas a commercial chargers (which account for approximately 40% of additional electric sales from transportation electrification but comprise only 10% of chargers in 2042) may experience several sessions across multiple vehicles per day. The difference in efficiency of use of residential and commercial chargers contributes to their imbalanced contribution to peak energy demand.

Electric Vehicle Charger Adoption

Figure 36 shows the cumulative number of EV chargers adopted by year and scenario. The figure shows that residential chargers make up the vast majority of adopted chargers each year and in every scenario. However, as illustrated in Figure 36 the absolute number of chargers does not equate to total energy and demand impacts, as commercial chargers are used more than residential chargers.

Figure 36. Electric Vehicle Charger Adoption by Charger Type and Scenario (Chargers)



Industrial Electrification Results

This study considered electrification impacts from industries located in Tacoma Power service territory. The Port of Tacoma accounts for approximately 11.5% of industrial sales. Given the Port of Tacoma's high electric use and its own electrification roadmap, this study section breaks out the impact from port electrification separately from other industries in Tacoma Power service area. The study's estimates for industrial electrification were informed by interviews with representatives from ten of Tacoma Power's most energy-intensive industries not including the Port of Tacoma. This report section provides key findings from these interviews, in addition to the peak demand and energy sales impacts from industrial electrification. Unlike the other results sections, this section does not provide the number of units adopted (such as number of gas boilers converted to electric boilers) because the industrial analysis relied on an end-use level approach, as compared to a units-based approach.

Industrial Customer Interview Results

Ten industrial customers provided insight for this study. The company representatives included facility managers and engineers with knowledge of their facilities' energy consumption and plans for electrification. As shown Table 41, Tacoma Power's industrial customers provided a variety of insights regarding drivers for electrification, as well as barriers to electrifying their processes. The interviews elicited the following key observations:

- For the Petroleum & Refining Sector and Paper Manufacturing sector, the costs of converting fossil-fuel powered process to electricity are prohibitive. Some customers indicated that they would relocate or close their facilities before converting equipment.
- Many industrial customers are considering electrifying processes, given corporate target to decarbonize their operations.
- Downtime and fuel costs are the most common concerns with electrification.
- Multiple customers mentioned the benefits of electrification including reduced upkeep and maintenance costs. Others also indicated that volatile natural gas prices made electric equipment options more attractive.
- Electric forklifts and electric cargo-handling equipment are the most common electrification measures customers are considering in the near term.
- Multiple customers indicated that electric equipment availability is important when it comes to equipment replacement due to failure.

Table 41. Key Findings from Tacoma Power Industrial Customer Interviews

Industry and Facility Information	Facility Energy and Fuel Use	Electrification Perceptions, Opportunities, Barriers
Miscellaneous Industrial, Yard processing old scrap steel	• 60% to 70% electric, 35% diesel, very small percentage of load is natural gas. • Non-electric equipment mainly uses diesel: cranes, forklifts, trains, ship cranes. • Some natural gas for the torch and water treatment plant but very small amounts.	• Already exploring electrification of cargo-handling equipment and funding opportunities through the United States Department of Energy. • Cost is main barrier to electrification. • Corporate and operations team understands need for reducing emissions. Mentioned co-benefits of electrification including less downtime for maintenance, lower maintenance costs.
Primary Metal Manufacturing, Medium to large castings and many specialized pieces	• Electricity is their top fuel due to electric arc furnace. • Natural gas usage mainly for induction furnace, which can push temperatures to 2000 F. • Diesel use for forklifts, estimating that 60% of fuel is for heavy duty forklifts for which there are no electric options and 40% of fuel is for lighter duty forklifts.	• Corporate wants to stop using natural gas and has emissions reduction targets. • Electric options are on their radar although electrification of some high heat processes and heavy-duty forklifts are not feasible with current technology.
Cement and Concrete Product Manufacturing, Manufacture large, custom concrete products (parts for highway bridges, docks)	• Curing process previously used natural gas but now ~90% products are heated with electric. The ~10% heated with natural gas are small custom orders where it is not cost-effective to build a custom-electric element. Natural gas kilns are not custom built and are thus more cost-effective for these orders. • Diesel use for cargo-handling equipment.	• Already in the process of electrifying their crane and have one electric forklift. Open to future electrification opportunities. • Have seen huge efficiency gains with the electrification of their process heating. • Cost is a barrier but exploring incentives and funding. • Corporate understands change is coming and is looking to be “ahead of the game”.

Industry and Facility Information	Facility Energy and Fuel Use	Electrification Perceptions, Opportunities, Barriers
Glass and Nonmetallic Mineral Product Manufacturing, Fiber cement siding and trim products for construction	• Electricity is top fuel, followed by diesel and then natural gas. • Diesel is used for forklifts. • Natural gas is mainly for boilers and induction ovens, both of which could feasibly be electric based on temperature set points.	• Company doesn't like a lot of change, and electrification efforts would require more direction from someone at a higher level. Currently no clear direction or plan at the site level. • Key consideration for replacing equipment that breaks is availability because operation downtime is a major concern. If electric heater is the first thing available, higher chance of adopting but if gas equipment available first, would choose that (and have made that choice recently).
Food Manufacturing, Manufacture plastic water bottles	• Electricity is main fuel for processes and cargo-handling equipment. • Using limited gas for boiler and dryers. • Dryers are hybrid gas/electric but always use gas because it is cheaper. • Boiler is a gas boiler but used only once a month so very low usage.	• No discussion of emissions reduction or any efforts or plans to electrify current gas end uses. • Electrification of four delivery trucks in the future is on their radar but they will not be early adopters. They will wait until it is proven that electric shipping works for their industry.
Chemicals, Manufacture carbon fibers and carbon fiber prepreg	• Only using electricity and natural gas, with electricity 70% of energy use. • All forklifts are already electric. • Boilers are main gas user.	• Company has emissions reduction goals, and this is driving conversations around looking at boiler electrification. • Barriers include downtime and cost of electricity *versus* gas.
Petroleum and Coal Products Refining,	• Using internally produced fuel for most heating process with natural gas as a supplement. Some end uses always use natural gas. • Electricity is used for pumping products.	• No incentive to electrify processes and stop using their excess internally produced gas since they will have to pay to flair it anyway. • Corporate sustainability strategy but no current facility decarbonization plan, just not expanding current operations and not exploring cleaner alternative operations.

Industry and Facility Information	Facility Energy and Fuel Use	Electrification Perceptions, Opportunities, Barriers
Paper Manufacturing, Kraft pulp paper mill with CHP onsite	• Processes create a huge amount of steam, which is mainly produced from recovery boiler or biomass boiler. • Natural gas is used to start boilers and for swing boiler. • Process heating via lime kilns also uses natural gas and reaches temperatures up to 1500 F. • Very small amounts of natural gas for HVAC and propane for forklifts.	• Manager does not think electrification is possible on the scale at which they are operating due to either cost or technical feasibility. Signaled that many of the electrification upgrades would put the plant out of business.
Wood Product Manufacturing, Produces wood veneers and mulch from logs	• Using natural gas and hog fuel for boilers and heating processes. Dryer also using natural gas. • Some heavy- duty diesel and propane cargo handling equipment, which is not feasible for electrification yet.	• No corporate sustainability plan. Any electrification actions will be driven by a value proposition rather than sustainability strategy/carbon footprint. • Open to electric options when beneficial or not too costly. The recent volatility of natural gas prices is also making electric options more appealing. • Although hog fuel is not a very clean fuel, it is a byproduct of wood product manufacturing, so little incentive to stop using it.

Industrial Electrification Peak Demand Impacts

The Port of Tacoma accounts for almost half of the peak demand impacts of this study. Key port industrial processes drive these impacts, including shore power (converting a vessel's power generation with generators to electric shore power provided by the Port of Tacoma), electric refrigeration (reefers), and electric cargo handling equipment (CHE). For the Port of Tacoma, electric shore power contributes the most to peak demand and scales relatively quickly compared with other processes with higher barriers to adoption.

For other Tacoma Power industries this study estimates that boiler electrification will provide the most peak demand impact and additional electric sales relative to other industrial process and end uses, despite high barriers to boiler electrification. Given significant barriers to electrifying boilers, the study estimates that the pace of electrifying boilers will be slow compared with shore power electrification. Table 42 shows this study's estimates of industrial electrification peak impacts by scenario, industry segment (Port or non-port industries), and industrial process/equipment. The study estimated that winter AM and winter PM peaks would be identical. This study did not consider peak demand mitigation scenarios such as industrial demand response. This study did not assume any growth in electrification from West Rock given their planned closure.

Table 42. Industrial Peak Demand Impacts by Industrial Process/Equipment (MW)

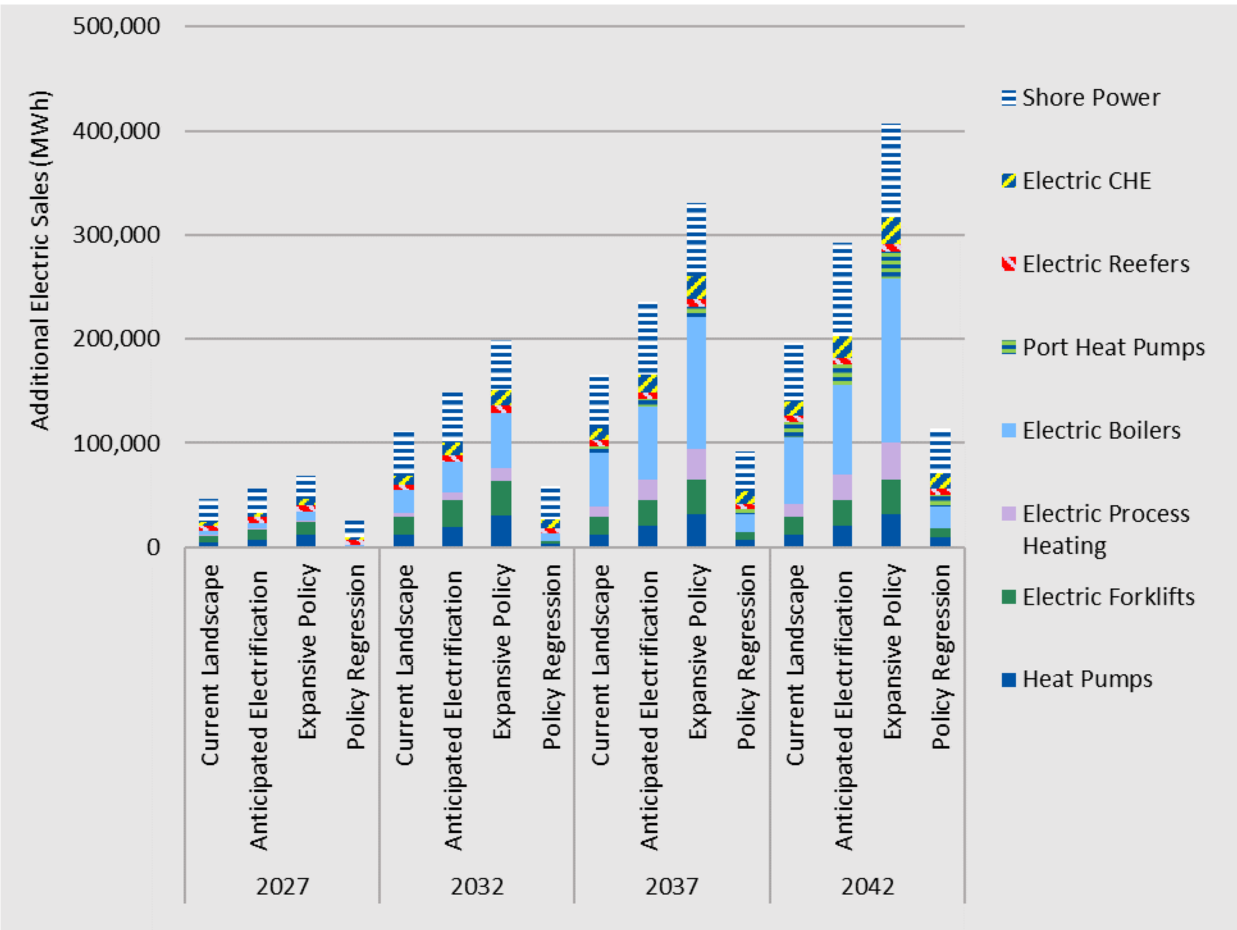
Scenario	Industrial Process / Equipment	Industry	2027		2032		2037		2042	
			Summer PM	Winter AM/PM	Summer PM	Winter AM/PM	Summer PM	Winter AM/PM	Summer PM	Winter AM/PM
Current Landscape	Shore Power	Port	4	3	8	6	10	7	11	8
	Electric CHE		1	0	2	1	2	2	3	2
	Electric Reefers		1	1	1	1	1	1	1	1
	Heat Pump		0	0	0	0	1	1	3	2
	Electric Boiler	Non-Port	1	0	4	3	9	7	11	9
	Electric Forklifts		1	1	3	2	3	2	3	2
	Electric Process Heating		0	0	1	1	2	1	2	2
	Heat Pump		1	1	2	2	2	2	2	2
Scenario Total			**8**	**7**	**20**	**16**	**30**	**24**	**35**	**28**
Anticipated Electrification	Shore Power	Port	4	3	9	7	13	10	17	13
	Electric CHE		1	1	2	2	3	2	4	3
	Electric Reefers		1	1	1	1	1	1	1	1
	Heat Pump		0	0	0	0	1	1	4	3
	Electric Boiler	Non-Port	1	1	5	4	12	10	15	12
	Electric Forklifts		2	1	4	4	4	4	4	4
	Electric Process Heating		0	0	1	1	3	3	4	3
	Heat Pump		1	1	3	3	4	3	4	3
Scenario Total			**10**	**8**	**27**	**21**	**42**	**34**	**52**	**42**
Expansive Policy	Shore Power	Port	4	3	9	7	13	10	17	13
	Electric CHE		1	1	3	2	4	3	5	4
	Electric Reefers		1	1	1	1	1	1	1	1
	Heat Pump		0	0	0	0	2	1	5	4
	Electric Boiler	Non-Port	1	1	9	8	22	18	27	22
	Electric Forklifts		2	2	6	5	6	5	6	5

Scenario	Industrial Process / Equipment	Industry	2027		2032		2037		2042	
			Summer PM	Winter AM/PM	Summer PM	Winter AM/PM	Summer PM	Winter AM/PM	Summer PM	Winter AM/PM
	Electric Process Heating		0	0	2	2	5	4	6	5
	Heat Pump		2	2	5	4	5	4	5	4
Scenario Total			**12**	**10**	**35**	**28**	**58**	**47**	**72**	**58**
Policy Regression	Shore Power	Port	3	2	6	4	7	5	8	6
	Electric CHE		1	1	2	1	2	2	3	2
	Electric Reefers		1	1	1	1	1	1	1	1
	Heat Pump		0	0	0	0	1	1	2	2
	Electric Boiler	Non-Port	0	0	1	1	3	2	4	3
	Electric Forklifts		0	0	0	0	1	1	1	1
	Electric Process Heating		0	0	0	0	0	0	0	0
	Heat Pump		0	0	1	0	1	1	2	1
Scenario Total			**5**	**4**	**11**	**8**	**17**	**13**	**21**	**16**

Figure 37 shows the study's estimated additional electric sales from industrial electrification. The figure illustrates that electric boilers account for most additional electric sales, especially the later years, while electric shore power in the Port of Tacoma accounts for most of the electrification impacts and estimated additional sales in the earlier years of the study period. The figure also shows the later adoption of electric process heating equipment due to the technical and economic barriers. No electrification of process heating was included in the Policy Regression scenario as the barriers to adoption are very high and thus adoption is unlikely to occur without incentives or pressure.

Estimated electric sales are relatively sensitive to the scenario design due to increased achievability factors for the electrification of the most energy intensive end uses under the Anticipated Electrification and Expansive Policy scenarios. Increasing the achievability factor for boiler electrification from 15% in the Current Landscape scenario to 35% in the Expansive Policy scenario has a large impact on the overall estimated electric sales.

Figure 37. Additional Electric Sales from Industrial Electrification by Industry Segment and Process/Equipment (MWh)



Appendix A. Literature Review Summary

Table A-1 provides the data sources used to inform this study. The table includes links to data sources as available.

Table A-1. Literature Review Summary

Equipment/ Vehicle/ Demand Response	Characteristic	Methodology/Approach	Data Source
Transportation Electrification			
Residential	2022 vehicle saturation	Cadmus characterized Tacoma vehicle saturation using vehicle registration data (2022) from the Washington State Department of Licensing Database. As Washington law requires annual registration renewal, this data provides a comprehensive count of the vehicles and their locations within Tacoma. This saturation data provided the base for EV and charger adoption forecasts. Adoption forecasts were further adjusted according to Tacoma Power defined scenario goals.	Washington State Department of Licensing. 2023. 'Vehicle Registration Activity by Month.' Registration Activity by Month | State of Washington.
	2022 charging station saturation	Tacoma Power program data, which includes chargers installed through residential and multifamily initiatives, informed the calculation of existing residential EV chargers. Cadmus scaled vehicle load at each residential charger according to the number of EVs at a given premise.	Tacoma Power Charging Program Data. 2023.
	Charger per vehicle distribution	Cadmus made several assumptions (i.e., ratios) to translate EV adoption to charger adoption and forecast vehicle loads geographically. For multifamily housing, Cadmus based charger adoption on available parking. Note that parking was not a consideration in vehicle adoption.	Joint Office of Energy and Transportation. 2023. 'Electric Vehicle Charging Solutions for Multifamily Housing.' JOET 2023. Plug In America. 2022. 'Expanding the EV Market.' PIA 2019.
	Vehicle adoption forecast	Residential adoption relied on a mixed-mode approach, leveraging both top-down and bottom-up approaches to forecast EV growth. At its core, the model decomposed top-down forecasts across premises in Tacoma according to their propensity scores. Propensity scores (based on McFadden et. al 2019) were modeled at the premise level according to each premises' income, location, and ownership and household type.	McFadden et. al., 2019. 'Identifying Likely Electric Vehicle Adopters: National Average Results.' EPRI. EPRI 2019.

Equipment/ Vehicle/ Demand Response	Characteristic	Methodology/Approach	Data Source
	Load shapes	Cadmus developed load shapes for residential charging based on two sources: EV Watts Station Dashboard, which aggregates charging data from nearly 40,000 EVSE and 14 million charging sessions, and the Northwest Power and Conservation Council, who generated regional load profiles based on charging sessions from 439 ports.	Energetics. 2023. 'EV Watts Charging Station Dashboard.' EVWATTS 2023. Northwest Power and Conservation Council. 2023. 'Plug-In Electric Load Profiles. Plug-In Electric Load Profiles.
Commercial	2022 vehicle saturation	Cadmus defined a portion of the commercial vehicle saturation using vehicle registration data (2022) from the Washington State Department of Licensing Database. As commercial businesses oftentimes register out of state, Cadmus used assumptions tied to school sizing data, and retail and warehouse activity data to characterize the remainder of the commercial vehicle market.	Washington State Department of Licensing. 2023. 'Vehicle Registration Activity by Month.' Registration Activity by Month | State of Washington. US Department of Transportation, Bureau of Transportation Statistics. 2023. 'Number of US Truck Registrations by Type.' USDT 2023. U.S. Department of Transportation, Federal Highway Administration (FHWA). 2021. 'Highway Statistics.' USDT 2021. WA State Office of the Superintendent of Public Instruction. 2017. 'K-12 Capital Facilities Cost Study.' OSPI 2017.
	2022 charging station saturation	Cadmus characterized the population of existing commercial and public EV charging stations through Tacoma Power program data, as well as the Alternative Fuels Data Center's (AFDC) Electric Vehicle Charging Station Location data.	Tacoma Power Charging Program Data. 2023. US Department of Energy, Alternative Fuels Data Center. 2023. 'Electric Vehicle Charging Station Locations.' DOE 2023.
	Charger per vehicle distribution	Cadmus used assumptions to translate EV adoption to charger adoption and forecast vehicle loads geographically. For public EVSE, Cadmus based charger adoption on a percentage of available parking at a given premise.	Cadmus Group, Energetics Incorporated. 2022. 'Standard Review Projects and AB 1082/1083 Pilots.' Cadmus 2022. Plug In America. 2022. 'Expanding the EV Market.' PIA 2022.
	Vehicle adoption forecast	Commercial vehicle adoption forecasts used on a top-down modeling approach that weighted and validated third-party forecasts according to Tacoma Power defined scenario goals. Cadmus forecast light-duty, medium-duty delivery trucks, medium-duty school buses, heavy-duty school buses and heavy-duty long-haul vehicles independently.	ICCT. 2023. 'Analyzing the Impact of the Inflation Reduction Act on Electric Vehicle Uptake in the United States.' ICTT 2023. IEA. 2021. 'Global EV Outlook: Prospects for Electric Vehicle Adoption.' EIA 2021. IEA. 2022 'Global EV Outlook: Trends in Electric Heavy-Duty Vehicles.' EIA 2022. NREL. 2022. 'Decarbonizing Medium- & Heavy-Duty On-Road Vehicles: Zero-Emission Vehicles Cost Analysis.' NREL 2022.

Equipment/ Vehicle/ Demand Response	Characteristic	Methodology/Approach	Data Source
	Load shapes	The EV Watts Station Dashboard, which aggregates charging data from nearly 40,000 EVSE and 14 million charging sessions, informed load shape development for commercial vehicle, workplace, and public charging were mainly informed. Additional data sources for medium- and heavy-duty vehicle load profiles supplemented EV Watts data.	Energetics. 2023 'EV Watts Charging Station Dashboard.' EVWATTS 2023. Pacific Northwest National Laboratory. 2020. 'Electric Vehicles at Scale – Phase 1 Analysis: High EV Adoption Impacts on the Western U.S. Power Grid.' Energetics 2023. State of California Energy Commission. 2021. 'Medium and Heavy-Duty Vehicle Load Shapes.' CEC 2021.
Distributed Energy Resources			
Demand Response: Managed Charging	Program and event participation	Cadmus applied demand response program (20%) and event participation (95%) assumptions from the 2021 Northwest Power and Conservation Council Power Plan.	Northwest Power and Conservation Council. 2022. 'The 2021 Northwest Power Plan'. The 2021 Northwest Power Plan.
	Load shapes	Cadmus modified load shapes from unmanaged charging to curtail during forecasted peak periods based on 2022 Tacoma Power Integrated Resource Plan. Cadmus assumed that there are two events called per day in the winter a morning and a late afternoon/early evening event, and one afternoon event in the summer. Cadmus assumed that in the two winter events half of the enrolled customers participate in the first event, and the other half participate in the second event.	NYSERDA. 2022. Whitepaper: 'Managed Charging for Electric Vehicles.' Tacoma Power. 2022. 'Integrated Resources Plan.'
Demand Response: Smart Thermostats	Program and event participation	Cadmus applied demand response program and event participation assumptions from the 2021 Northwest Power and Conservation Council Power Plan.	Northwest Power and Conservation Council. 2022. 'The 2021 Northwest Power Plan'. The 2021 Northwest Power Plan.
	Smart thermostat saturation	Cadmus used smart thermostat saturation data from the NEEA RBSA II from the western slope of Washington (to maintain a high sample size).	Northwest Energy Efficiency Alliance. 2016-2017. Residential Building Stock Assessment. RBSA II.
	Load shapes	Cadmus sourced load shapes from a Portland General Electric study on smart thermostats, with heat pumps and averaged the reduction values across observed program events.	Cadmus Group. 2022. 'Smart Thermostat Pilot Final Evaluation Report'. Prepared for Portland General Electric.
Demand Response: Water Heater	Program and event participation	Cadmus applied demand response program and event participation assumptions from the 2021 Northwest Power and Conservation Council Power Plan.	Northwest Power and Conservation Council. 2022. 'The 2021 Northwest Power Plan'. The 2021 Northwest Power Plan.

Equipment/ Vehicle/ Demand Response	Characteristic	Methodology/Approach	Data Source
Direct Load Control	Electric water heater saturation	Cadmus used electric water heater saturation data from the NEEA RBSA II from the western slope of Washington (to maintain a high sample size).	Northwest Energy Efficiency Alliance. 2016-2017. Residential Building Stock Assessment. RBSA II.
	Load shapes	Cadmus used water heater load shapes from the 2021 NWPCC plan, which to develop load shapes for water heater demand response assumptions.	Northwest Power and Conservation Council. 2022. 'The 2021 Northwest Power Plan'. The 2021 Northwest Power Plan.
Rooftop Solar	2022 system saturation	Cadmus used Tacoma Power net metering participation data to as the basis for 2022 solar system adoption.	Tacoma Power. Solar Net Metering Data. 2023.
	System adoption forecast	Cadmus used the NREL dGen model to forecast solar system adoption. Cadmus developed model inputs from Tacoma Power data (historical adoption and 2022 system costs), the Washington State University Energy Program (net metering cap and incentives assumptions) and the 2022 NREL Annual Technology Baseline (cost forecasts).	Tacoma Power. Solar Net Metering Data. 2023. Washington State University Energy Program. Renewable Energy System Incentive Program and Net Metering Report. Washington State University Energy Program. National Renewable Energy Laboratory. 2022. Annual Technology Baseline. NREL 2022 ATB.
	Load shapes	Cadmus used NREL's System Advisor Model with Typical Meteorological Year data for Tacoma from the National Solar Resource Database and default model inputs to produce kW/kW-DC shapes.	National Renewable Energy Laboratory. System Advisor Model. NREL SAM.
	Potential System size	To estimate potential system sizes Cadmus used Tacoma Power solar program data and rooftop size data to estimate a kW per rooftop square footage ratio. Cadmus applied this ratio to Tacoma Power homes to calculate potential system sizes for each building.	Tacoma Power. Solar Net Metering Data. 2023. Tacoma Power. Customer Database for Conservation Potential Assessment.
Battery Storage	Program and event participation	Cadmus assume demand response will be deployed during the Tacoma Power winter and summer peaks. Cadmus assumed that systems would dispatch similar to storage demand response pilot programs in the northeast, in which storage systems dispatched at a reduced rate and did not fully discharge batteries to prolong useful life and maintain some battery charge for unexpected outage events.	Green Mountain Power. 2021. 'Integrated Resource Plan'. Green Mountain 2021. New Hampshire Docket No. DE 17-136. 2020. 'Demand Reduction Initiatives Supplemental Information'. NHCEC 2021'. Massachusetts SMART program. 2018-2023. SMART.
	2022 system saturation	Cadmus used Tacoma Power net metering participation data to as the basis for 2022 solar system adoption.	Tacoma Power. Solar Net Metering Data. 2023.

Equipment/ Vehicle/ Demand Response	Characteristic	Methodology/Approach	Data Source
	System adoption forecast	Cadmus tied storage system adoption to solar adoption rates, applying a storage attachment rates (% of new solar systems which include storage). Cadmus developed an attachment rate based on Tacoma Power data, current national attachment rate, and current California attachment.	Lawrence Berkeley National Laboratory. 2022. 'Tracking the Sun Report – Battery Adoption Rates.' LBNL 2021 California Solar Initiative. 'California Distributed Generation Statistics'. CA DG Stats. Verdant. 2021. 'Net-Energy Metering 2.0 Lookback Study'. Verdant 2021. Energy+Environmental Economics. 2021. 'Alternative Ratemaking Mechanisms for Distributed Energy Resources in California'. E3 2021.
	Load shapes	Cadmus reviewed utility pilot programs data (utility-owned batteries and customer-owned batteries) to develop discharge estimates and rebounding charging patterns following demand response events.	Guidehouse. 2020. '2019/20 Residential Energy Storage Demand Response Demonstration Evaluation.' Guidehouse 2020 Green Mountain Power. 2021. 'Integrated Resource Plan'. Green Mountain 2021. New Hampshire Docket No. DE 17-136. 2020. 'Demand Reduction Initiatives Supplemental Information'. NHCEC 2021'.
	Potential system size	Cadmus reviewed publicly available data from Pacific Gas & Electric territory to estimate representative system sizes (kW and kWh).	California Solar Initiative. 'California Distributed Generation Statistics'. CA DG Stats.
	Round trip efficiency	Cadmus used the NREL Annual Technology Baseline to estimate round trip efficiency (86%).	National Renewable Energy Laboratory. 2022. Annual Technology Baseline. NREL 2022 ATB.

Equipment/ Vehicle/ Demand Response	Characteristic	Methodology/Approach	Data Source
Building Electrification			
All	2022 equipment saturation	Cadmus used Tacoma Power data and NEEA RBSA II and CBSA II data to estimate 2022 equipment saturations. For residential and commercial heating systems Cadmus used Tacoma Power data. Cadmus further classified building using equipment saturations distributions from the RBSA II and CBSA II. Thes distributions informed heat pump type, water heater type and fuel, clothes washers saturation, clothes dryer saturation and fuel, cooking equipment fuel, and commercial building controls. Cadmus subset RBSA II and CBSA II saturation data to the western slope of Washington (to maintain a high sample size). Cadmus estimated commercial cooling equipment saturation based on building heating system. Cadmus also estimated the electric panel size for residential buildings based on contractor survey data from Puget Sound Energy. Building panel informs the applicability of heat pumps.	Tacoma Power. Customer Database for Conservation Potential Assessment. Northwest Energy Efficiency Alliance. 2016-2017. Commercial Building Stock Assessment. CBSA II. Northwest Energy Efficiency Alliance. 2016-2017. Residential Building Stock Assessment. RBSA II. Puget Sound Energy. 2023. Integrated Resource Plan Progress Report. PSE 2023.
	Adoption forecast	To estimate case scenario adoption rates Cadmus used ramp rates from the Northwest Power and Conservation Council Power Plan. Cadmus adjusted the rates to account property ownership, building type, non-energy benefit, new construction code, and applicability. For applicability Cadmus used assumptions from the Northwest Power and Conservation Council Power Plan and 2023 Puget Sound Energy IRP Progress Report. Adoption forecasts were further adjusted according to Tacoma Power defined scenario goals.	Northwest Power and Conservation Council. 2022. 'The 2021 Northwest Power Plan'. The 2021 Northwest Power Plan. Puget Sound Energy. 2023. Integrated Resource Plan Progress Report. PSE 2023.
	Competition factor	To estimate the factor by which equipment types that can be installed in the same building compete with each other, Cadmus used data from Northwest Power and Conservation Council Power Plan.	Northwest Power and Conservation Council. 2022. 'The 2021 Northwest Power Plan'. The 2021 Northwest Power Plan.
	Building Square Footage	Building square footage is necessary to estimate load impacts estimated from load shapes, which are structured on a watt per square foot basis for building electrification equipment. Cadmus	Tacoma Power. Customer Database for Conservation Potential Assessment.

Equipment/ Vehicle/ Demand Response	Characteristic	Methodology/Approach	Data Source
		used Tacoma Power data to estimate the square footage of buildings.	
	Load shapes	Cadmus calibrated load shapes for electrification equipment by applying Tacoma Power data to load shapes from NREL's ResStock and ComStock load shape database. Cadmus calibrated the NREL load shapes by Tacoma Power's 2022 Assessment of Potential end-use consumption data.	National Renewable Energy Laboratory. ResStock. NREL ResStock. National Renewable Energy Laboratory. ComStock. NREL ComStock. Tacoma Power. 2022. Assessment of Potential, 2022
Industrial Electrification			
Industrial sectors not including the Port of Tacoma	Sector-specific end-use fuel share	As customer fossil-fuel consumption is unavailable, Cadmus estimates industry-type specific fossil fuel consumption by applying ratios of electric-fuel energy consumption to customer-specific electric consumption. Tacoma Power provided customer electric consumption and Cadmus estimate end-use fuel shares by adapting ratios from the EIA's MECS based on interviews with Tacoma Powers ten most electric-consuming industrial customers.	Tacoma Power. 2023. Industrial Customer Electric Consumption Data. Energy Information Administration. 2018. 'Manufacturing Energy Consumption Survey.' 2018 EIA MECS. Cadmus interviews with ten Tacoma Power industrial customers.
	Gas and electric end-use efficiency	Cadmus estimated the efficiency of gas and electric end-use based on a variety of sources, including EIA, NREL, DOE, and EPRI white papers, interviews with Tacoma Power industrial interviews, and Washington code requirements.	Schoenenberger, Carrie et al. Advances in Applied Energy. 2022. 'Electrification potential of U.S. industrial boilers and assessment of the GHG emissions impact.' Advances in Applied Energy 2022. Energy Information Administration. 2018. 'Manufacturing Energy Consumption Survey.' 2018 EIA MECS. Oregon State University. 2018. 'Oven Turning and Recirculation'. OSU 2018. Power Coating. 2012. 'Improving your powder curing process'. Power Coating 2012. United States Department of Energy. 2015. 'Improving Process Heating System Performance: A Sourcebook for Industry'. DOE 2015. Advanced Energy. 2020. 'Infrared Heating Offers Beneficial Opportunity for Industrial Processes'. AE 2020.

Equipment/ Vehicle/ Demand Response	Characteristic	Methodology/Approach	Data Source
			United States Department of Energy. 2015. ‘Energy Saving Melting and Revert Reduction Technology: Melting Efficiency in Die Casting Operations’. DOE 2012. Ariff, Tasnim et al. ARPN Journal of Engineering and Applied Sciences. 2015. ‘Enhanced heating mechanism of the electric metal melting furnace in traditional foundry’. ARPN 2015. National Academies. 1985. ‘Plasma Processing of Materials. NA 1985. Electric Power Research Institute. 2012. ‘Electric Forklifts’. EPRI 2015. Washington State Energy Code. 2021. Table C403.3.2(5). WA 2021 Energy Code.
	Adoption forecast	Cadmus used planning ramp rates from the 2021 Northwest Power and Conservation Council Power Plan as the basis for electrification adoption forecast, adjusting the ramp rates to account for Inflation Reduction Act incentives for heat pumps and electric forklifts, and based on interviews with industrial customers.	Northwest Power and Conservation Council. 2022. ‘The 2021 Northwest Power Plan’. The 2021 Northwest Power Plan. Cadmus interviews with ten Tacoma Power industrial customers.
Port of Tacoma	Electrification potential	For the Port of Tacoma Cadmus used electrification potential developed by the South Harbor Electrification Roadmap.	Port of Tacoma. 2023. ‘South Harbor Electrification Roadmap’.
	Adoption forecast	To estimate electrification in the Port of Tacoma, Cadmus leveraged South Harbor Electrification Roadmap adoption curves, adjusting maximum achievability by terminal group as per Tacoma Power’s feedback.	Port of Tacoma. 2023. ‘South Harbor Electrification Roadmap’.