EXH. JJJ-6
DOCKETS UE-22___/UG-22___
2022 PSE GENERAL RATE CASE
WITNESS: JOSHUA J. JACOBS

BEFORE THE
WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION, **Complainant,** **v.** **PUGET SOUND ENERGY,** **Respondent.**	**Docket UE-22____** **Docket UG-22____**

FIFTH EXHIBIT (NONCONFIDENTIAL) TO THE
PREFILED DIRECT TESTIMONY OF

JOSHUA J. JACOBS

ON BEHALF OF PUGET SOUND ENERGY

JANUARY 31, 2022

Energy+Environmental Economics

E3 PSE Gas Utility Decarbonization

Beyond Net Zero Scenario Analysis

2021-9-3

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Agenda

- **Context**
- **Decarbonization options**
- **Scenario Results**
  - Gas System Impacts
  - Electric System Impacts
  - Costs
- **Conclusions**
  - Key Takeaways
  - Next Steps

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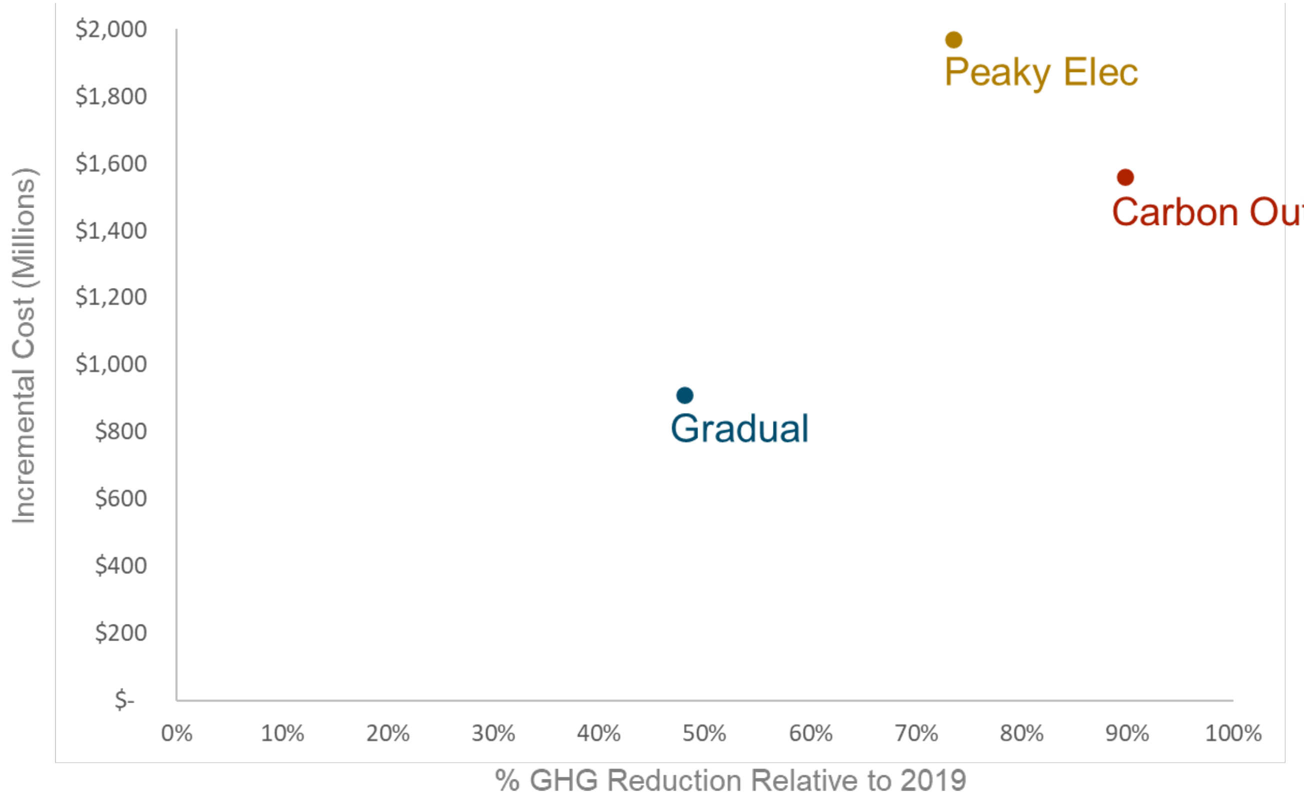
Context

E3's 2020 Study

2050 total Scenario Costs from E3's 2020 Analysis

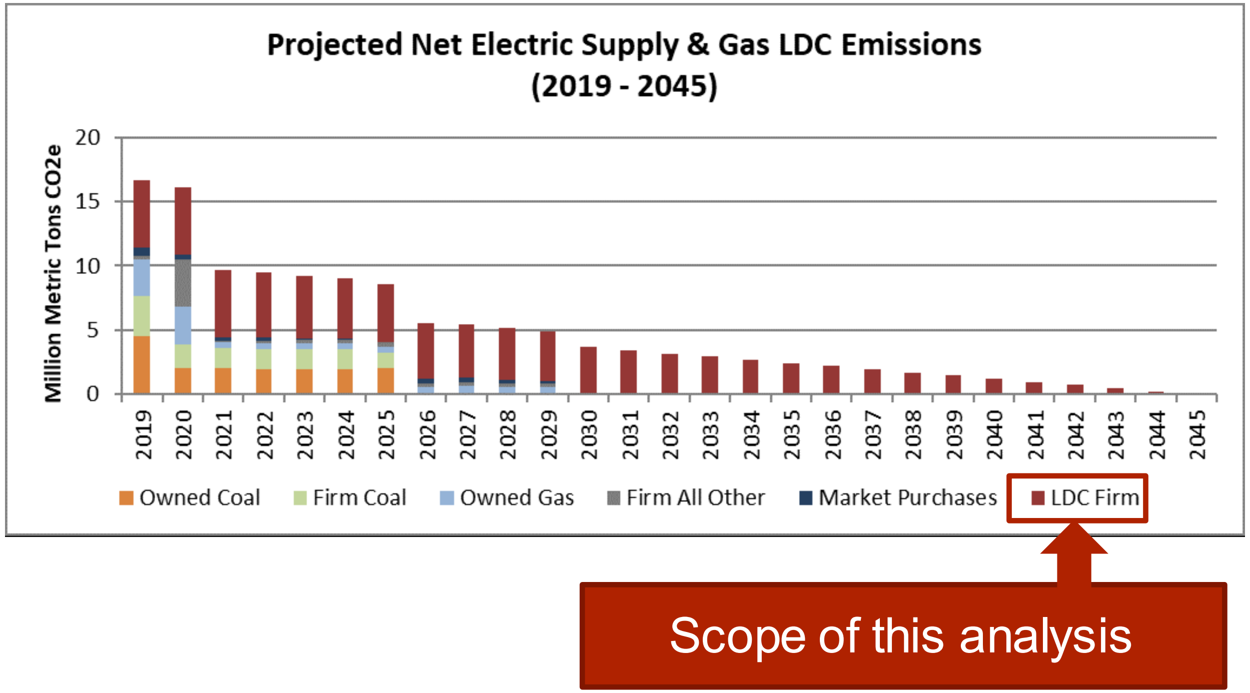


- In 2020, E3 developed an assessment of decarbonization scenarios for PSE's gas utility.
- We found the Carbon Out scenario that balances electrification with continued use of the gas system to be the most cost effective decarbonization option.
- That study used high level assumptions and did not include a deep dive into impacts on PSE's system and customers.
- In early 2021, PSE published its "Beyond Net Zero" white paper, targeting 30% reductions in gas utility emissions by 2030 and 100% reductions by 2045.

This Study

- **This study takes a more detailed look at gas decarbonization scenarios consistent with Beyond Net Zero**
  - All scenarios are assumed to achieve both the 2030 and 2045 GHG reduction targets
- **Both PSE and E3 conducted modeling in support of this study**
  - E3 developed scenarios that track overall GHG emissions, assed the annual and peak demand impacts of scenarios on both PSE's gas and electric systems, evaluated the cost of decarbonizing gas supply and developed a framework to examine customer costs.
  - PSE's gas and electric system planning teams, as well as the electric resource planning team, used the loads produced by E3 to model changes in infrastructure and investment in each scenario. Those changes, combined with the gas supply costs developed by E3, were then used by PSE's financial planning team to estimate long-run impacts on revenues and rates.
  - E3 used PSE's rate outputs in our customer cost framework to draw out the implications of the decarbonization scenarios for residential customers.
- **PSE also provided additional input on E3's modeling assumptions**
  - Example: PSE identified limitations in the Northwest Pipeline's system that reduce the amount of hydrogen that can be delivered to PSE's system through existing infrastructure.

Scope of E3's analysis



In addition to the analysis described in this presentation, E3 also provided PSE with a model that can be used to evaluate gas decarbonization scenarios on an ongoing basis.

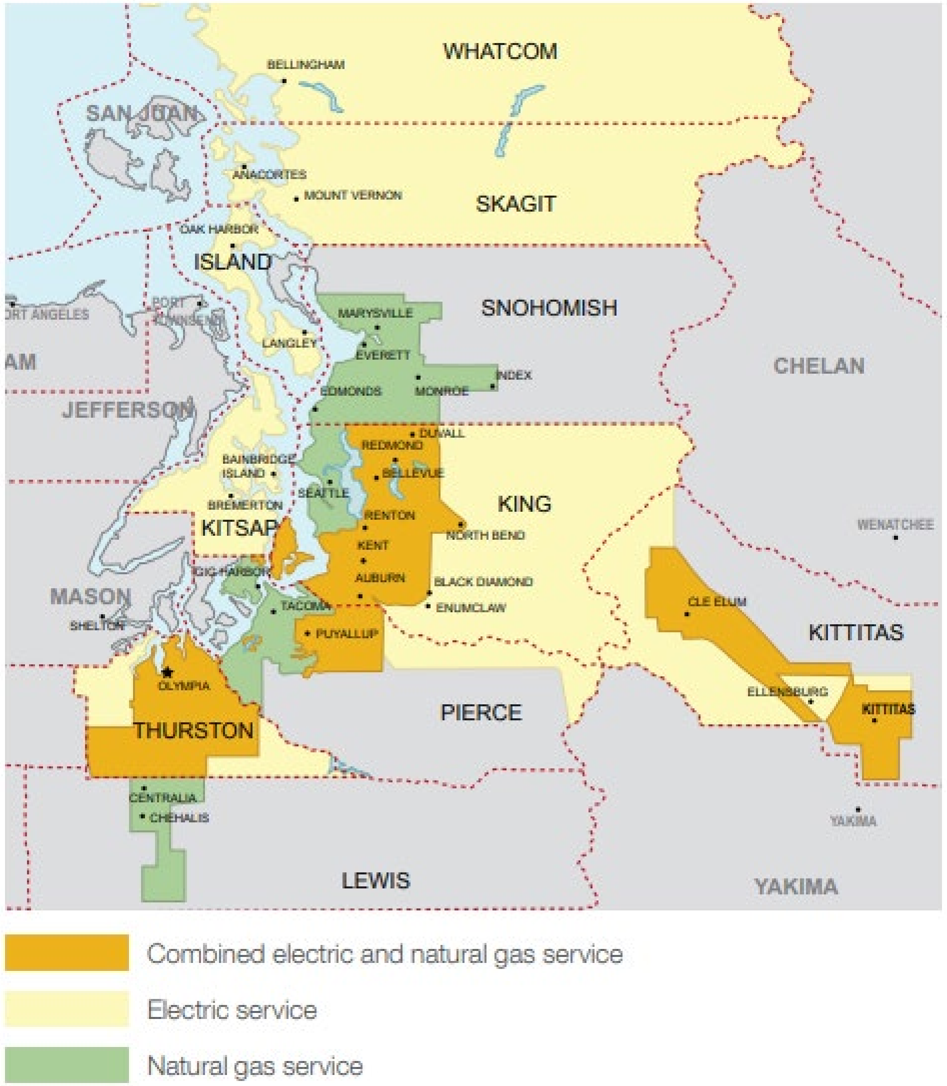
+ Context

- In 2020, E3 worked with PSE and BCG to inform the "PSE 2030" initiative
- In 2021, PSE made the "Beyond Net-Zero" commitment. This includes an aspirational goal of a 30% reduction in gas utility emissions by 2030 and net-zero emissions by 2045

+ This study

- Develop a gas utility decarbonization supply curve
- Implement decarbonization scenarios, first-pass rate impacts and customer economics
- Pass outputs to PSE for system planning and resource planning analysis
- PSE financial analysis
- Updated rate impacts and customer economics

Geography of PSE's gas system



+ **Approximately 50% of PSE's gas customers are also PSE electric customers.**
+ **The remainder are served by SCL, Tacoma and Snohomish PUD**

PSE Electric/ Cascade
160k Gas Customers

PSE Gas Only
400k Gas Customers

PSE Combined
400k Gas Customers

PSE Gas
Today's focus

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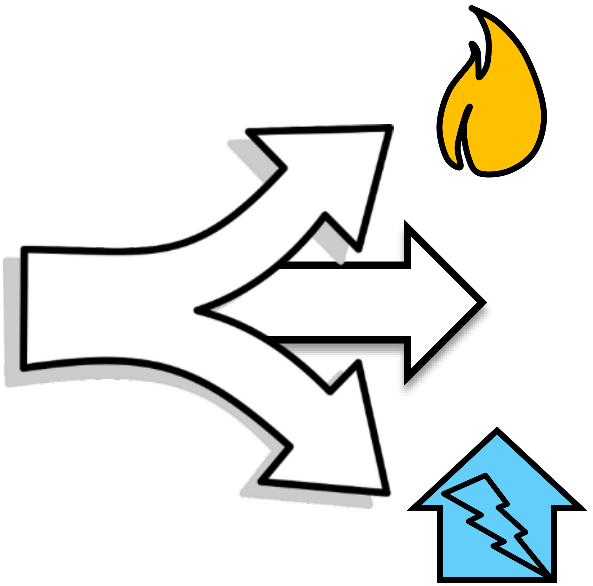
Decarbonization Options

Decarbonization options

Business as Usual Financial Model



<u>Decarbonized gas</u>
Renewable natural gas or hydrogen

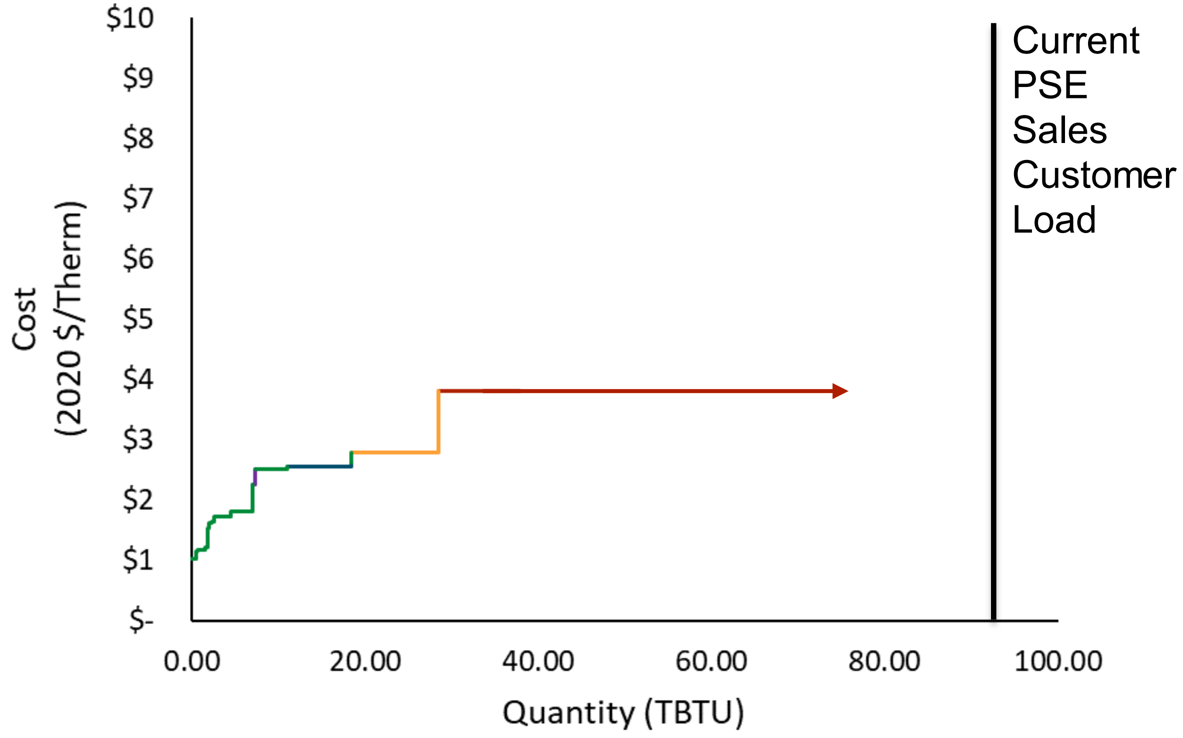
<u>Hybrid</u>
Heat pumps paired with gas

<u>Electrification</u>
Heat pumps, induction stoves

These different scenarios will affect both PSE’s gas supply costs and the utilization of PSE’s gas infrastructure. Those changes will in turn affect rates and customer economics.

Decarbonized Gas

2050 decarbonized gas supply curve

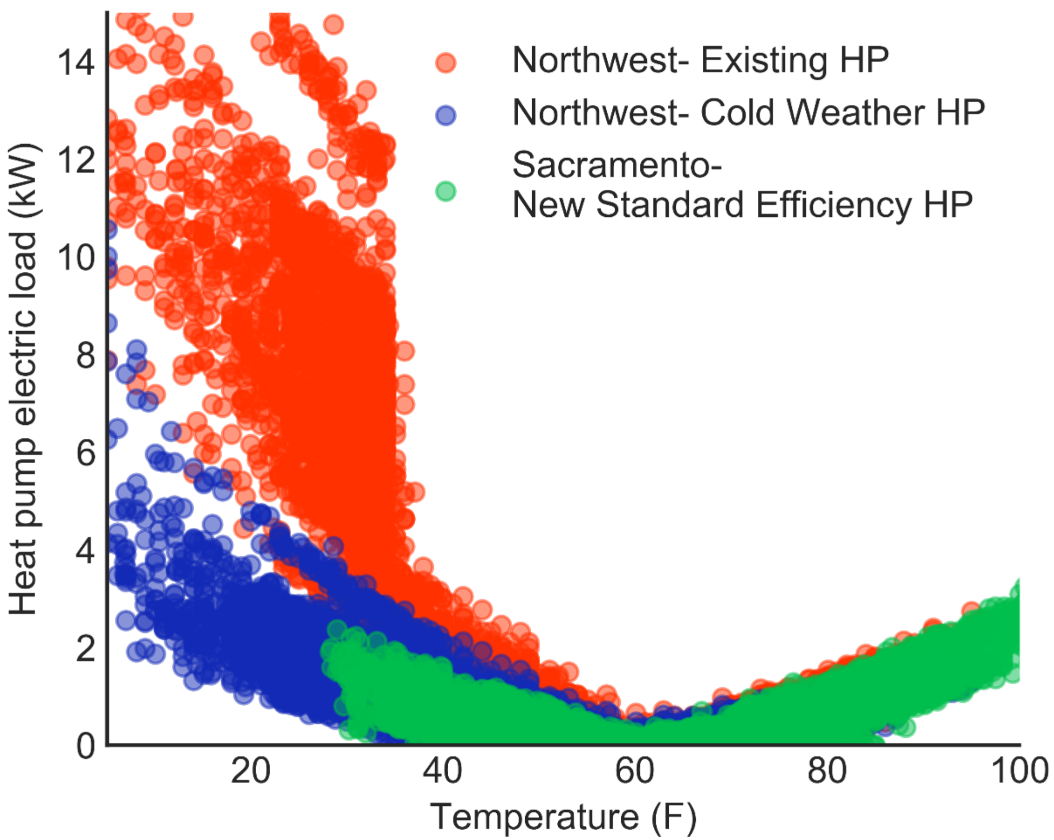


+ E3 worked with PSE to develop refined decarbonized gas supply curves, including the following resources:

- **Biomethane**: sourced from feedstocks like wastewater treatment plants, dairies and agricultural/forest wastes. This resource is lowest cost but is limited by feedstock availability.
- **Hydrogen**: produced via electrolysis using renewable energy. This resource is limited by the suitability of existing infrastructure to deliver hydrogen.
- **Natural Gas Offset by Direct Air Capture (DAC)**: as a proxy for dependable offsets. This resource was capped at no more than 8% of the total decarbonization effort.
- Synthetic Natural Gas (SNG): combines hydrogen and a climate neutral form of CO2. Two sources of CO2 include
  - **SNG made with waste CO2**
  - **SNG made with DAC**

Electrification in PSE's heating dominant climate would add large new electric loads, particularly on peak

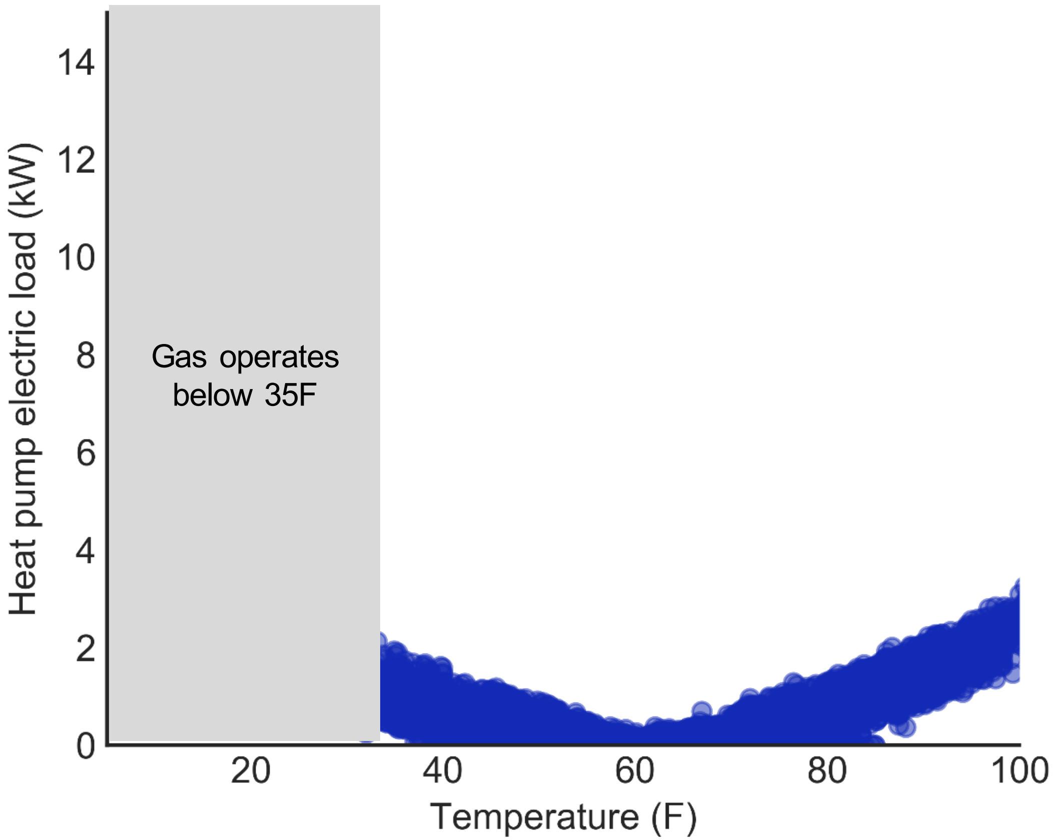
ASHP HVAC loads for a 2200 ft² Home



- **Air-source heat pumps are very efficient on an annual basis, with coefficients of performance (COPs) of 3 or higher possible in Washington today**
- **However, heat pump efficiencies drop as the outdoor temperature falls. This can lead to large impacts on peak demands.**
- **The magnitude of peak demands depends on what type of heat pump is installed**
  - Traditional heat pumps **(Existing HP)** require large amounts of electric resistance backup heat and have large peak impacts.
  - Cold-climate heat pumps **(Cold Weather HP)** reduce, but do not eliminate peak impacts. They also come at a cost-premium.

Hybrid (also called "dual fuel") heat pumps could mitigate the peak impacts of electrification

Hybrid electric load for a 2200 ft² Home



- **Hybrid systems pair an air-source heat pump with a gas furnace or boiler.**
- **The heat pump provides heating energy during most of the year. Customers also receive cooling from the heat pump.**
- **At a certain temperature (typically 35F), the heat pump "locks out" and the furnace or boiler takes over the heating load of the building.**
- **Potential advantages of this approach**
  - Substantially reduces peak demands
  - Continued role for gas distribution system
- **Potential challenges**
  - Consumer economics
  - Ongoing need to maintain the gas system

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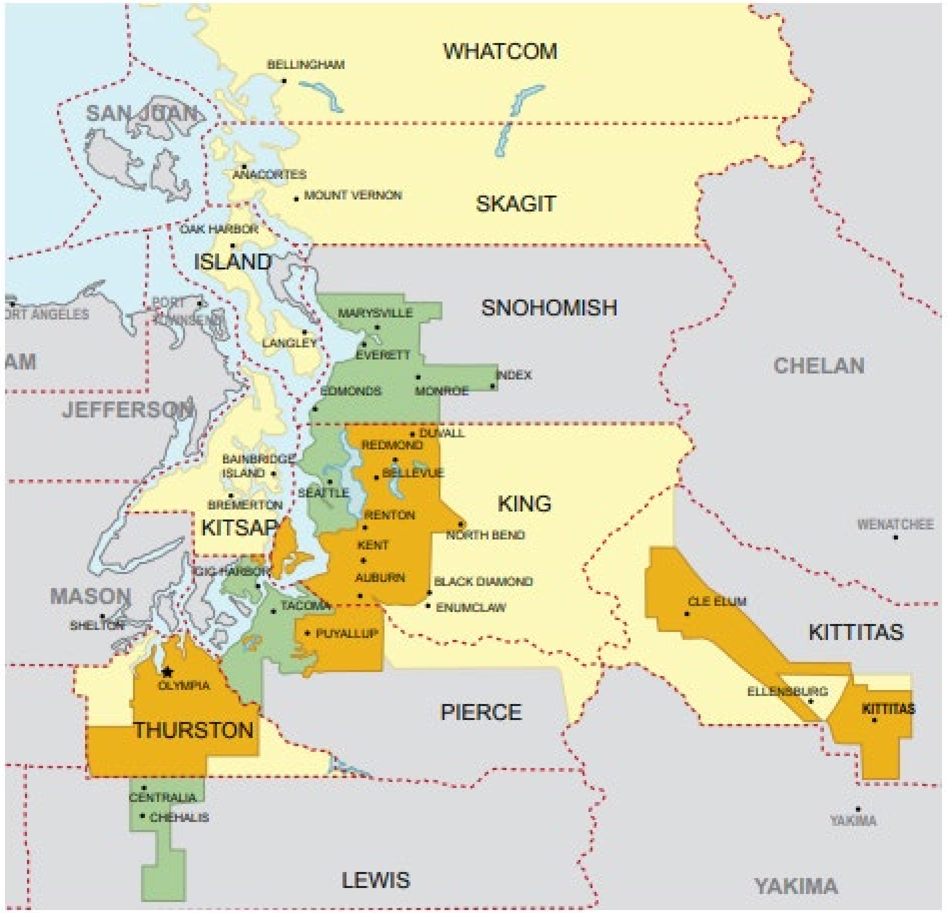
Scenario Analysis

Scenarios

	Scenario 1: Full Electrification	Scenario 2: Carbon Out	Scenario 3: Carbon Out + Additional Electrification
Carbon Target (Non-transport, relative to 2020)	**30% by 2030** **100% by 2045**	**30% by 2030** **100% by 2045**	**30% by 2030** **100% by 2045**
Electrification	**2030 Sales:** • 75% of residential appliances sold are all-electric • 50% of commercial appliances sold are all-electric **2040** • 100% of appliances sold are all-electric	**2030 Sales:** • 50% of water heaters and "Other" appliances sold are all-electric • 50% of HVAC systems sold are hybrid heat pumps • No electrification of gas cooking **2040** • WH, "Other" all-electric sales shares rise to 100% • 100% of HVAC sales are hybrid heat pumps • No electrification of gas cooking	**2030 Sales:** • 50% of water heaters and "Other" appliances sold are all-electric • 25% of HVAC systems sold are hybrid heat pumps, 25% are all-electric • No electrification of gas cooking **2040** • WH, "Other" all-electric sales shares rise to 100% • 50% of HVAC sales are hybrid heat pumps and 50% are all-electric • No electrification of gas cooking
Decarbonized Gas	**RNG and H2 blend as needed to reach 2030 and 2045 targets**		
Negative Emissions	**8% of GHG reductions**		

Impacts on PSE's Gas System

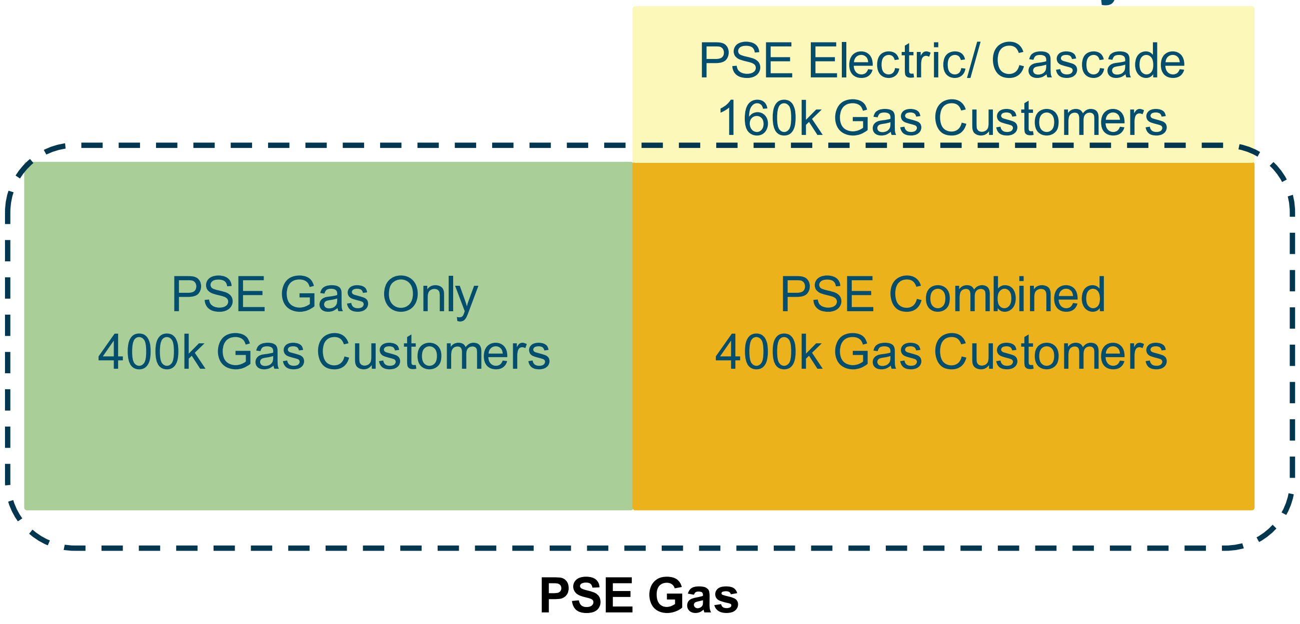


Combined electric and natural gas service

Electric service

Natural gas service

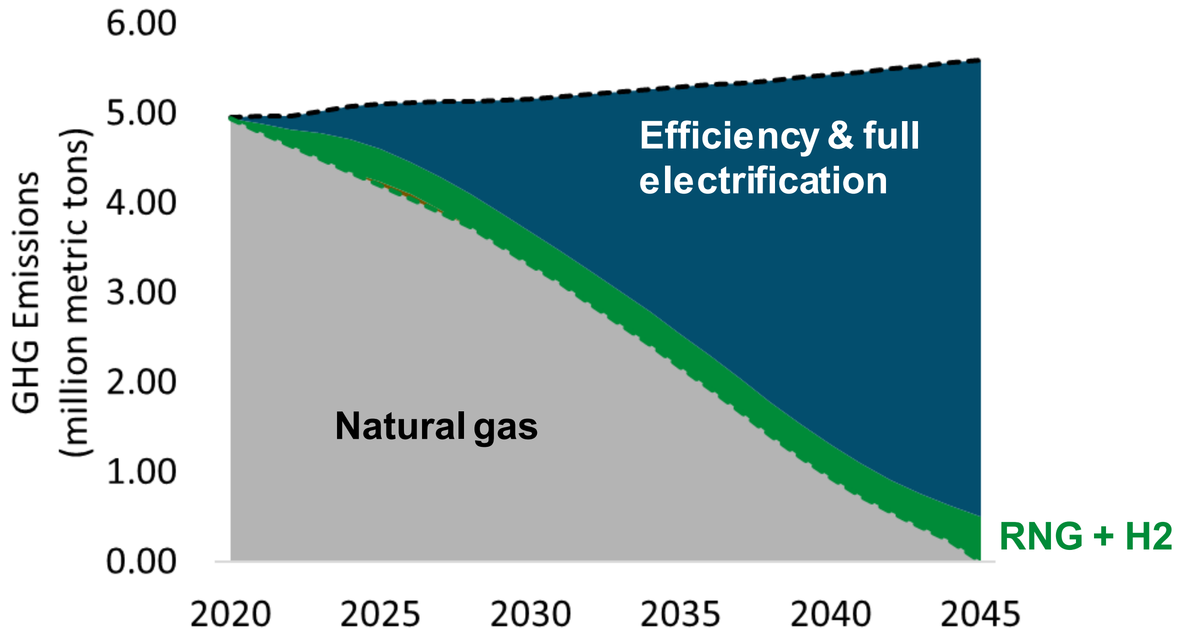
+ **Approximately 50% of PSE's gas customers are also PSE electric customers.**
+ **Most of the remainder are served by SCL, Tacoma and Snohomish PUD.**
+ **PSE's electric system will also be impacted by Cascade Natural Gas customers who electrify.**



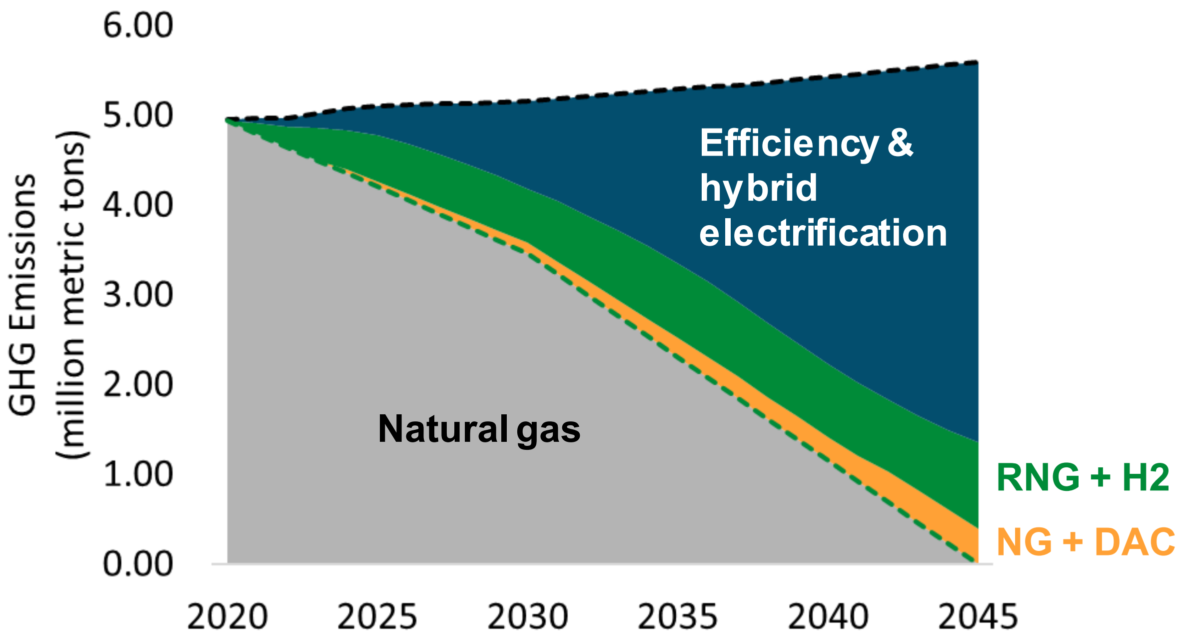
GHG Emissions Over Time

Scenarios vary in their relative emphasis on Electrification Vs RNG

High Electrification - GHGs



Carbon Out - GHGs

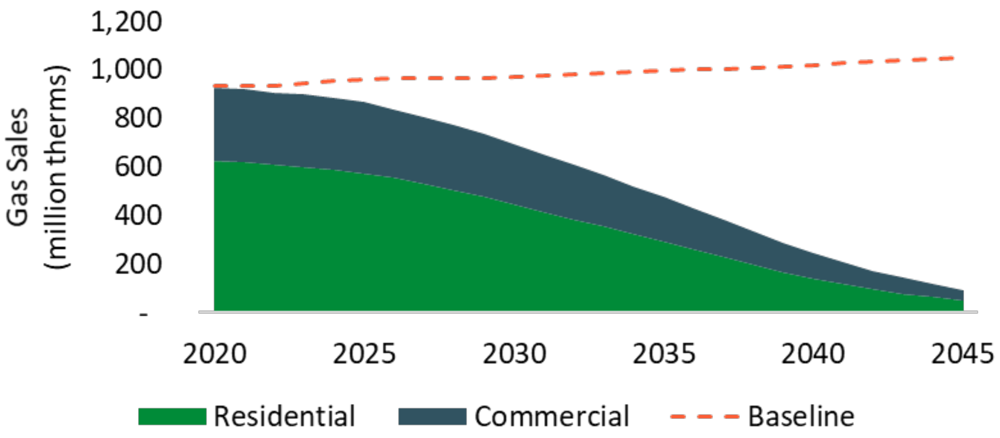


- Electrification is the largest single source of emissions reductions in both scenarios
- RNG is used in both scenarios, with substantial procurements in the 2020s to meet PSE's 2030 Beyond Net Zero Goal

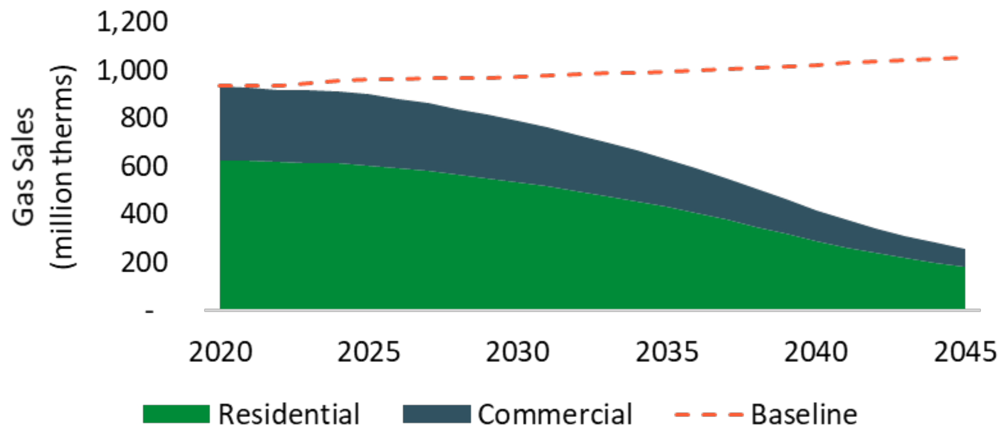
Gas Sales and Customers Over Time

Scenarios have similar changes in throughput, but distinct outcomes for PSE's customer base

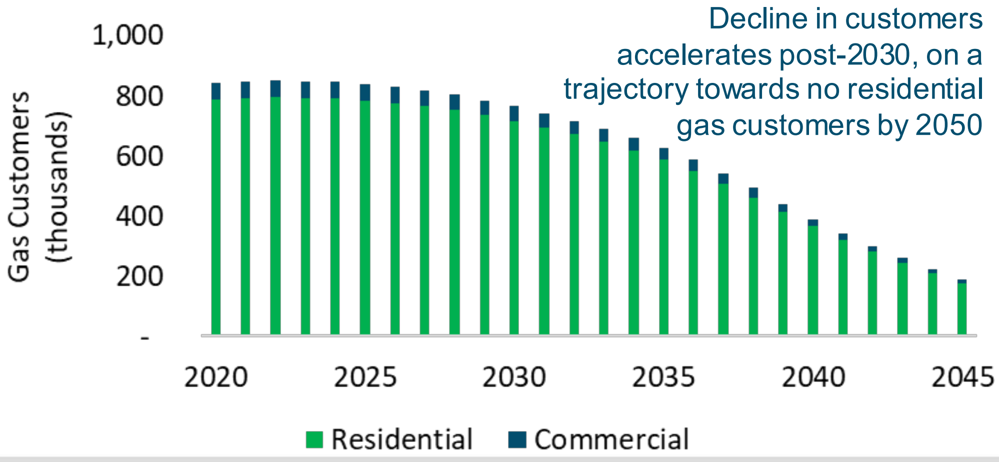
High Electrification Gas Sales



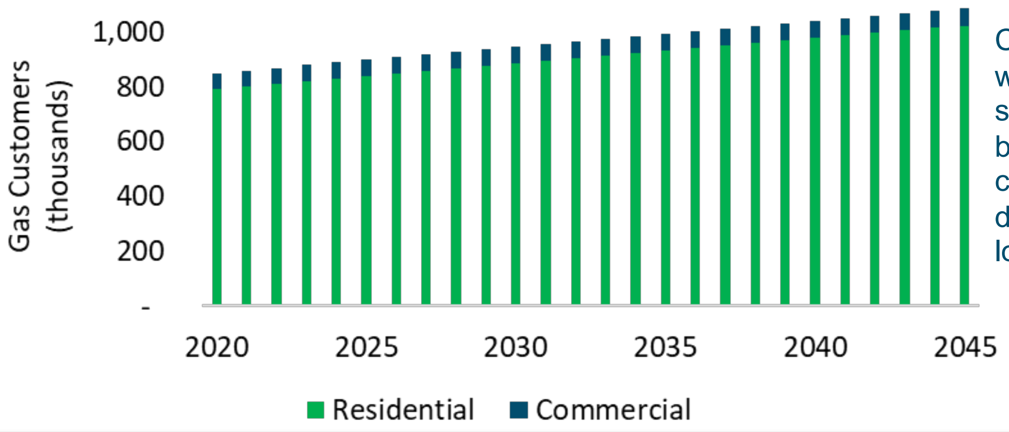
Carbon Out Gas Sales



High Electrification Gas Customers



Carbon Out Gas Customers



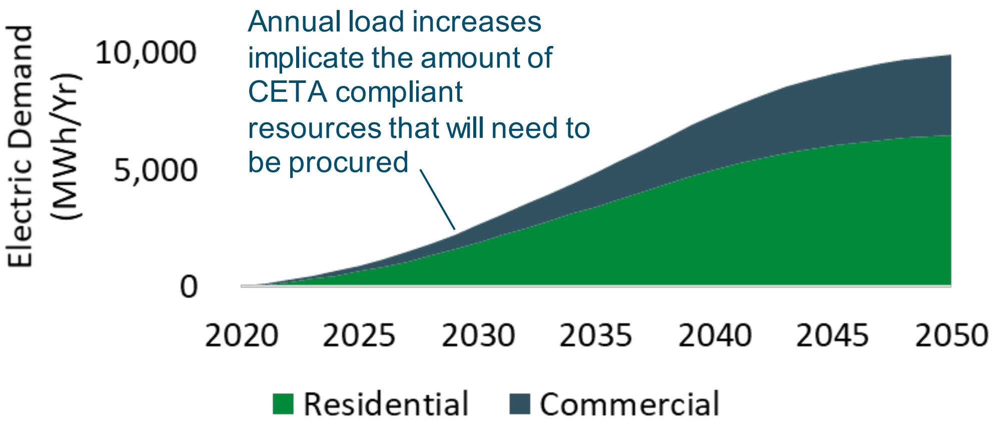
Customer growth was assumed for scenario purposes, but all-electric new construction may be driven by state and local policy

Electric impacts: PSE Gas

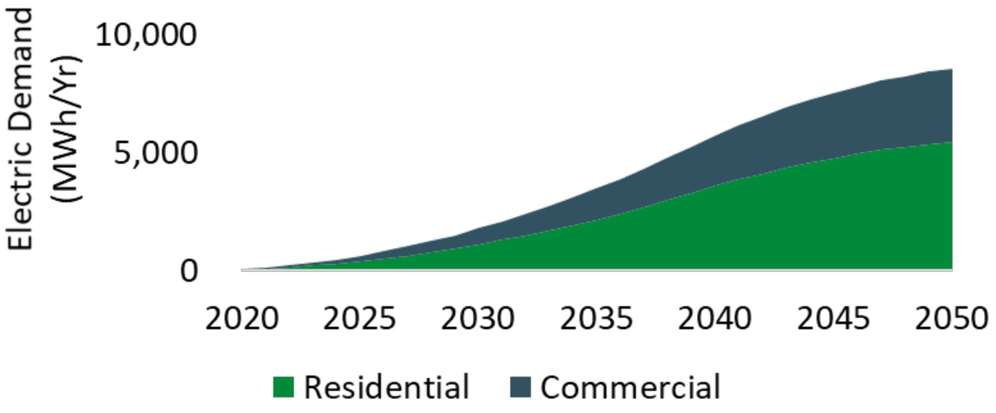
PSE Dual Fuel + Seattle + Snohomish + Tacoma + Other

High Electrification case yields large incremental peak demands, Carbon Out does not

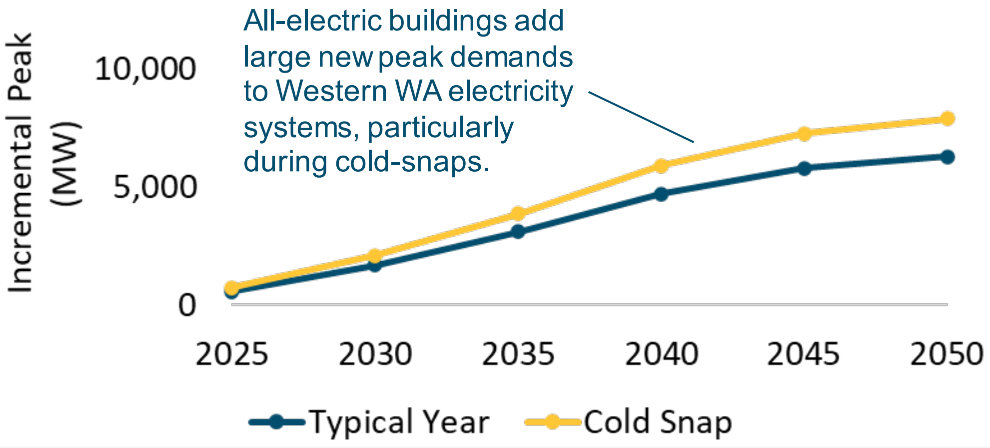
High Electrification - Annual Load



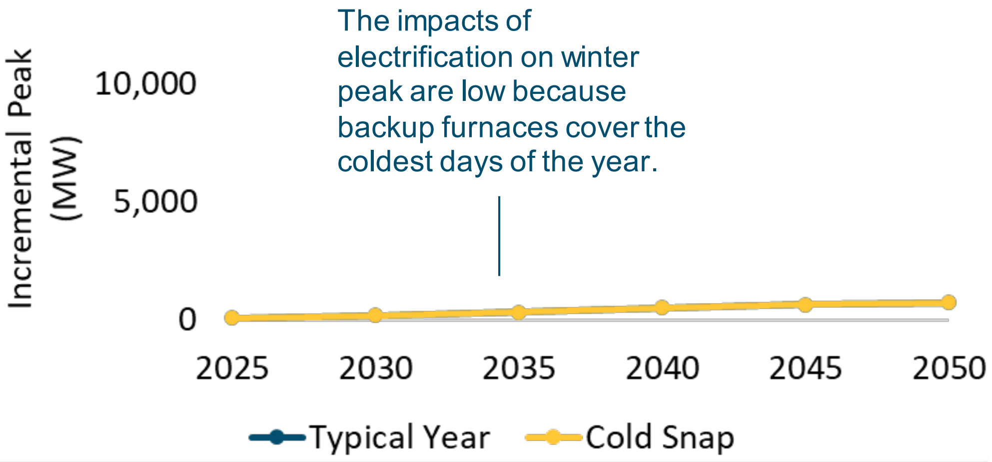
Carbon Out - Annual Load



High Electrification – Winter Peak Demand



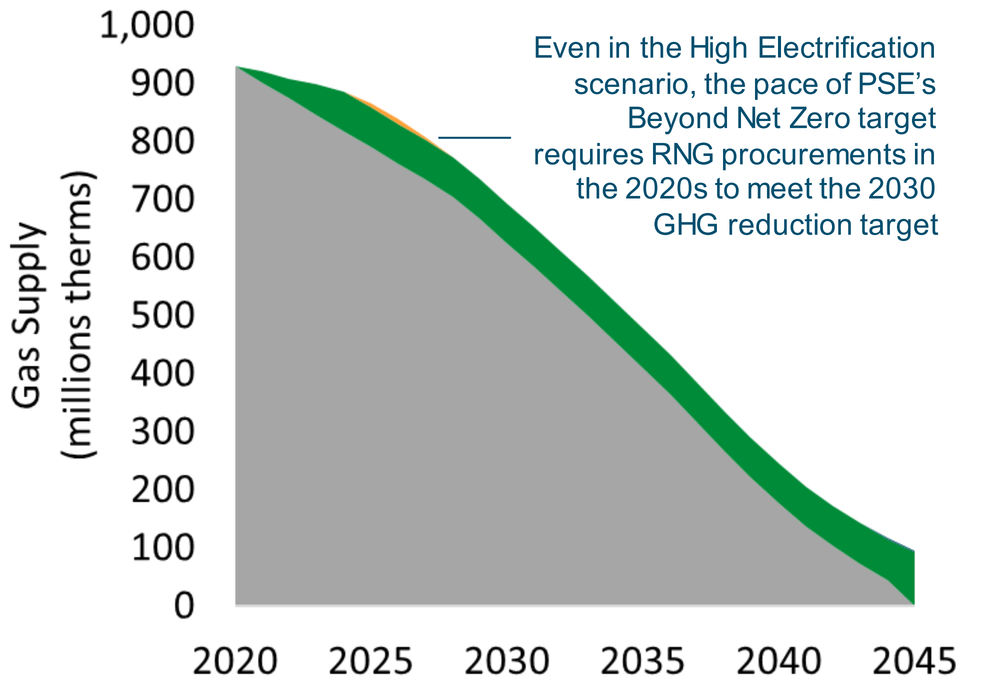
Carbon Out – Winter Peak Demand



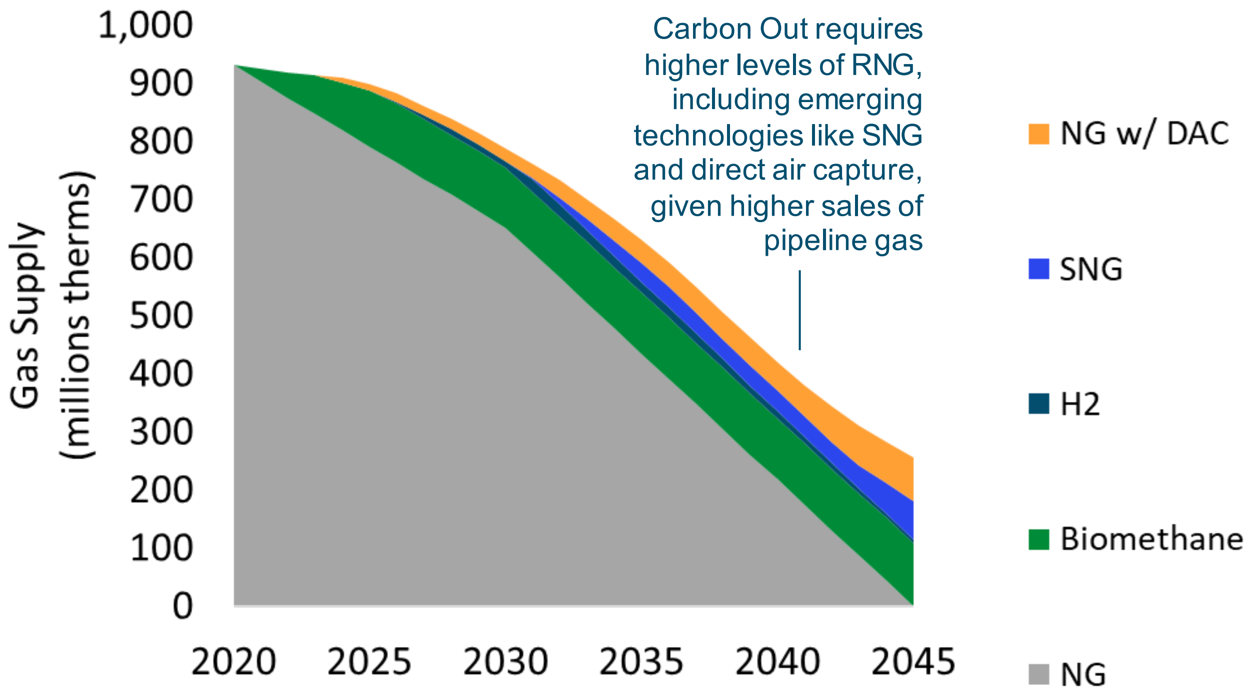
Gas supply

Both scenarios rely on RNG to ensure decarbonization stays on pace with the Beyond Net Zero goals

High Electrification Gas Supply



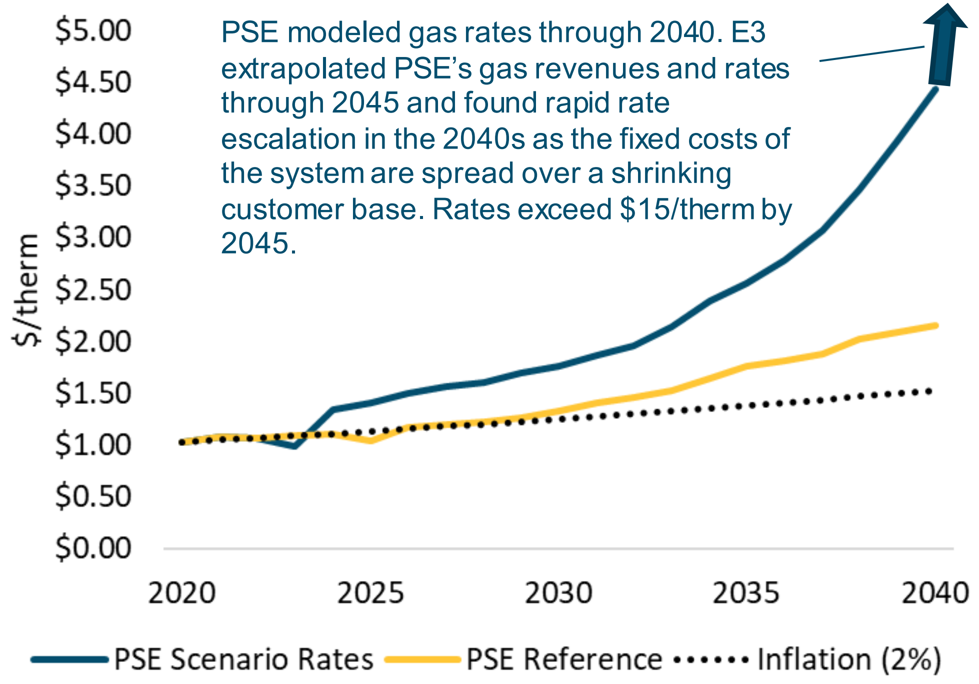
Carbon Out Gas Sales



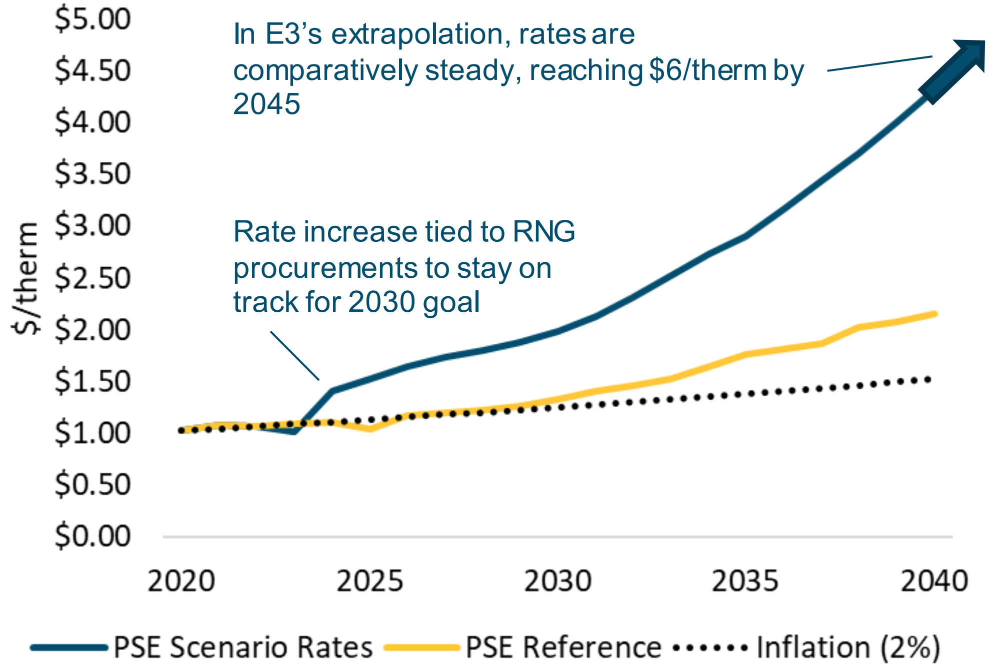
PSE gas rates

Both scenarios see upward pressure on gas rates, but the incidence of these costs are substantially different between the scenarios (discussed below)

High Electrification - Residential Gas Rates



Carbon Out - Residential Gas Rates



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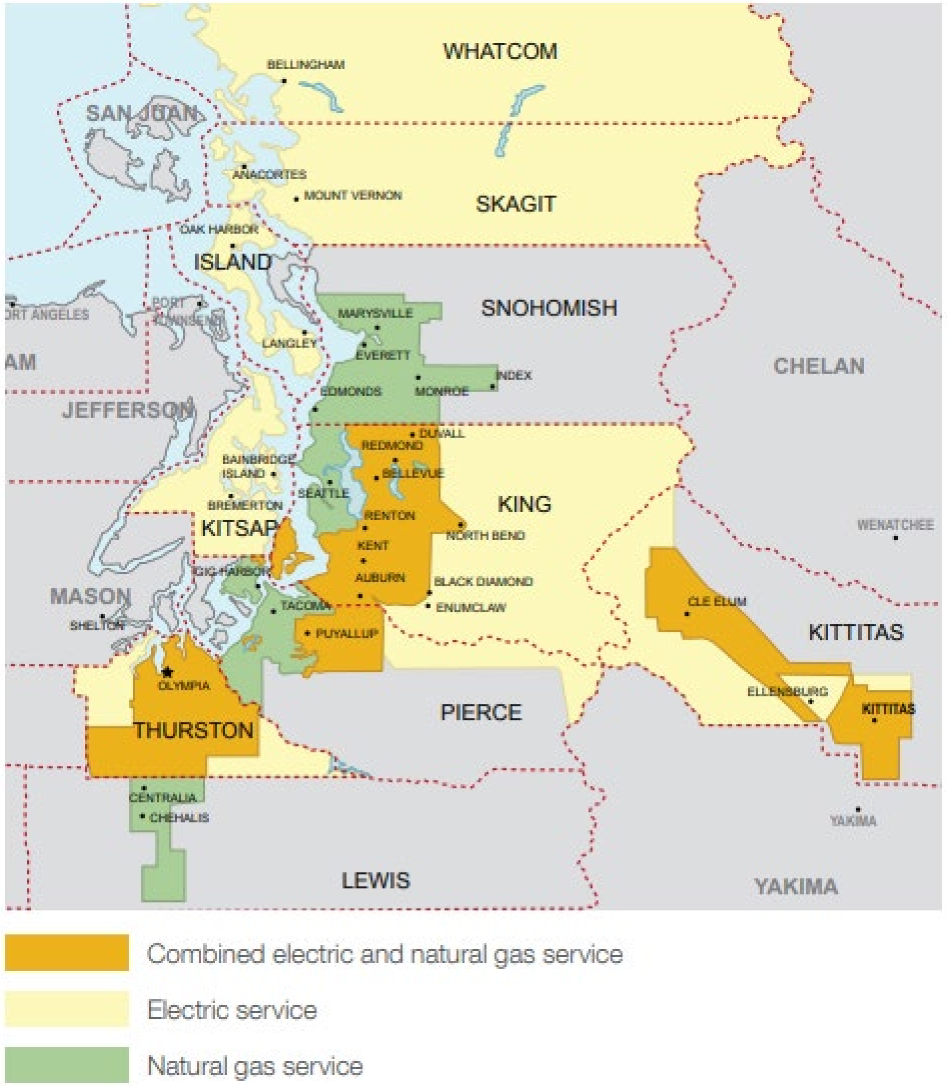
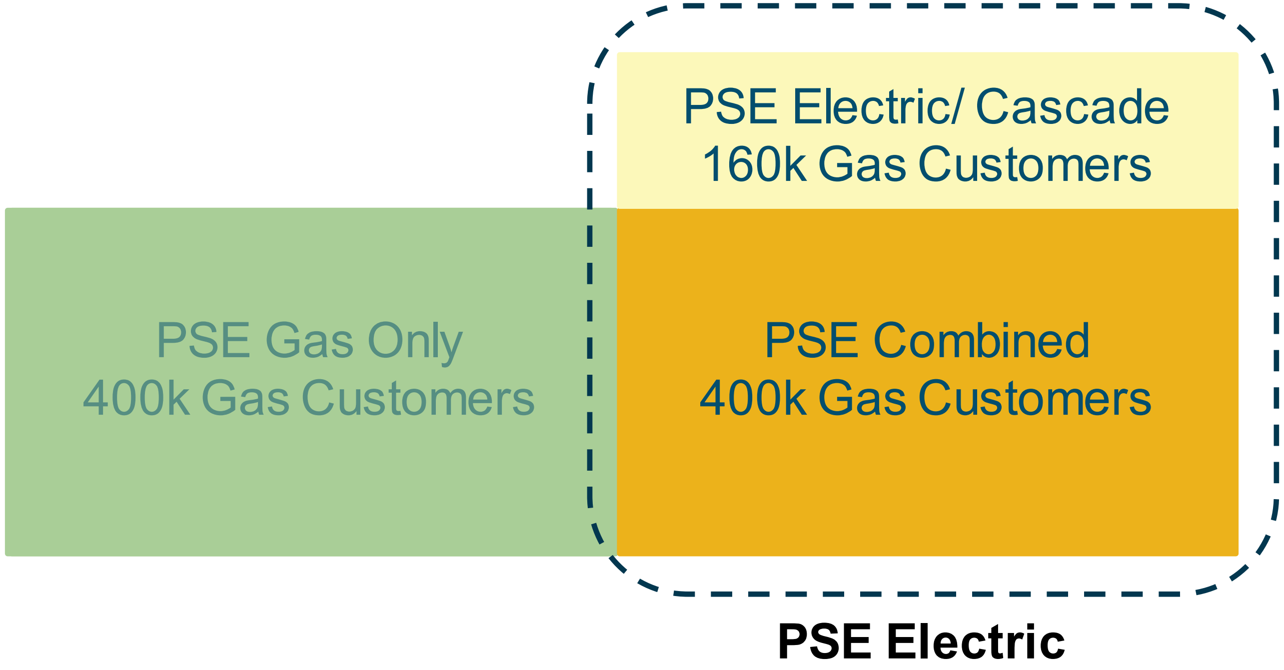
Electric System Impacts

Impact of gas end use electrification on PSE's electric system



+ **In a future with state-wide electrification efforts, PSE's electric system would add load currently served by Cascade Natural Gas.**



Electric sector impacts of gas decarbonization

+ Annual Sales

- In a typical year, the PSE gas system delivers over **26 TWh** of energy to its sales customers. For comparison, PSE's retail electricity sales in 2020 were **20 TWh.**
- Heat pumps can provide annual heating energy very efficiently on a site energy basis
  - In simpler systems, heat pumps are approximately three times more efficient than gas
  - In premium systems, heat pumps can be five times more efficient than gas

+ Peak

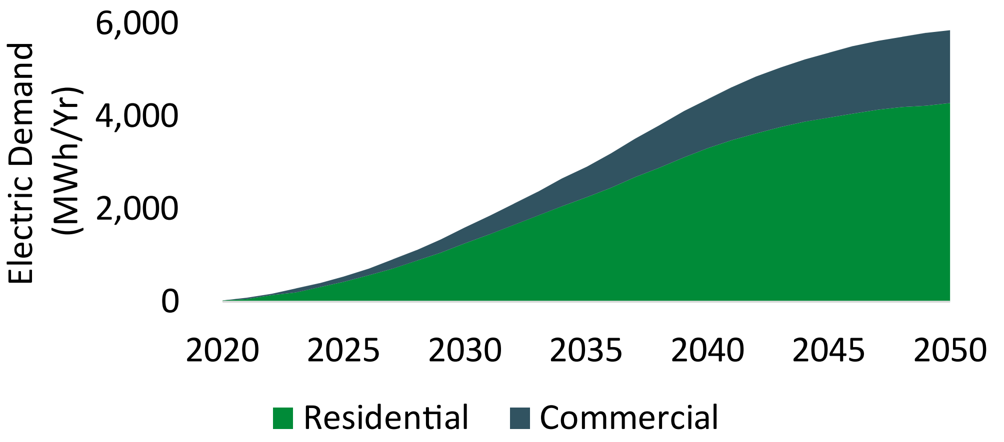
- The PSE gas system design day peak is equivalent to over **12 GW** of electric demand sustained over a 24-hour period. Gas demand during a peak hour is closer to approximately **17 GW**. For comparison, PSE's peak electric demand forecast in the 2021 IRP was **4.7 GW** in 2022**.**
- Modern heat pumps that are designed for cold-weather can continue to deliver heat during Western WA cold-snaps, but their efficiency drops.
  - In simpler systems, heating efficiency drops because electric resistance is used to supplement the heat pump.
  - In premium systems, the heat pump itself uses additional power to "overclock" itself

Electric Impacts: PSE Electric

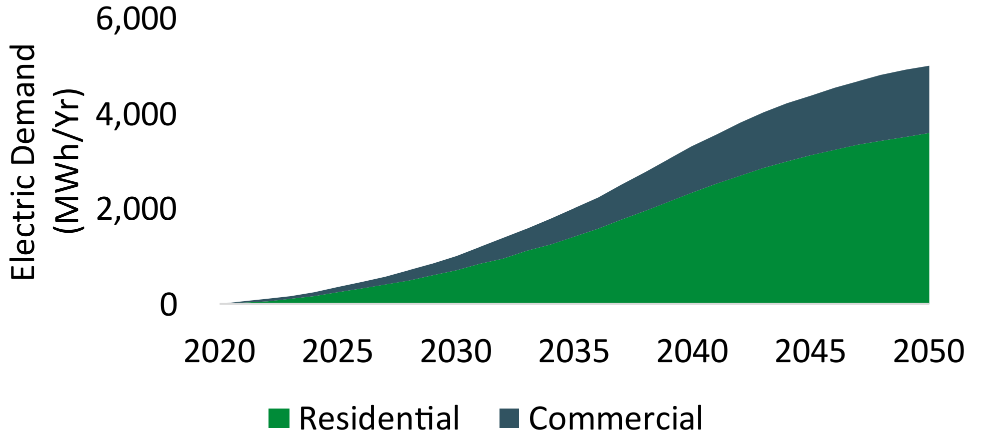
PSE Dual Fuel + Cascade Natural Gas (Whatcom, Kitsap, Skagit)

High Electrification case yields large incremental peak demand, Carbon Out does not

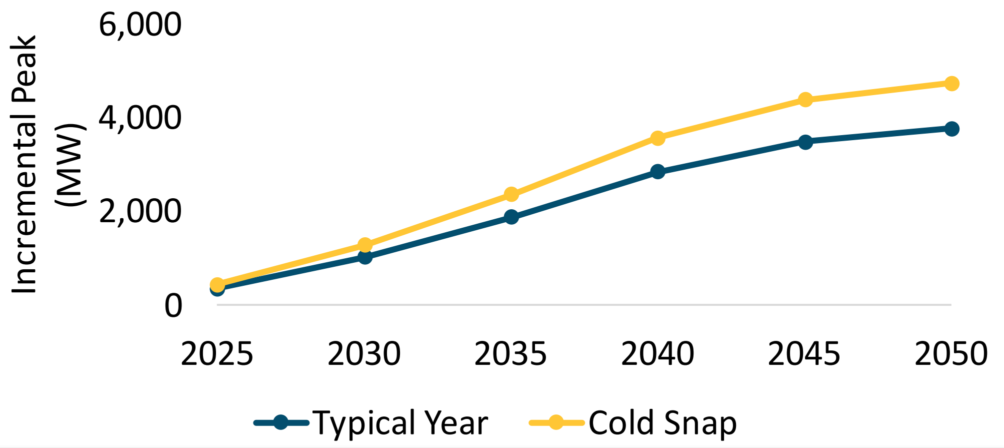
High Electrification - Annual Load



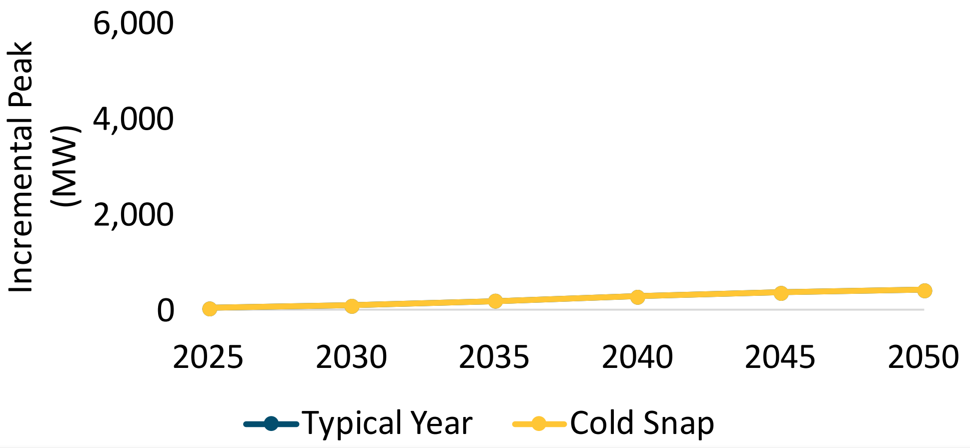
Carbon Out - Annual Load



High Electrification – Winter Peak Demand



Carbon Out – Winter Peak Demand



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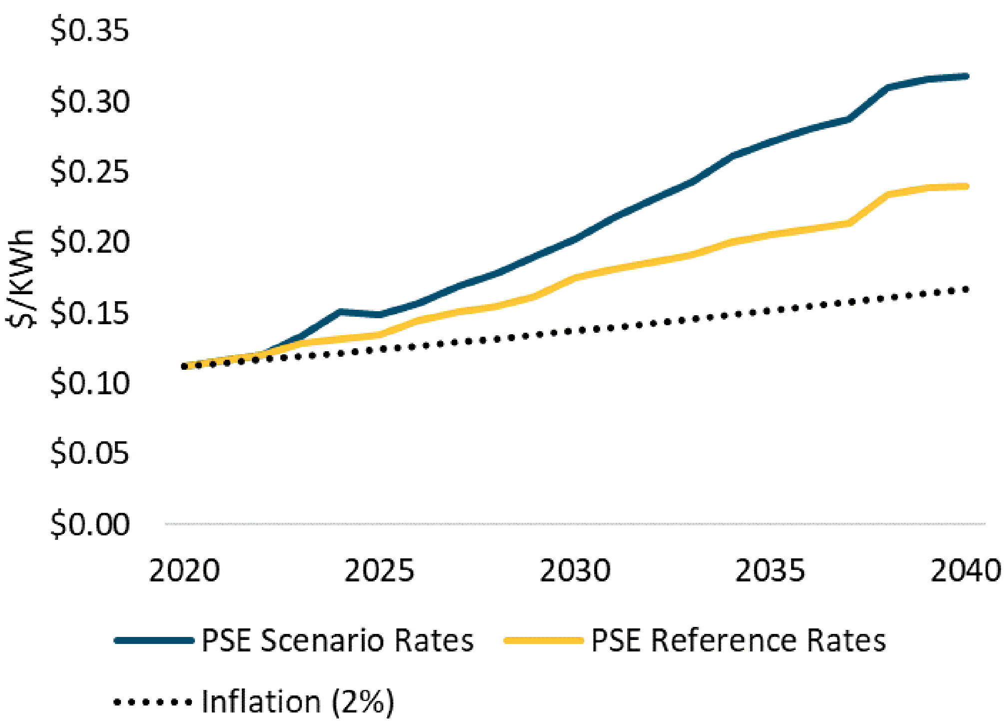
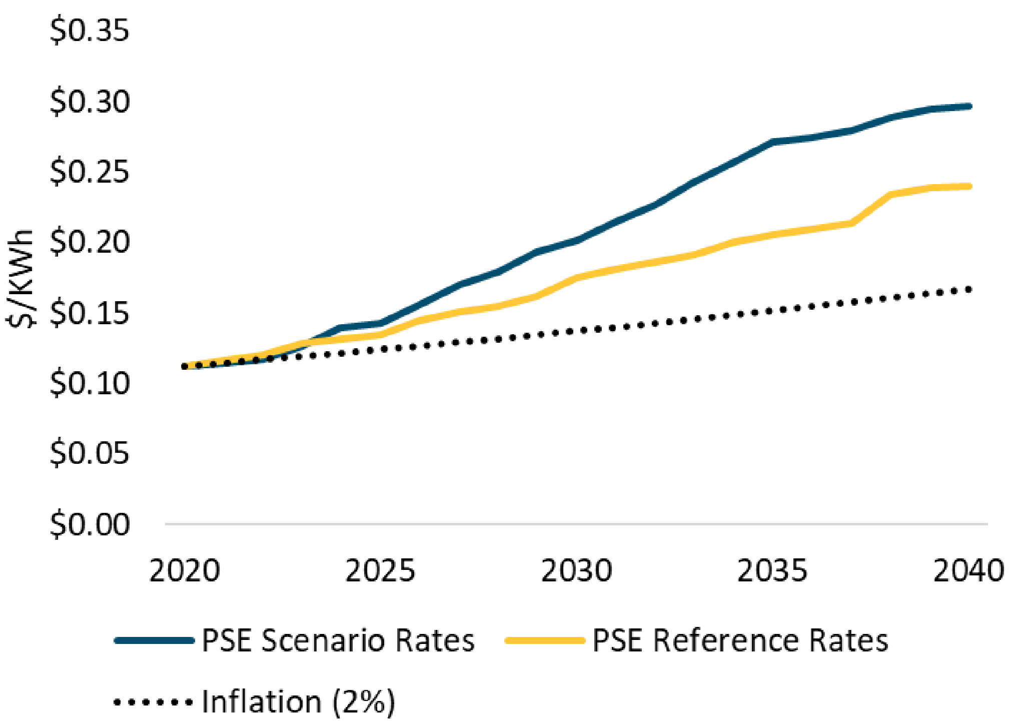
PSE electric rates

+ PSE used the outputs from E3's load scenarios to assess portfolio and system costs
+ Those costs were then converted into rates by PSE's financial planning team

High Electrification - Average Electric Rate



Carbon Out - Average Electric Rate



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Costs

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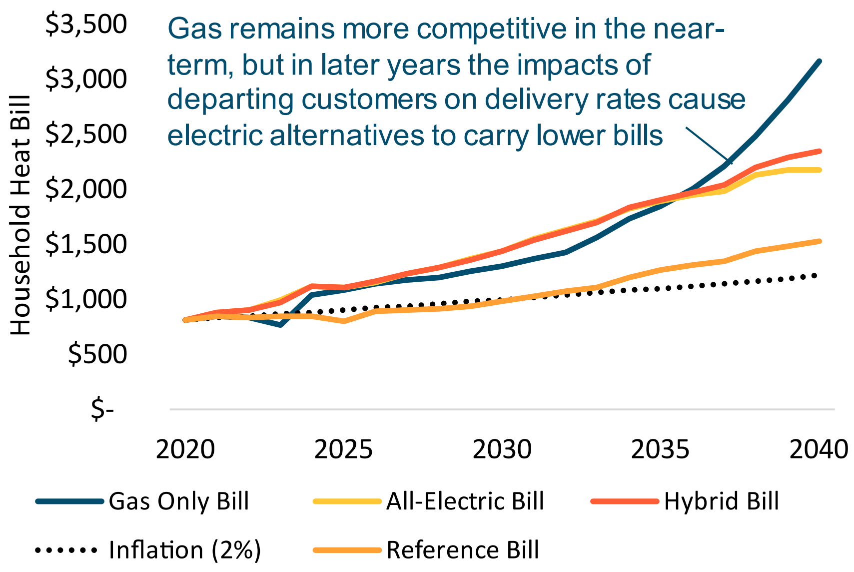
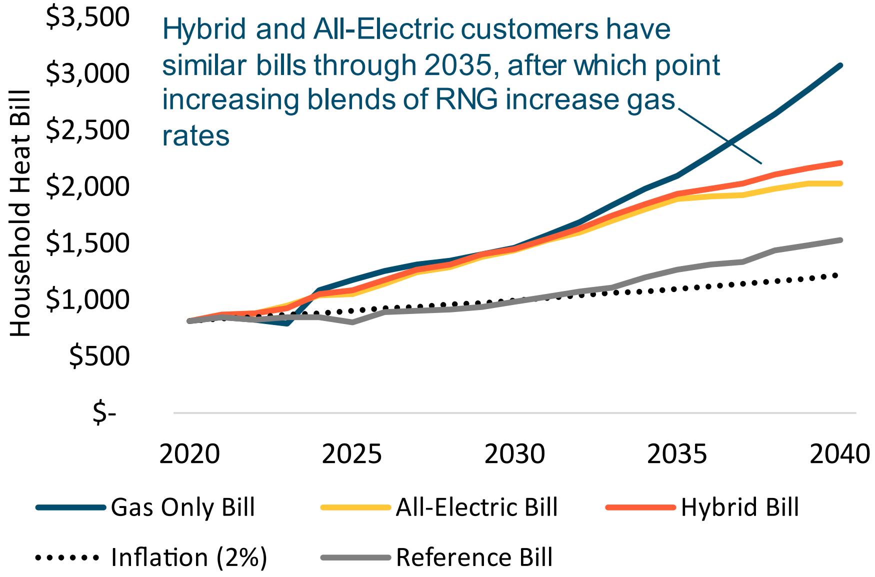
Residential customer bill impacts

Heating bills increase in all scenarios

High Electrification – Res Heating Bills



Carbon Out – Res Heating Bills



+ **In the near-term, increases in the cost of heating are driven by RNG procurements to meet the 30% reduction by 2030 goal.**
+ **Longer-term, bill increases are driven by a combination of electric supply and infrastructure costs, additional RNG procurements and higher gas delivery rates as utilization falls.**

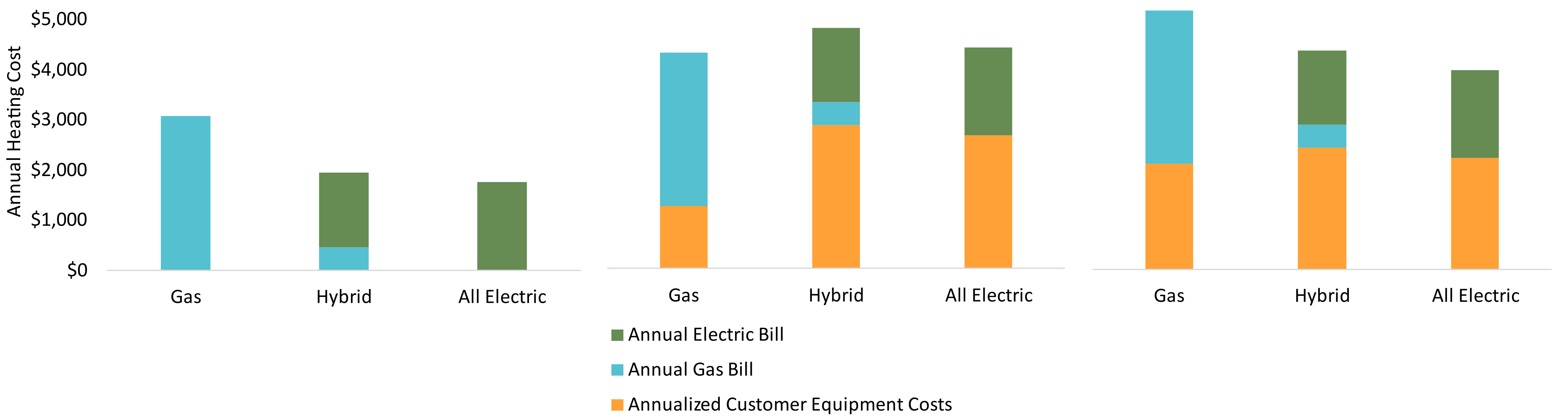
Notes on the consumer economics of electrification from a total cost of ownership perspective

+ **The consumer economics of electrification are heterogenous, but can be put into two broad categories for the residential sector**
+ **Lower cost residential opportunities: A customer in a newer home with central AC.**
  - A heat pump provides both heating and cooling, and so can replace both a furnace and a central AC unit.
  - These customers are also far more likely to have the necessary wiring and service panel capacity to accommodate a heat pump.
  - This category of customers is expected to increase over time
+ **Higher cost residential cases: A customer in an older home without AC**
  - A heat pump is approximately twice (or higher) the cost of a stand-alone furnace.
  - These customers are also more likely to require electrical and other home upgrades.
  - This category of customers is expected to decrease over time
+ **Hybrid systems: Carry a small price premium compared to lower cost all-electric heat pumps**
  - Furnaces are more costly than air handlers that accompany a heat pump
  - However, in some cases a hybrid may avoid the need for costly panel upgrades or ductwork
+ **The commercial sector is far more diverse**

In 2040, many customers will face an incentive to fully electrify their homes

- **Customers save on their heating bills because gas rates rise more quickly than electric rates**
- **The differential in bills is large enough that customers will also see savings in terms of total cost of ownership.**
  - This is true in both a High Conversion Cost retrofit case and a Low Conversion Cost retrofit case

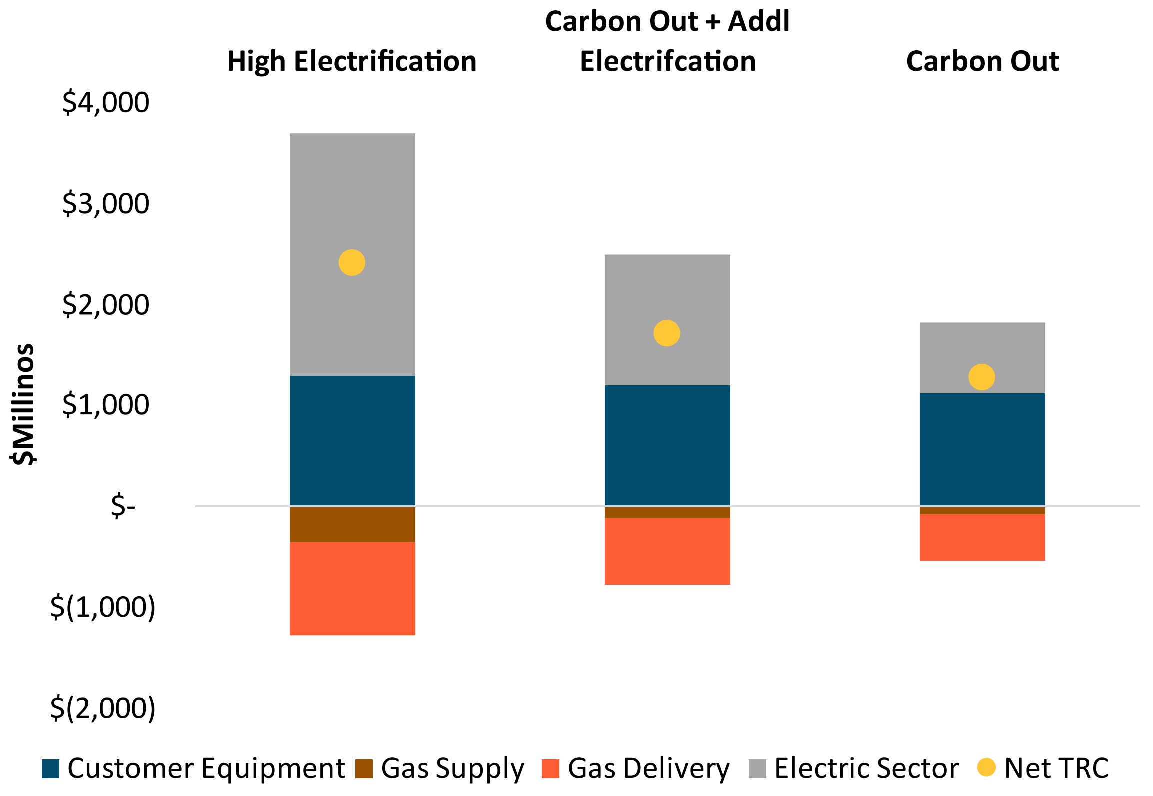
2040 Heating Bills	2040 TOC Heating Costs Higher Cost	2040 TOC Heating Costs Lower Cost



Note: units are in nominal dollars assuming 2% inflation per year

Total Cost to Decarbonized PSE's Gas Utility: Base Case

2045 Annual Total Resource Cost by Scenario ($2021)

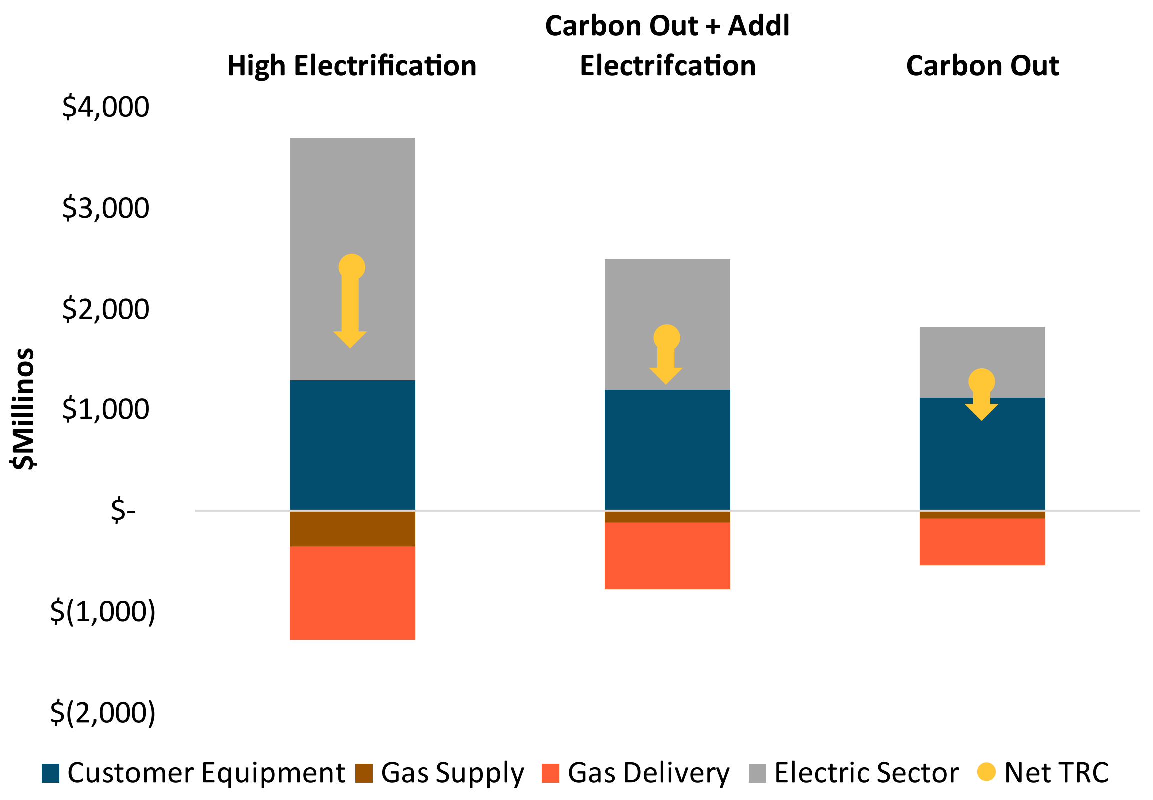


Note: these costs are for the entire PSE gas geography, including non-PSE electric service territories. Costs are derived from E3's Gas Decarbonization Model. E3 has attempted to align with PSE's model outputs, but there may be differences.

- **Consistent with our 2020 analysis, E3 found that Carbon Out is the lowest cost strategy to meet PSE's gas decarbonization goals among the scenarios considered here.**
  - The largest difference between the scenarios are electric sector costs, which are much lower in scenarios with hybrid heat pumps.
- **Total scenario costs are more differentiated than the customer costs shown on the previous slide**
  - This is because, under current regulation and ratemaking, the incremental costs of an all-electric customer are socialized.
  - Time-varying rates or demand response payments to hybrid customers may be needed to align customer incentives with energy system value.

Total Cost to Decarbonized PSE's Gas Utility: Lower Range

2045 Annual Total Resource Cost by Scenario ($2021)



Note: these costs are for the entire PSE gas geography, including non-PSE electric service territories. Costs are derived from E3's Gas Decarbonization Model. E3 has attempted to align the costs with PSE's model outputs, but there may be differences.

+ **Electrification costs could be considerably lower as technology improves over time**
  - The electric system impacts of electrification could be lower if customers install equipment with higher efficiencies and improved performance during cold-weather.
  - Today, those systems come at a substantial cost premium relative to conventional heat pumps, but those costs may fall over time.
+ **Decarbonized gas costs could be lower than modeled here**
  - E3 assumed cost declines in RNG and hydrogen.
  - However, costs could be lower if targets like the US DOE "Hydrogen Shot" ($1/kg H2 by 2030) are achieved.

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Key Takeaways

Key Takeaways

- Both RNG and electrification have important roles in decarbonizing PSE's gas utility
- Electrification alone leads to large peak demand impacts on PSE and its neighbor utilities
- Hybrid heat pumps can substantially reduce those electric peak impacts, lowering electric sector costs and providing a path forward for gas distribution infrastructure
- Consumer economics and decision-making will be an important determinant for how gas utility decarbonization occurs
  - Under current rates and policy, consumers may be incentivized to make decisions that are sub-optimal from a system perspective.
- Shifts in rates and policy are needed to better align consumer incentives with lower cost system outcomes

Potential Next Steps

+ Evaluate regulatory and policy changes needed to achieve Beyond Net Zero vision, for example

- **Align Customer Incentives with System Value**: identify rate or compensation structures that encourage customers to adopt hybrid heat pumps or take other actions to mitigate electric system impacts.
- **Find Mechanisms to Compensate the Gas System for its Value:** for example, Hydro Quebec and Energir recently developed an agreement whereby Hydro Quebec will compensate Energir for avoided electric peak system benefits of hybrid heat pumps.
- **Consider Changes to Cost Recovery and Cost Allocation**: in scenarios with declining and changing system utilization, gas system costs may need to be recovered (e.g., accelerated depreciation) and allocated (e.g., remaining commercial customers pay more) differently.
- **Supportive policies for RNG and hydrogen:** including subsidies and regulatory authorization to procure RNG and hydrogen.

+ Consider the impacts of heat decarbonization on a regional basis:

- **"PNW Peak Heat Study"**: In partnership with consumer owned utilities, other gas utilities, BPA and pipeline companies, the "Peak Heat" study would evaluate the ability of regional infrastructure to meet heating loads under alternative decarbonization scenarios.

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Thank You

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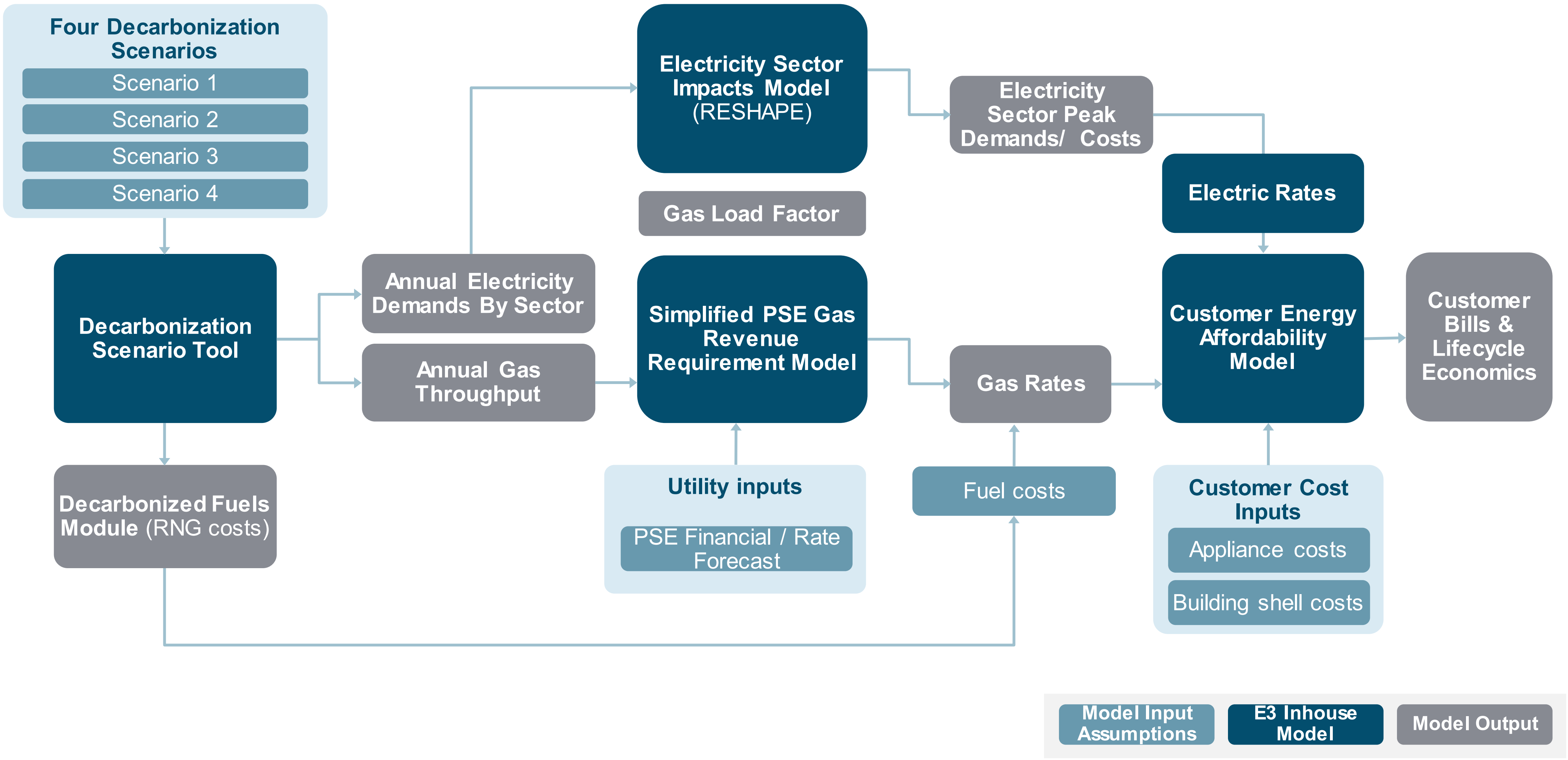
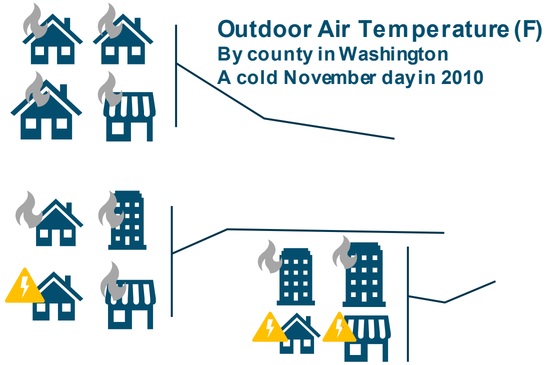
Analysis Flow



E3 uses our RESHAPE model to simulate hourly electrification load shapes at a system level

1. Building Stock and Weather History

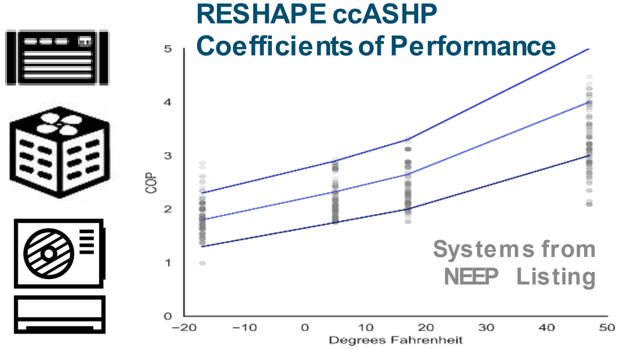


Create a diversified sample of buildings at the county level

Outputs

- A large sample of buildings by county, each with hourly building heat demand and distinct weather profile

2. Detailed Heat Pump Representation



Represent heat pump performance, sizing and supplemental heat

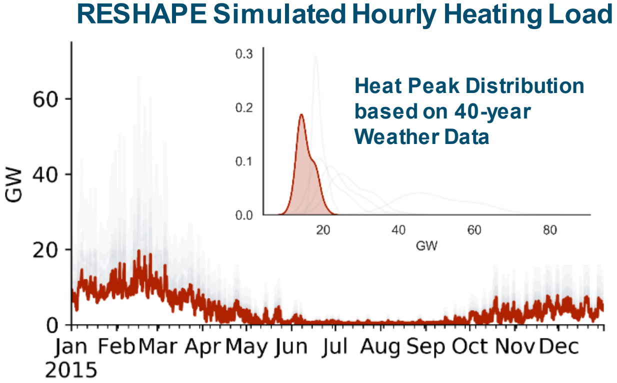
Inputs

- Heat pump configurations
- Heat pump sizing criteria and back-up heat source

Outputs

- Hourly heat load and supplemental heat requirement of each representative building

3. Hourly Building Electrification Loads



Simulate hourly loads and evaluate peak impact due to building electrification

Inputs

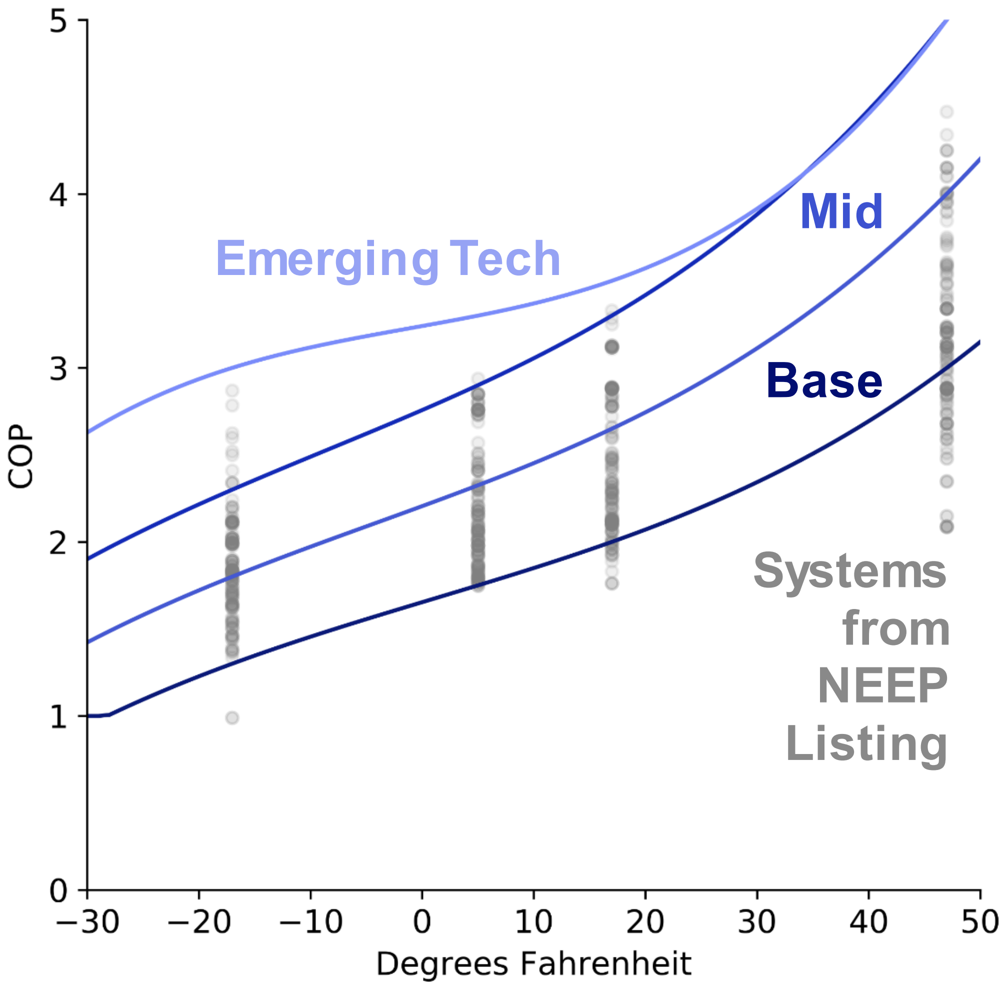
- Heat pump penetration level in the region

Outputs

- Hourly heat loads, at the **county** level
- 1-in-2, 1-in-10, or 1-in-40 peak load impact based on historical weather

Evaluating the performance of ASHP in RESHAPE

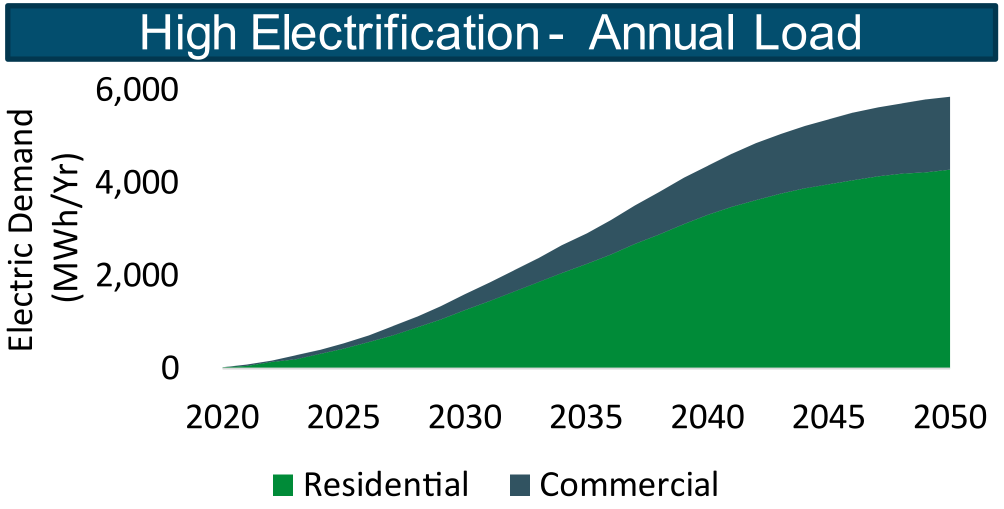
RESHAPE ccASHP Coefficients of Performance

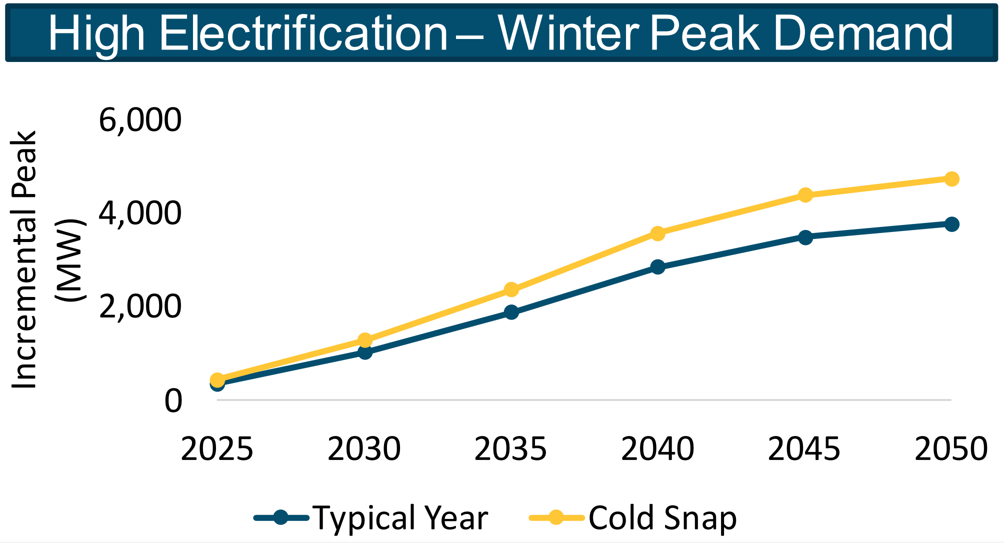


- E3 used manufacturer reported data on the performance of ccASHPs provided by NEEP in its Cold Climate Product Specification product listing to characterize COPs as a function of outdoor air temperature.
- Three representative ccASHP systems are considered:
  - **High**: consistent with the best performing systems available today COP of 2.3 @-17F
  - **Mid**: high efficiency systems COP of 1.8 @-17F
  - **Base**: systems that only just meet the NEEP requirement of a COP of 1.75 @5F, 1.3 @-17F
- Emerging Tech based on the DOE Building Technology Office's Emerging Technology development goal for variable speed ccASHPs

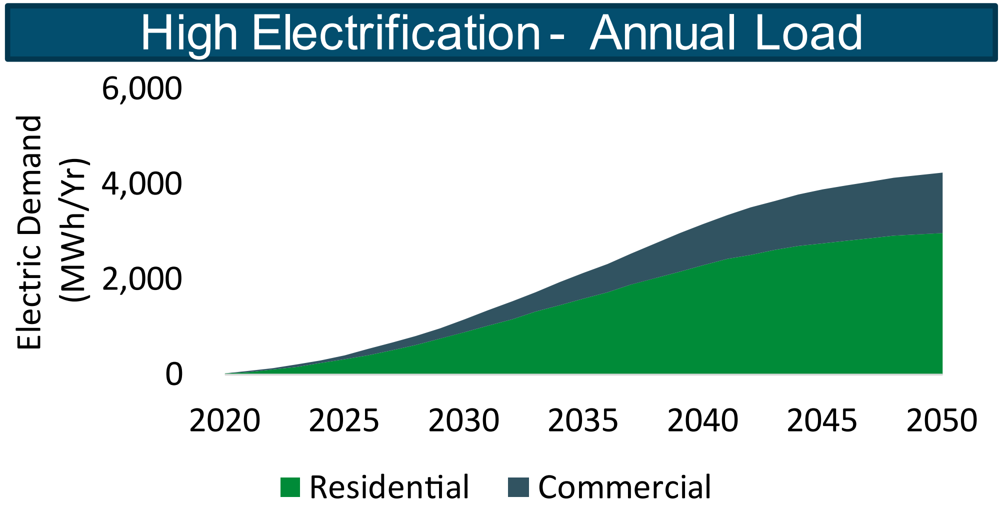
Electric Impacts: PSE Electric
High Performance Technology Sensitivity

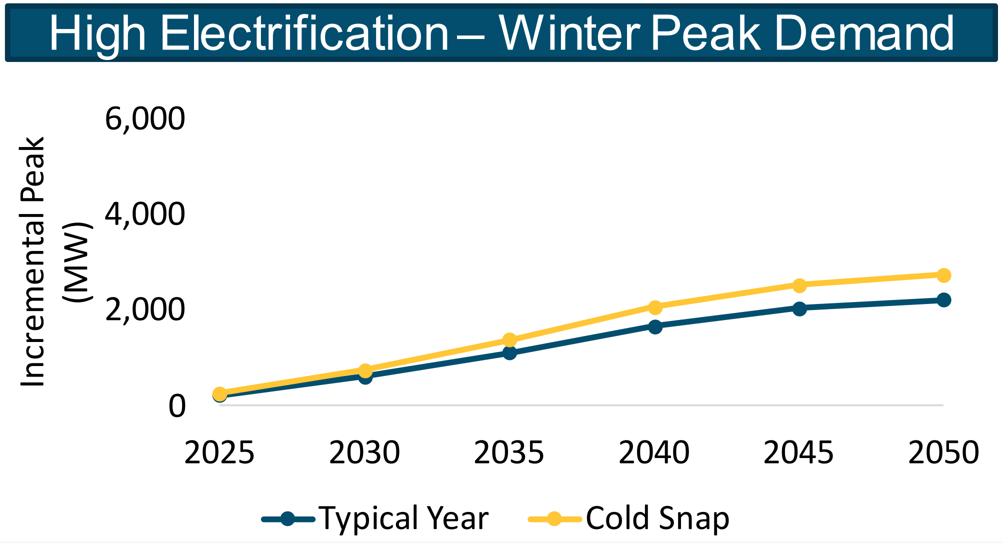
Base Case





High Performance Technology Sensitivity





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Additional Solutions to the "Peak Heat" Challenge

Solutions	Description	Pros	Cons
Building Shell Retrofits	• Reduce heat loss in buildings via measures including air sealing, insulation, high efficiency windows, etc…	• Reduces both annual and peak impacts • Improves occupant comfort & health • Additional non-energy benefits (e.g. health) possible	• High impact interventions may be more costly than electric or gas infrastructure cost savings. • Deep shell retrofits may be challenging to scale at the same pace as electrification
Load Flexibility	• Shift load out of coincident peak morning/evening hours • Could be accomplished via improved building shells or dedicated thermal energy storage	• Water heaters are likely to be shiftable • Smoothing our intraday loads could reduce peak demands by 20% to 30%	• Load flexibility cannot fully address sustained loads over multi-day cold-snaps • Water heaters are a small share of peak demand • Similar challenges as building shell improvements • The cost and performance of thermal energy storage technologies are uncertain
Electric Resistance to Heat Pump Conversions	• Convert existing resistance heating loads to heat pumps	• Substantial annual energy savings • Meaningful peak savings possible as well with ductless heat pumps	• Upfront cost, particularly for lower income consumers or renters • Increased load factor, rate impacts

+ **Further work is needed to assess the cost of these measures, their load implications and the feasibility of scaling them alongside electrification**

Decarbonized Gas

Biomethane		Power-to-Gas (P2G)	
Waste biogas	**Gasification of biomass**	**Hydrogen**	**Synthetic Natural Gas (SNG)**
Sources: Municipal waste, manure	**Sources:** Agriculture and forest residues, and purpose grown crops, e.g. switchgrass;	**Sources:** Electrolysis + zero-carbon electricity or Steam Methane Reforming of natural gas with Carbon Capture and Sequestration	**Sources:** Renewable hydrogen + CO_2 from biowaste (bi-product of biofuel production) and/or direct air capture (DAC)
Constraints: Very limited supply	**Constraints:** Limited supply and competing uses for biofuels	**Constraints:** Limited pipeline blends (3.3% by energy) without infrastructure upgrades, cost	**Constraints:** Limited commercialization, low round-trip efficiency, high cost

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Negative emissions technologies and offsets

+ In some cases, it may be less costly to remove GHGs from the air than to directly reduce them.