GAS ANALYTICAL METHODOLOGY & RESULTS

APPENDIX F

PUGET SOUND ENERGY

2023 Gas Utility Integrated Resource Plan

Contents

1. Analytic Methodology

We begin our analysis of Puget Sound Energy's (PSE's) natural gas supply portfolio by comparing 27-year demand forecasts with existing long-term resources to estimate resource needs. Once we identify the resource need, we use planning tools, optimization analyses, and input assumptions to determine the lowest-reasonable-cost portfolio of natural gas resources presented in multiple scenarios.

In the natural gas industry, supply planning is done on a daily basis -- not on an hourly basis. When we say **peak temperature**, we mean 13°F on average for the day, not just during one hour.

2. Gas Peak Day Planning Standard

We completed a detailed cost-benefit analysis during the 2005 least cost plan (LCP), the basis for the current planning standard.[1] In this plan, the 2023 Gas Utility Integrated Resource Plan (2023 Gas Utility IRP), we updated the demand forecast to incorporate the effects of climate change on annual heating and cooling degree days and daily average peak temperatures. Although the annual heating degree days decline over the study period of this plan, the peak temperatures, based on extreme temperature occurrences, support a winter design day peak standard of 13°F, consistent with the prior standard.[2] Thus, we used the 13°F peak design standard in this plan.

3. Deterministic Optimization Analysis

We developed two natural gas scenarios for this plan's analysis: The reference and electrification scenarios, as shown in Table F.1. Scenario analysis allows us to understand how different resources perform across various future economic and regulatory conditions. Scenario analysis also clarifies the robustness of a particular resource strategy; it helps determine if a specific strategy is reasonable under a wide range of possible circumstances.

Table F.1: 2023 Gas Utility IRP Analysis Scenarios

Condition	Reference Case[1]	Electrification WA State Energy Strategy (SES)[2]
CCA Constraint Parameter[1]	Price	Follow SES Line
Allowance Price[2]	Mid	Floor
Renewable Fuel Source Location	North America	North America
Heating Load shift	Economic	Force in Electrification Supply Curve
Demand	Mid (F22)	Mid (F22)
Gas Growth?	Yes	Yes
Gas Price	Mid	Mid

Notes:

1. The price constraint allows PSE to purchase allowances to meet Climate Commitment Act (CCA) requirements. The Follow SES Line constraint imposes a physical emissions constraint as the priority before allowance purchases are permitted.

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[1] For a detailed discussion of the peak planning standard see Chapter Nine in the 2021 IRP.

[2] For a more detailed discussion on the climate models and impacts on energy and peak temperatures, see Chapter Five: Demand Forecast.

2. Climate Commitment Act-related analysis used three allowance prices:
   - Ceiling Price — an allowance issued by the Washington State Department of Ecology (Ecology) at a fixed price to limit price increases.
   - Floor Price — the minimum price at which bids are accepted during an auction.
   - Mid-Price — a hybrid pricing scheme; the pre-2030 period based on the forecast from Ecology and post-2030 period leverages are linked to the California Energy Commission 2021 forecast, modeling the future connection between the two carbon markets.
3. We also tested seven sensitivities in the natural gas sales analysis. Sensitivity analysis allows us to isolate the effect of a single resource, regulation, or condition on the portfolio.

Table F.2: 2023 Gas Utility IRP Natural Gas Portfolio Sensitivities

#	Sensitivity Name	CCA Constraint Parameter	CCA Allowance Price	Renewable Fuel Source location	SCGHG Added?	Demand**	Gas Price**
1	Reference Case	Price	Mid	PNW	No	Mid (F22)	Mid
A	Allowance Price High	Price	Ceiling*	PNW	No	Mid (F22)	Mid
B	Allowance Price Low	Price	Floor*	PNW	No	Mid (F22)	Mid
C	Limit Emissions Without Regard to Price	No-cost Allowance Line*	Floor*	PNW	No	Mid (F22)	Mid
D	Alternative Fuel Location WA	Price	Mid	North America*	No	Mid (F22)	Mid
E	HHP Policy	Price	Mid	PNW	No	Mid (F22) - policy-driven HHP adoption*	Mid
F	Zero gas growth	Price	Mid	PNW	No	Zero gas growth after 2026*	Mid
G	High Gas Price	Price	Mid	PNW	No	Mid (F22)	High*

Notes:
* Indicates change as compared to the reference case
** Typical Gas IRP parameters

PUGET SOUND ENERGY

4. Gas Portfolio Model

We used a gas portfolio model (GPM) to analyze natural gas resources for long-term planning and natural gas resource acquisition. The current GPM is SENDOUT Version 14.3.0 from Hitachi Energy, a widely used model that employs a linear programming algorithm to help identify the long-term, least-cost combination of integrated supply- and demand-side resources that will meet stated loads.

Although the deterministic linear programming approach used in this analysis is a helpful analytical tool, it is important to acknowledge that this technique provides the model with perfect foresight — its theoretical results may not be achievable. For example, the model knows the exact load and price for every day throughout a winter period and can therefore minimize cost in a way that is impossible in the real world. One way we navigate the uncertainty is to create scenarios and sensitivities which help us understand the impacts on the portfolio when variables change. Numerous critical factors about the future will always be uncertain; therefore, we rely on linear programming analysis to help inform decisions, not to make them.

4.1. SENDOUT Model

SENDOUT is an integrated toolset for gas resource analysis that models the gas supply network and the portfolio of supply, storage, transportation, and demand-side resources (DSR) needed to meet demand requirements. Table 1.1 shows how we used SENDOUT for natural gas resource analysis. We included loads, existing resources, emission adders, and resource alternatives as inputs in the SENDOUT model, and it produces a least-cost portfolio based on those inputs.

SENDOUT can operate in two modes: For a defined planning period, it can determine the optimal set of resources to minimize costs; or, for a defined portfolio, it can determine the least-cost dispatch to meet demand requirements for that portfolio. SENDOUT solves both problems using a linear program (LP) to determine how a portfolio of resources (energy efficiency, supply, storage, and transport), including associated costs and contractual or physical constraints, should be added and dispatched to meet demand in a least-cost fashion. The LP considers thousands of variables and evaluates tens of thousands of possible solutions to generate a solution. A standard planning-period dispatch considers the capacity level of all resources as given and therefore performs a variable-cost dispatch. A resource-mix dispatch can look at various potential capacity and size resources, including their fixed and variable costs.

Puget Sound Energy's gas portfolio model analysis follows a five-step process:

1. Set up a database with existing resources and demand forecasts.
2. Update the inputs for natural gas prices, carbon adders, and new resource alternatives.
3. Perform a long-run capacity expansion analysis to get a least-cost portfolio for each scenario and sensitivity.
4. Analyze the results.
5. Develop a resource plan.

4.2. SENDOUT Inputs

Natural Gas Prices

For natural gas prices, PSE uses a combination of forward market prices and fundamental forecasts acquired in spring 2020 from the consulting firm Wood Mackenzie. The natural gas price forecast is an input for SENDOUT.

➔ We described natural gas price inputs in Chapter Four: Key Analytical Assumptions.

CO_2 Price Inputs

RCW 80.28.380[3] requires that the natural gas analysis include the cost of greenhouse gases when evaluating the cost-effectiveness of natural gas conservation targets. We added the social cost of greenhouse gas (SCGHG) to the natural gas commodity price to implement this requirement.

➔ We provided detailed inputs in Chapter Four: Key Analytical Assumptions.

Demand-side Resources

SENDOUT provides a comprehensive set of inputs to model a variety of energy efficiency programs. Costs can be modeled at an overall program level or broken down into detailed accounts. We can model the impact of demand-side resources on the load at the same level of detail as demand. SENDOUT can integrate demand- and supply-side resources in the long-run resource mix analysis to determine the most cost-effective size of demand-side resources.

➔ We provided detailed inputs in Appendix C: Conservation Potential Assessment.

Natural Gas Supply

SENDOUT allows a system to get supply from long-term natural gas contracts or short-term spot market purchases. We can model specific physical and contractual constraints such as maximum flow levels and minimum flow percentages daily, monthly, seasonal, or annually. SENDOUT uses standard gas contract costs; we can change the rates monthly or daily.

[3] RCW 80.28.380

Storage

➔ More information on natural gas storage is in Appendix E: Existing Resources and Resource Alternatives.

SENDOUT allows leased or company-owned storage sources to serve the system. Storage input data include the minimum or maximum inventory levels, minimum or maximum injection and withdrawal rates, injection, and withdrawal fuel loss to and from interconnects, and the period of activity (i.e., when the gas is available for injection or withdrawal). There is also the option to define and name volume-dependent injection and withdrawal percentage tables (ratchets), which we can apply to one or more storage sources.

Transportation

SENDOUT provides the means to model transportation segments to define flows, costs, and fuel loss. Flow values include minimum and maximum daily quantities available for sale to gas markets or for release. Costs include standard fixed and variable transportation rates and a per-unit cost generated for released capacity. We can also model seasonal transportation contracts.

➔ More information on natural gas transportation is in Appendix E: Existing Resources and Resource Alternatives.

Demand

SENDOUT allows the user to define multiple demand areas, and it can compute a demand forecast by class based on weather. We segregated the demand input into two components:

1. Base load, which is not weather dependent
2. Heat load, which is weather dependent

We also computed both factors as a function of customer counts. The heat load factor is estimated by dividing the remaining non-base portion of the load by historical monthly average heating degree days (HDD) and monthly forecasted customer counts to derive energy per HDD per customer. The demand is input into SENDOUT monthly and includes the customer forecast, the baseload factors, and the heat load factors computed over the 20-year demand forecast period.

➔ More information on the natural gas demand forecast is in Chapter Five: Demand Forecast.

5. Gas Portfolio Results

The results of the SENDOUT model runs provide a view of the lowest cost portfolios in each scenario and sensitivity. In this section, we provide the results of the portfolio analysis. There are two scenarios in the gas analysis: the reference and electrification scenarios.

➔ More information on the natural gas portfolio results is in Chapter Six: Gas Analysis.

5.1. Scenario One: Reference Scenario

Portfolio additions represent the least cost builds for that scenario or sensitivity.

Figure F.1: Reference Scenario Portfolio Additions

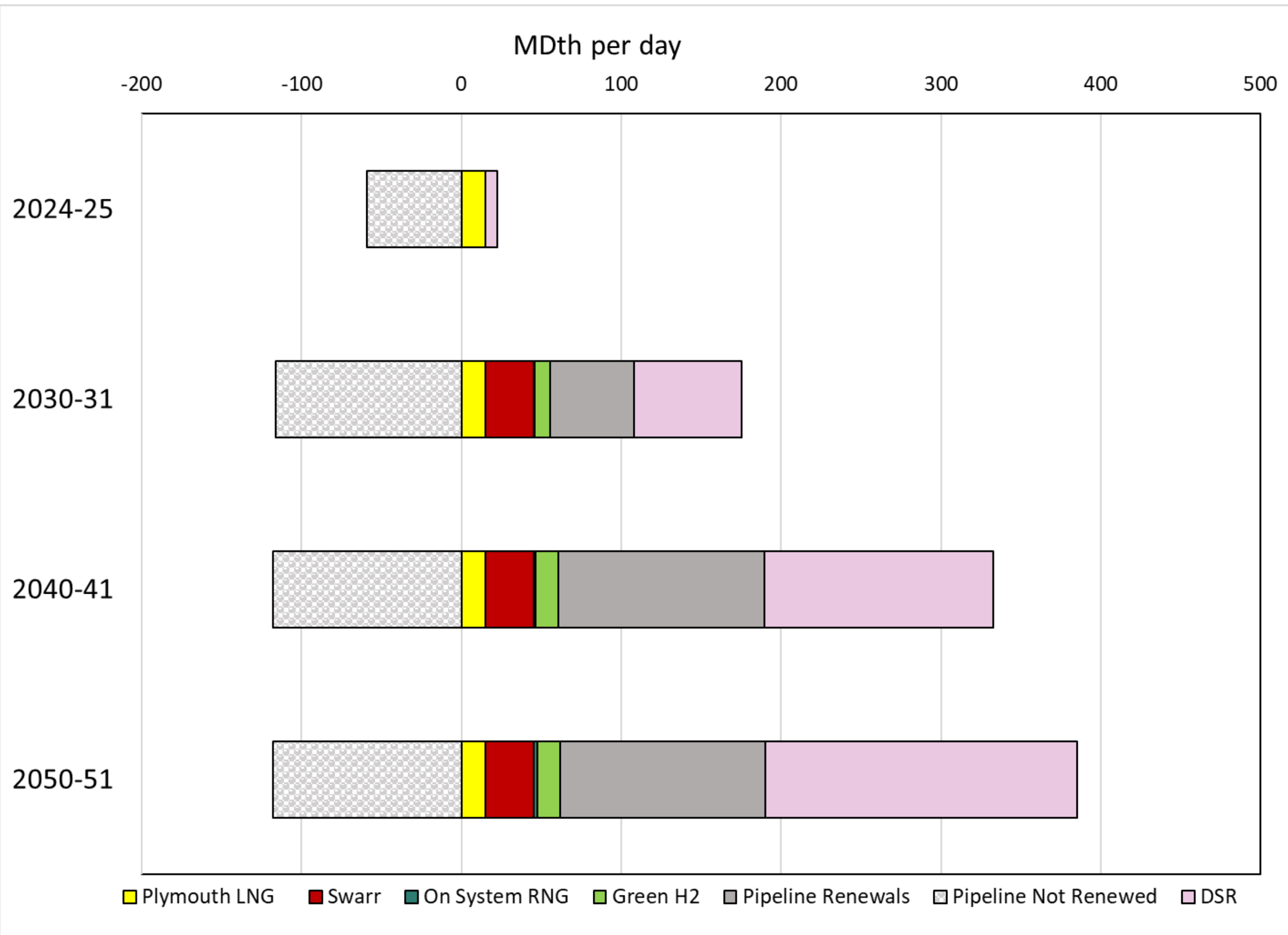
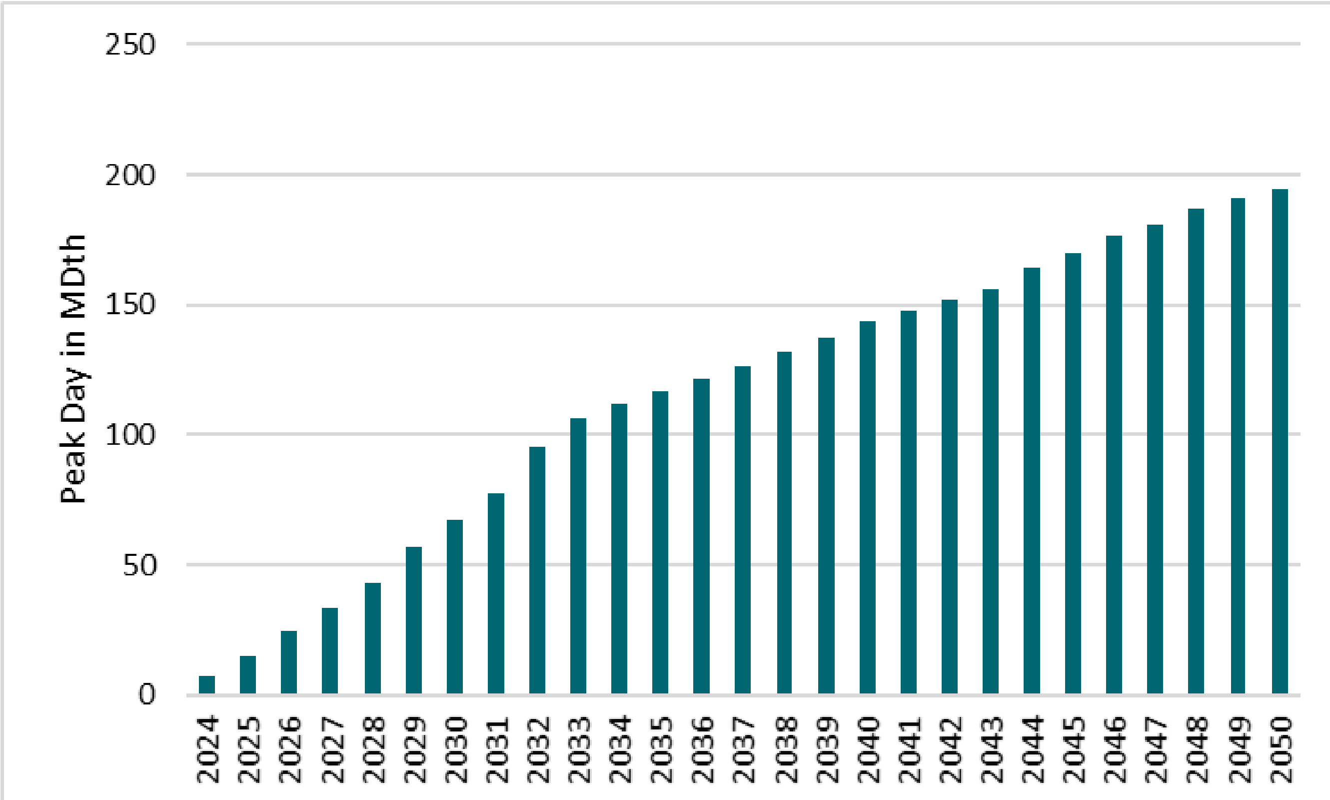
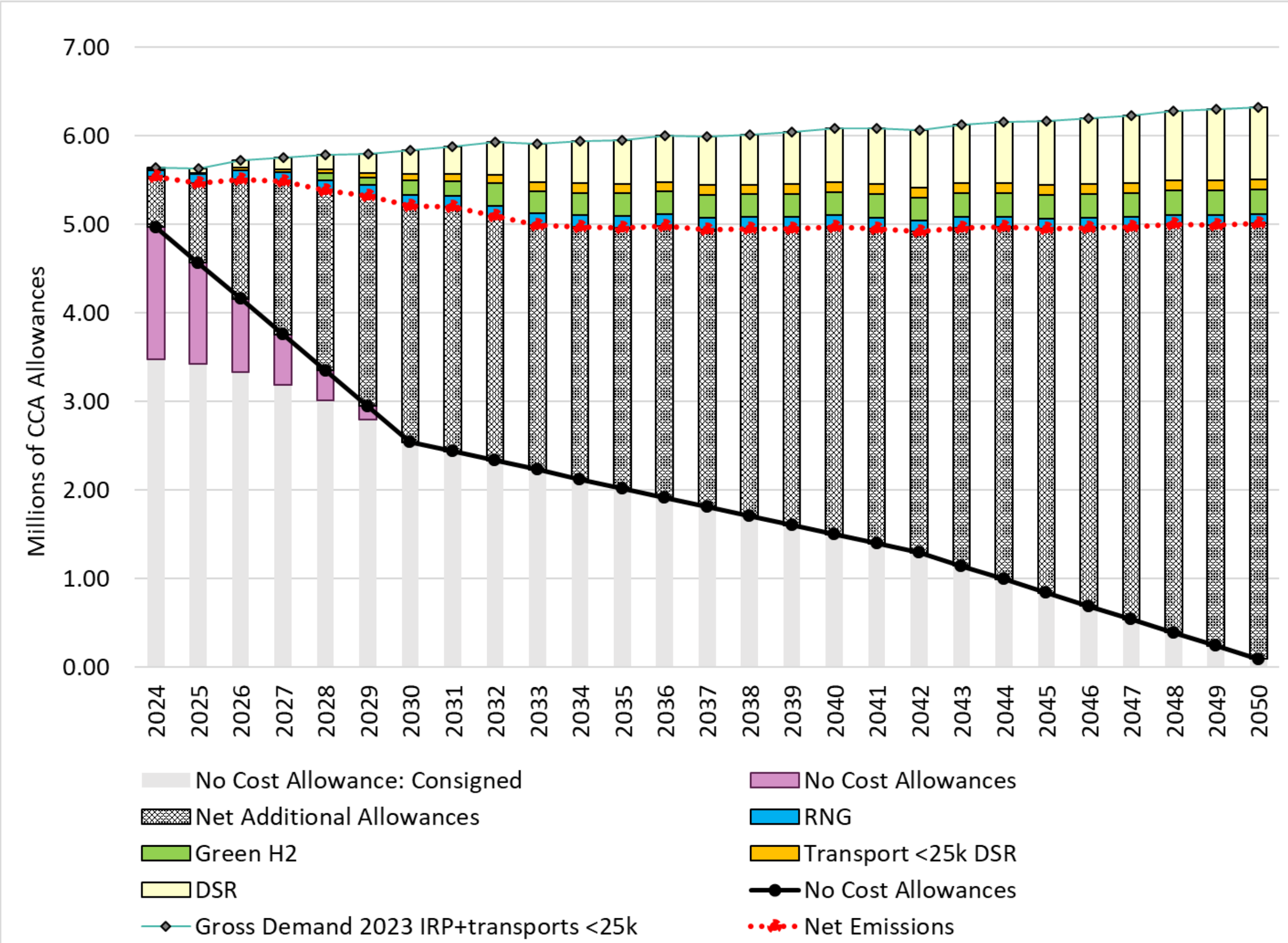


Figure F.2: Reference Scenario — Demand-side Resource Additions



We provided the data for portfolio additions in the output data files on the 2023 Gas Utility IRP website. We based the emissions profile for the portfolios on the least cost portfolio in that scenario or sensitivity.

Figure F.3: Reference Scenario — CCA Emissions



5.2. Scenario Two: Electrification Scenario

Portfolio additions represent the least-cost builds for that scenario or sensitivity.

Figure F.4: Electrification Scenario — Portfolio Additions

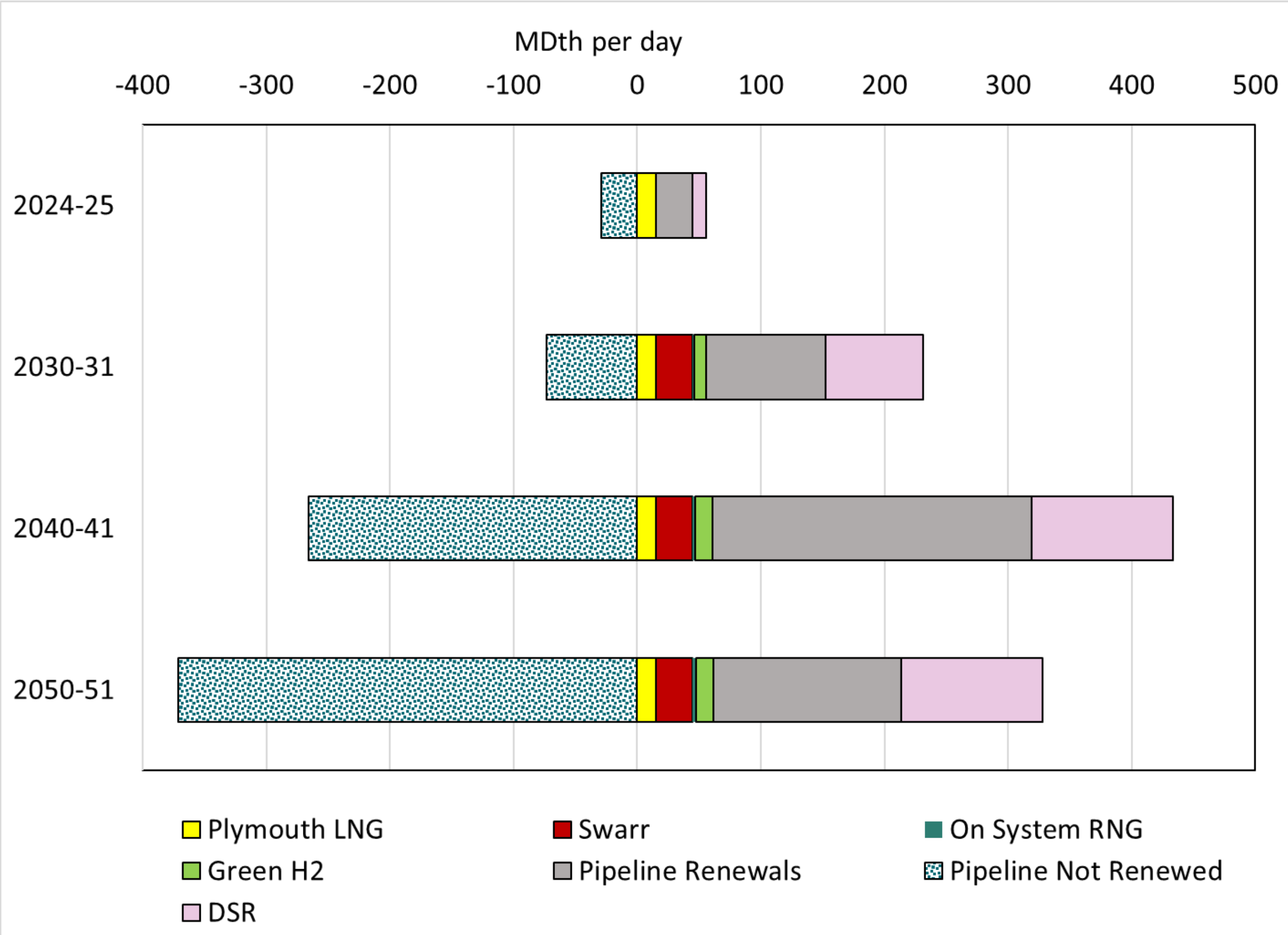
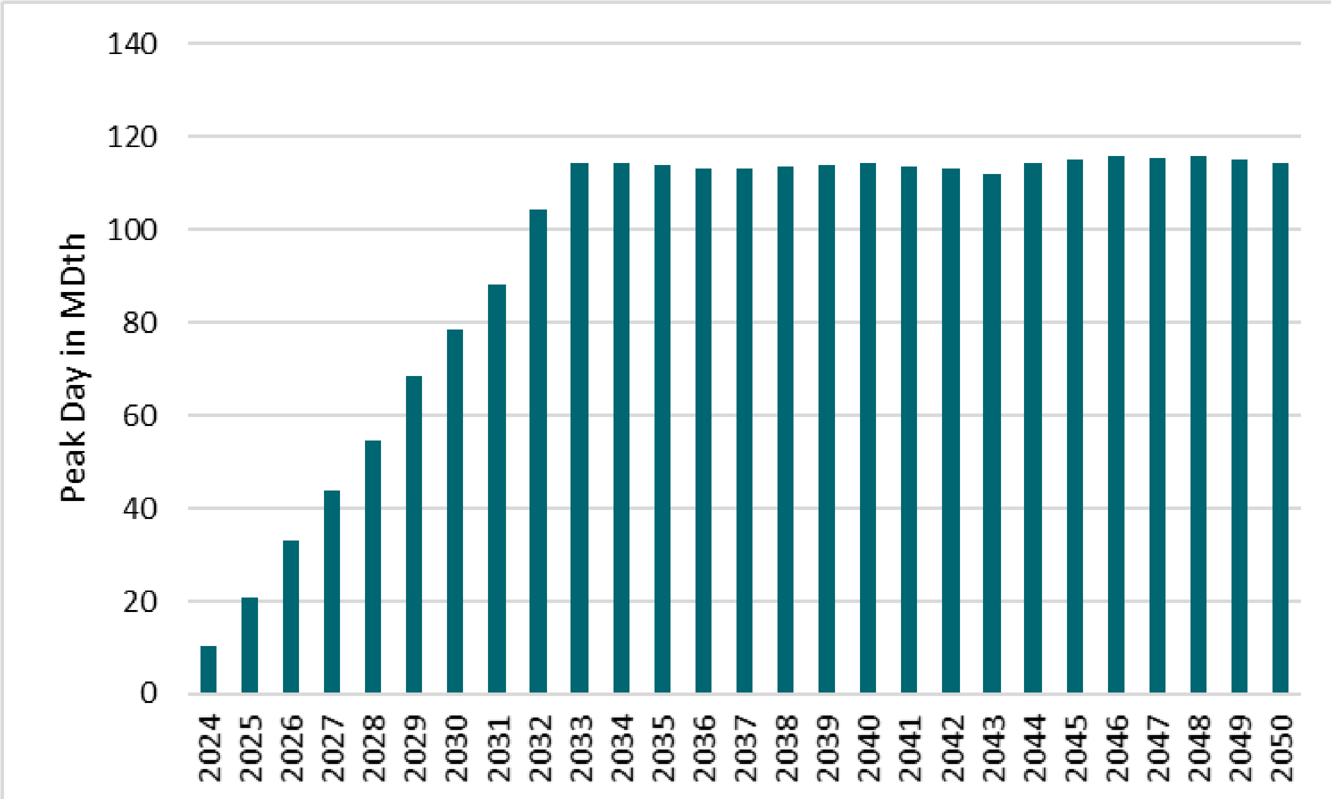
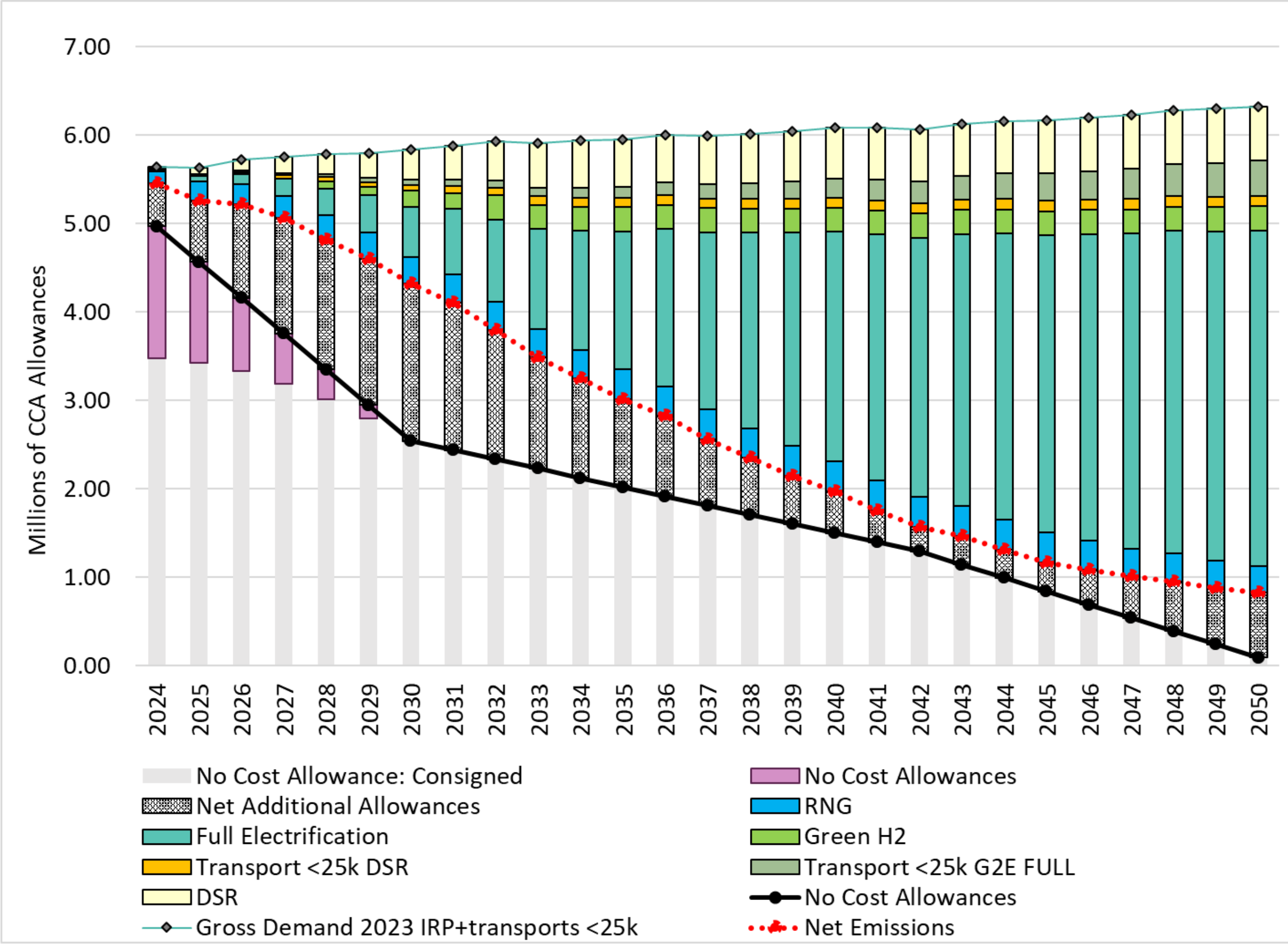


Figure F.5: Electrification Scenario — Demand-side Resources Additions



Data for portfolio additions is in the output data files on the 2023 Gas Utility IRP website. We based the portfolio emissions profile on the least-cost portfolio in that scenario or sensitivity.

Figure F.6: Electrification Scenario — CCA Emissions



5.3. Gas Portfolio Sensitivities

Sensitivities start with the optimized, least-cost reference scenario portfolio produced in the scenario analysis. We change a single resource, environmental regulation, or other condition to examine the effect of that variable on the portfolio. We summarized the sensitivities in Table F.3 and described them in the following sections.

Table F.3: 2023 Gas Utility IRP Sensitivities

#	Sensitivity Name	CCA Constraint Parameter	CCA Allowance Price	Renewable fuel source location	SCGHG Added?	Demand**	Gas Price**
1	Reference Case	Price	Mid	PNW	No	Mid (F22)	Mid
A	Allowance Price High	Price	Ceiling*	PNW	No	Mid (F22)	Mid
B	Allowance Price Low	Price	Floor*	PNW	No	Mid (F22)	Mid
C	Limit Emissions Without Regard to Price	No-cost allowance line*	Floor*	PNW	No	Mid (F22)	Mid
D	Alternative Fuel Location WA	Price	Mid	North America*	No	Mid (F22)	Mid
E	HHP Policy	Price	Mid	PNW	No	Mid (F22) - policy driven HHP adoption*	Mid
F	Zero gas growth	Price	High	PNW	No	Zero gas growth after 2026*	Mid
G	High Gas Price	Price	Mid	PNW	No	Mid (F22)	High*

Notes:

* Indicates change as compared to the reference case

** Typical Gas IRP parameters

A — CCA Allowance Price High

This sensitivity tests the impacts of a high ceiling allowance price.

Figure F.7: CCA Allowance Price High — Portfolio Additions

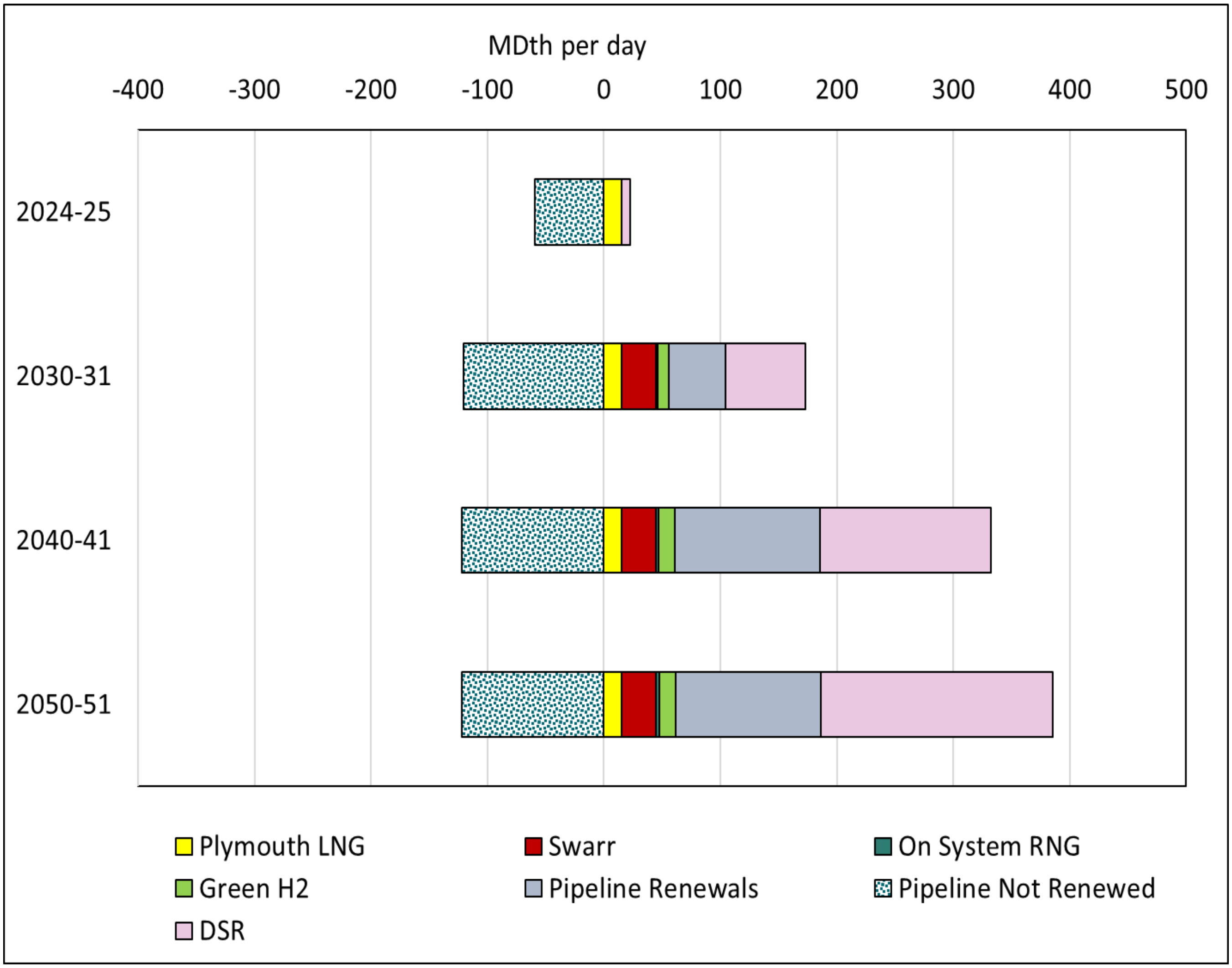
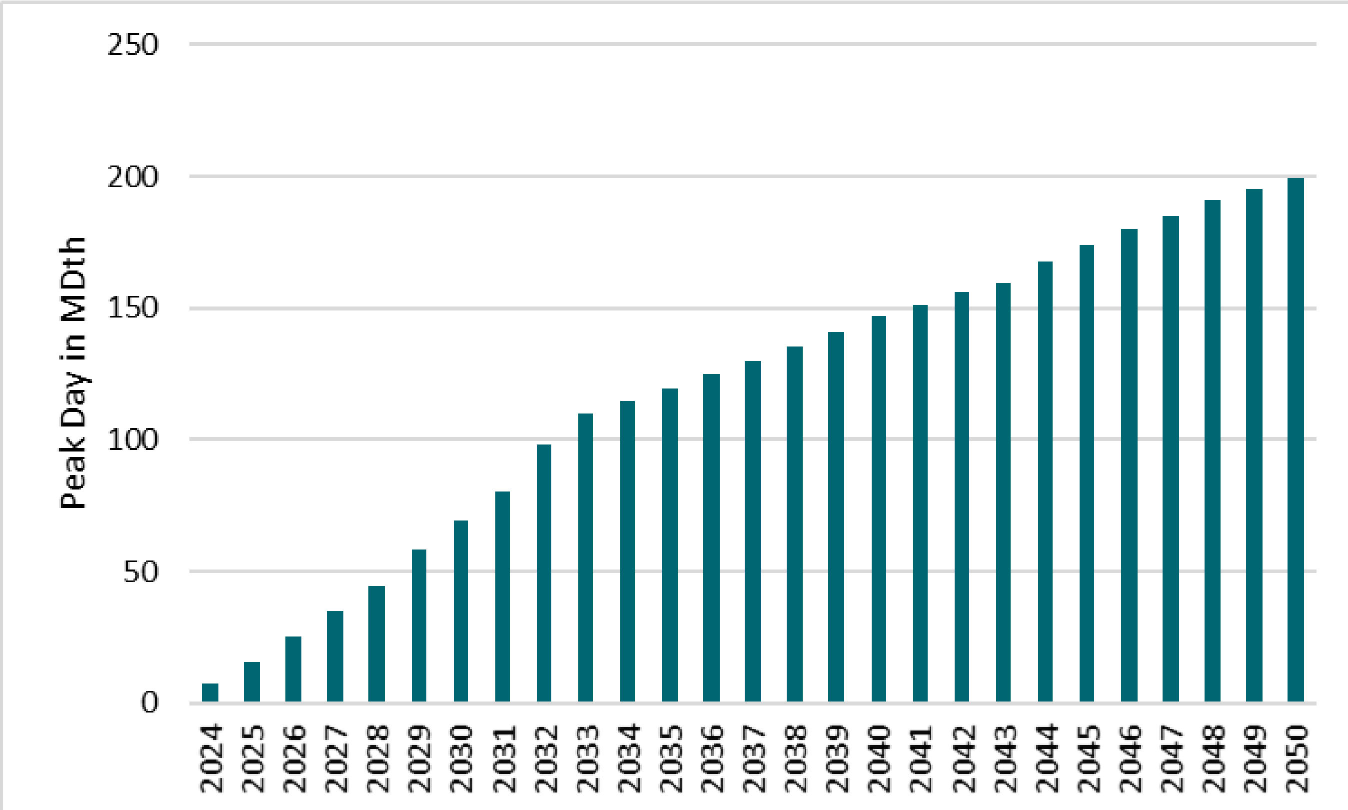
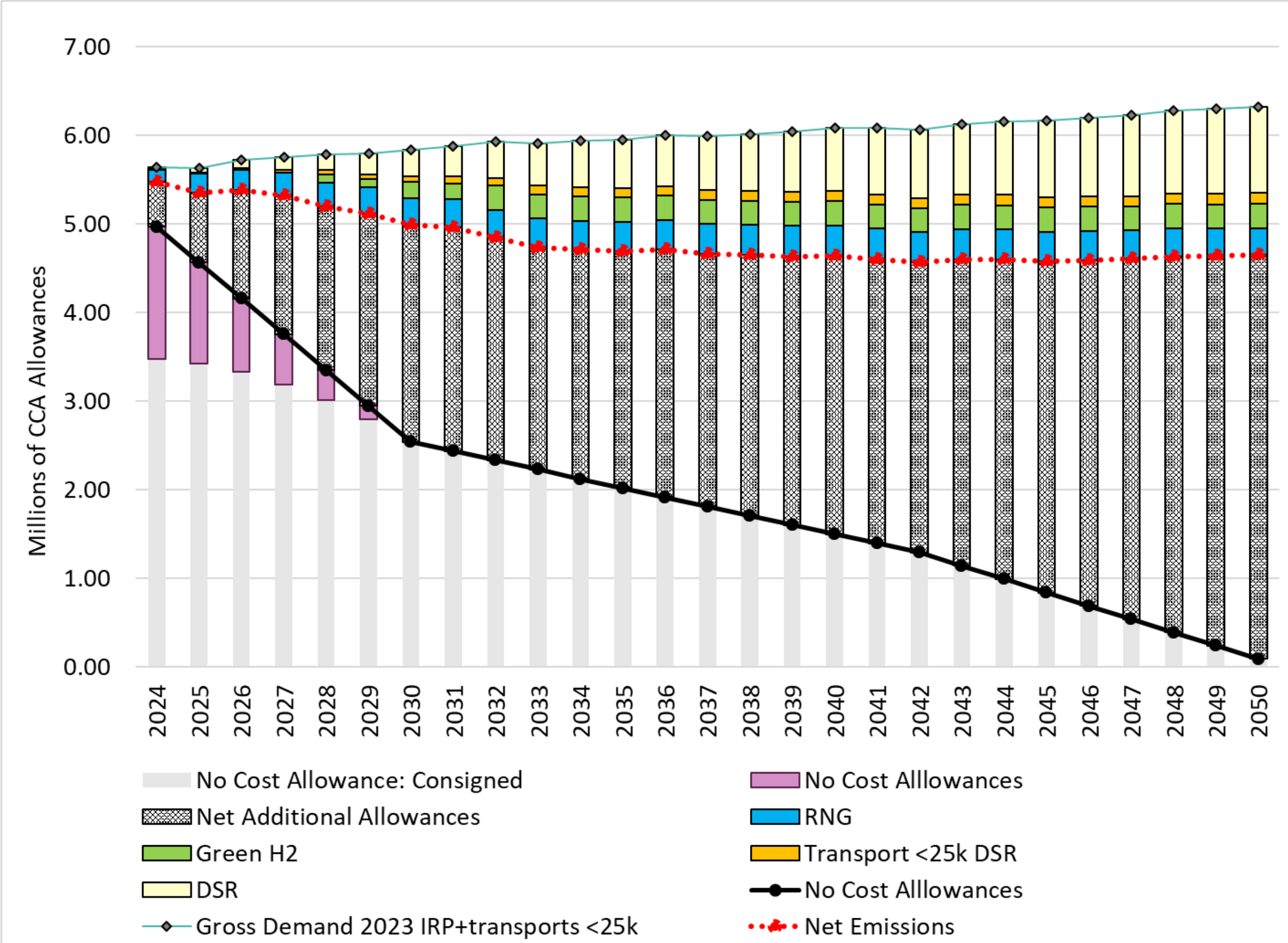


Figure F.8: CCA Allowance Price High Demand-side Resources Additions



Data for portfolio additions is in the output data files on the 2023 Gas Utility IRP website. We based the emissions profile for the portfolios on the least- cost portfolio in that scenario or sensitivity.

Figure F.9: CCA Allowance Price High – CCA Emissions



B — CCA Allowance Price Low

This sensitivity tests the impacts of a low floor allowance price.

Figure F.10: CCA Allowance Price Low — Portfolio Additions

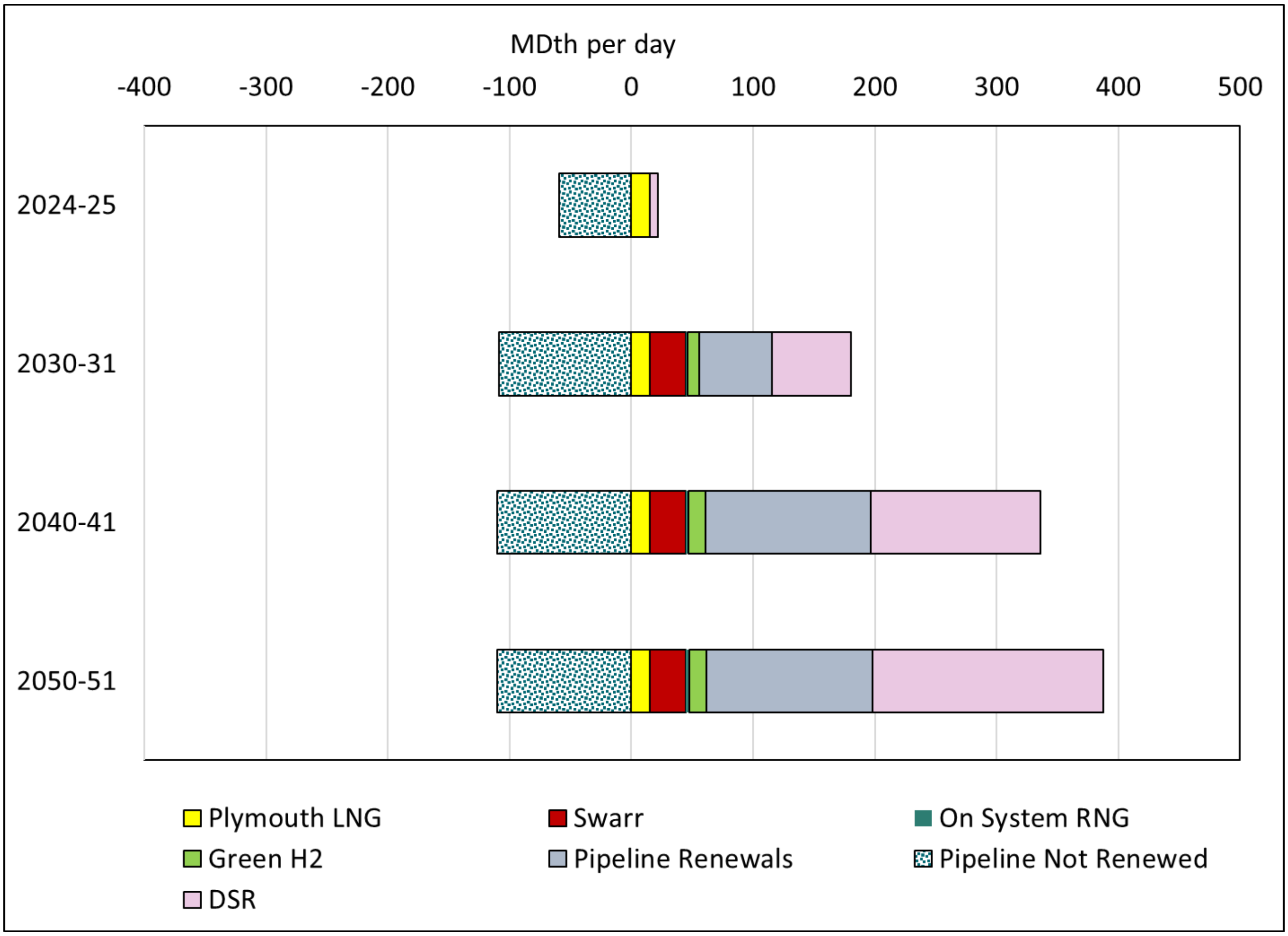
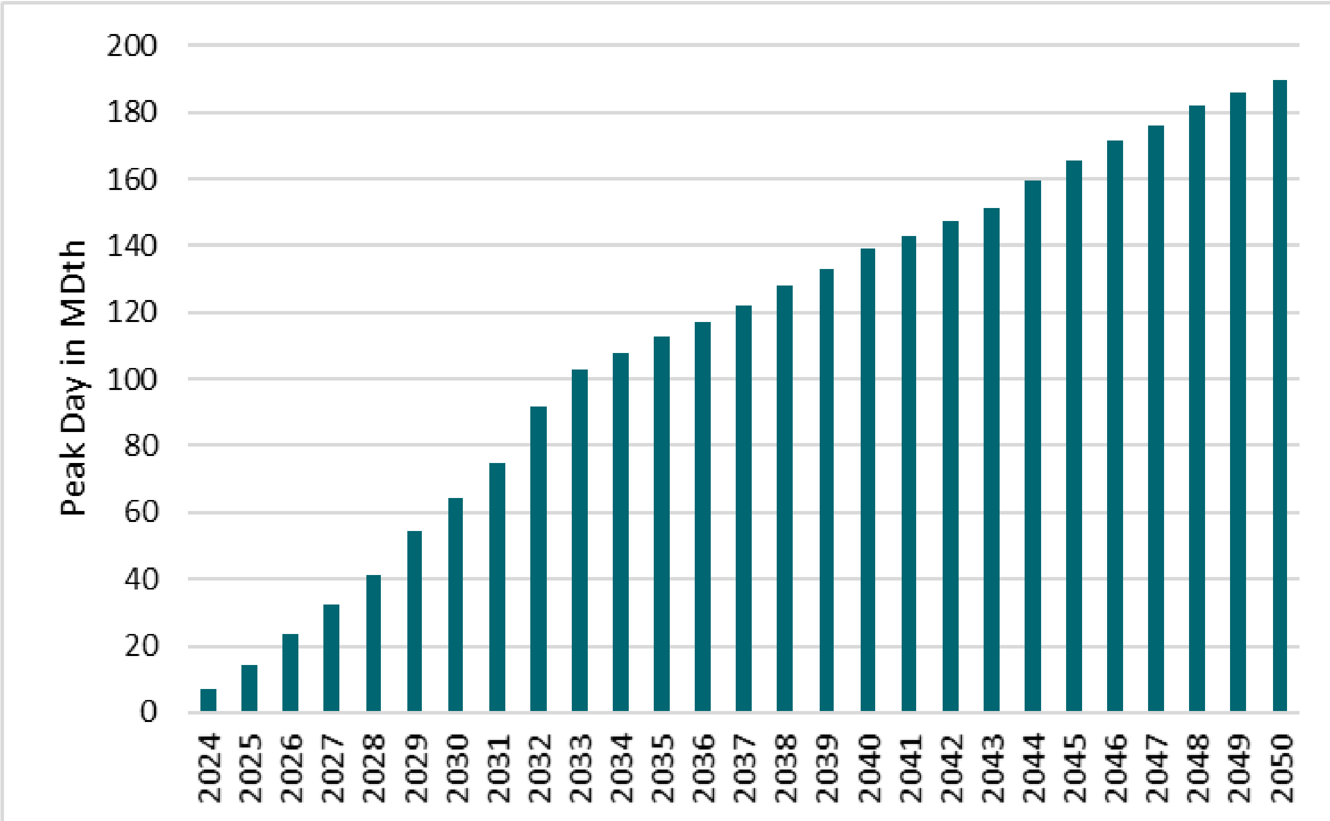
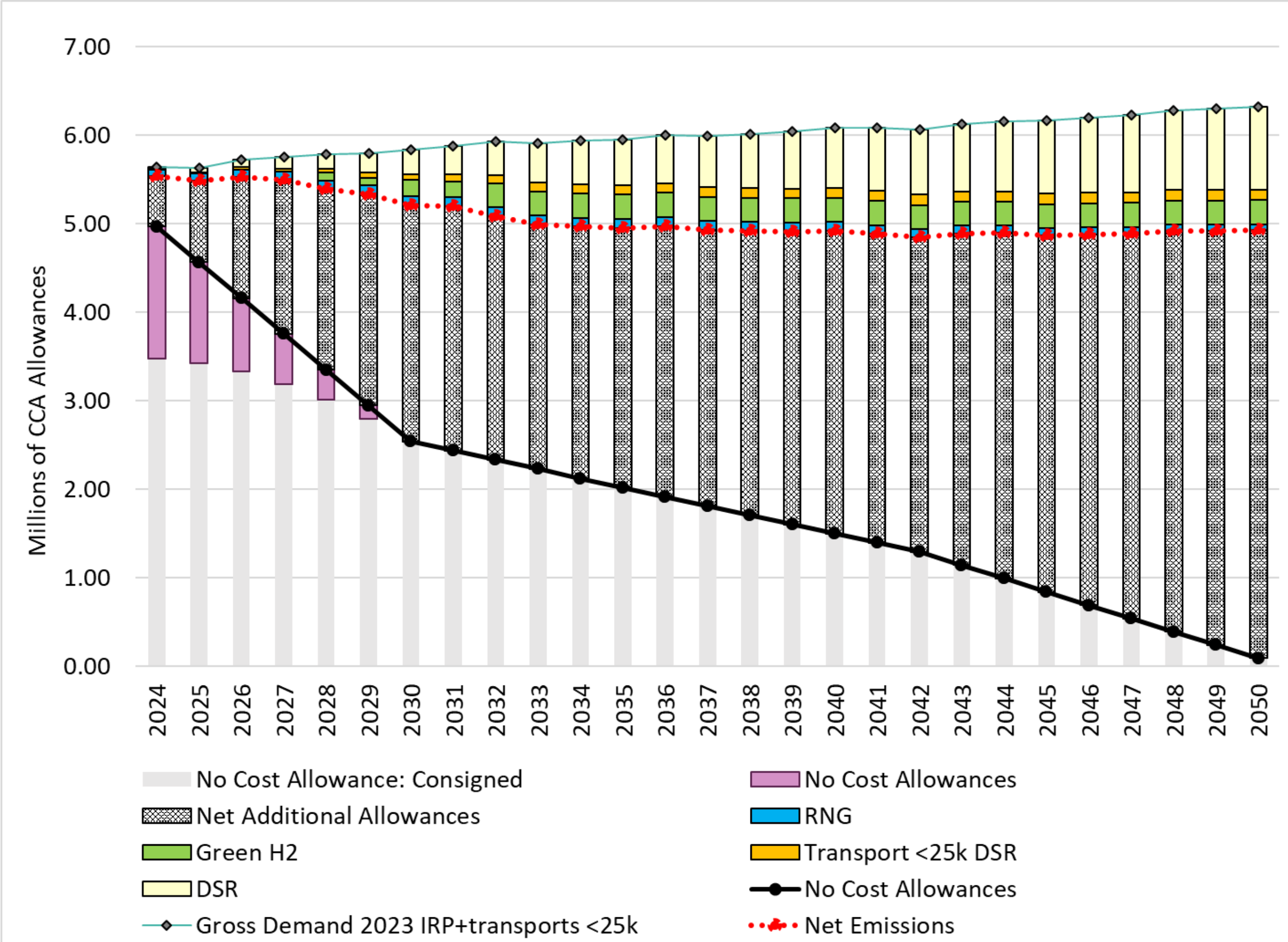


Figure F.11: CCA Allowance Price Low — Demand-side Resources Additions



Data for portfolio additions is in the output data files on the 2023 Gas Utility IRP website. We based the emissions profile for the portfolios on the least-cost portfolio in that scenario or sensitivity.

Figure F.12: CCA Allowance Price Low — CCA Emissions



C — Limiting Emissions Without Regard to Price

This sensitivity minimizes carbon emissions with the resource options in the gas model before it purchases above the allocated allowance trajectory under the CCA to fill the gap with additional allowance purchases at the floor price. It is essential to call out that this parameter is theoretical; the current CCA policy requires Ecology to offer allowances. Sensitivities limited by emissions do not reflect the least-cost approach.

Figure F.13: Limiting Emissions without Regard to Price — Portfolio Additions

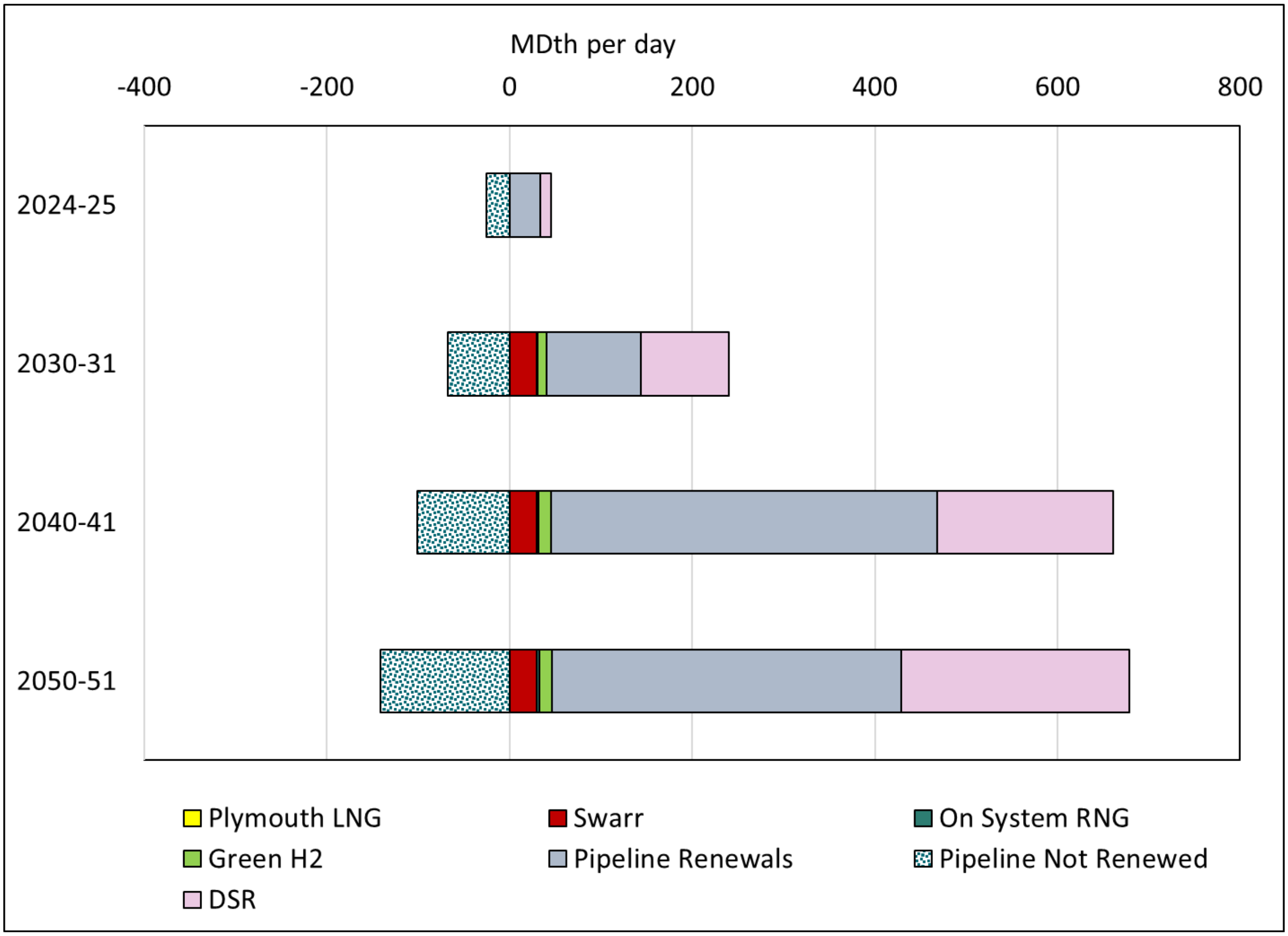
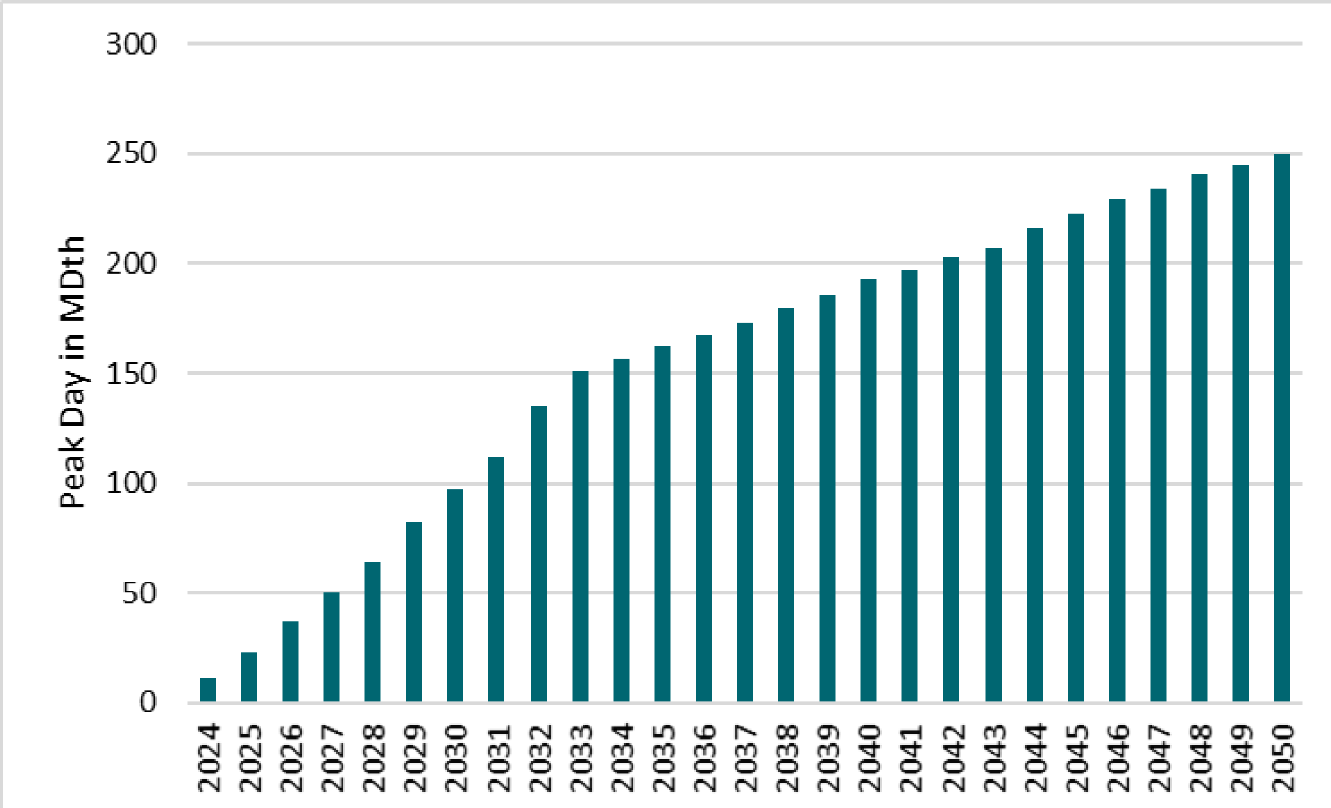
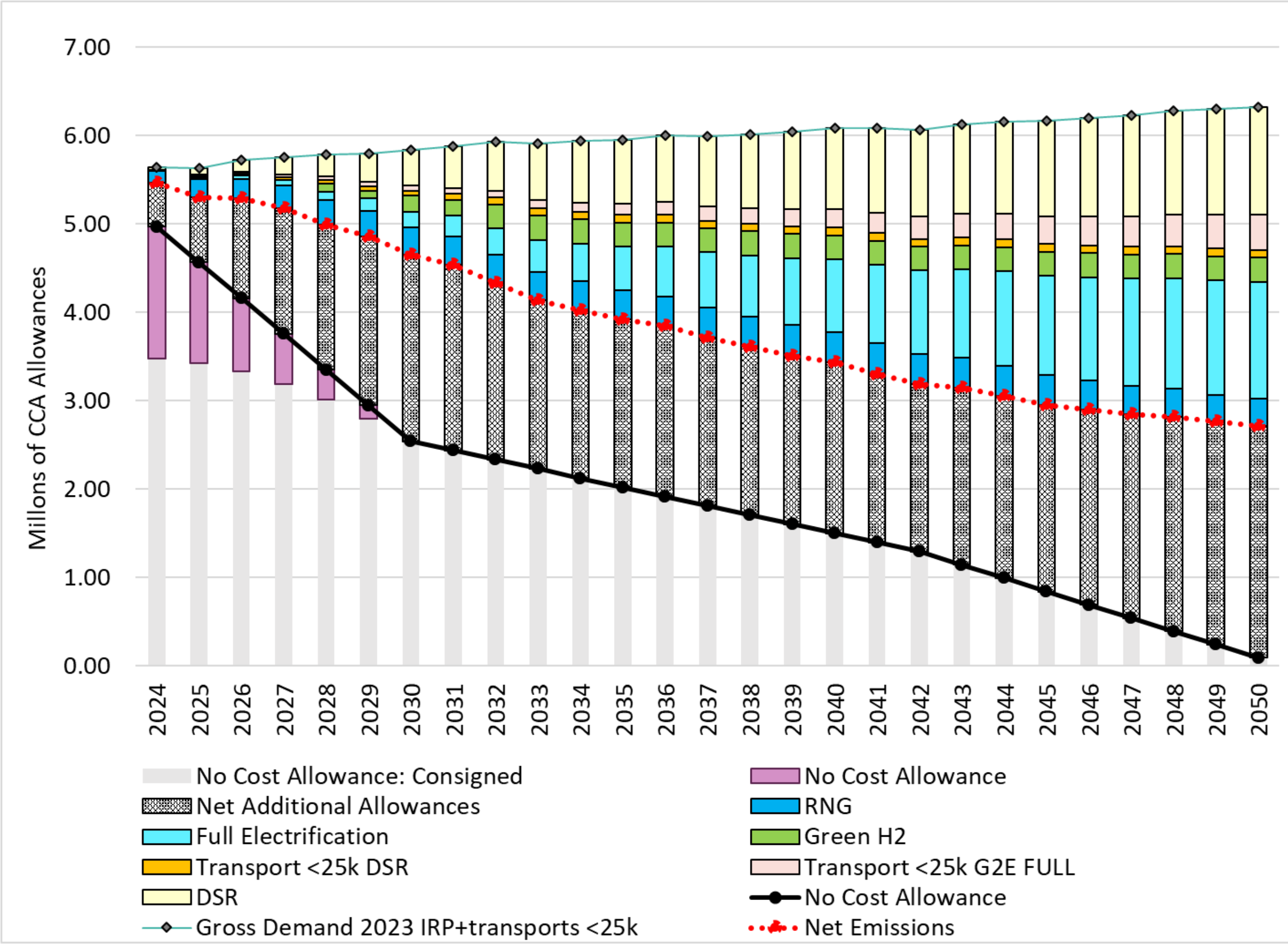


Figure F.14: Limiting Emissions without Regard to Price — Demand-side Resources Additions



Data for portfolio additions is in the output data files on the 2023 Gas Utility IRP website. We based the emissions profile for the portfolios on the least-cost portfolio in that scenario or sensitivity.

Figure F.15: Limiting Emissions without Regard to Price — CCA Emissions



D — Alternate Fuel Sourcing Not Limited to PNW

This sensitivity model removes the constraint of sourcing alternate renewable fuels from the PNW to include North America; this applies to RNG and green hydrogen.

Figure F.16: Alternate Fuel Sourcing Not Limited to PNW — Portfolio Additions

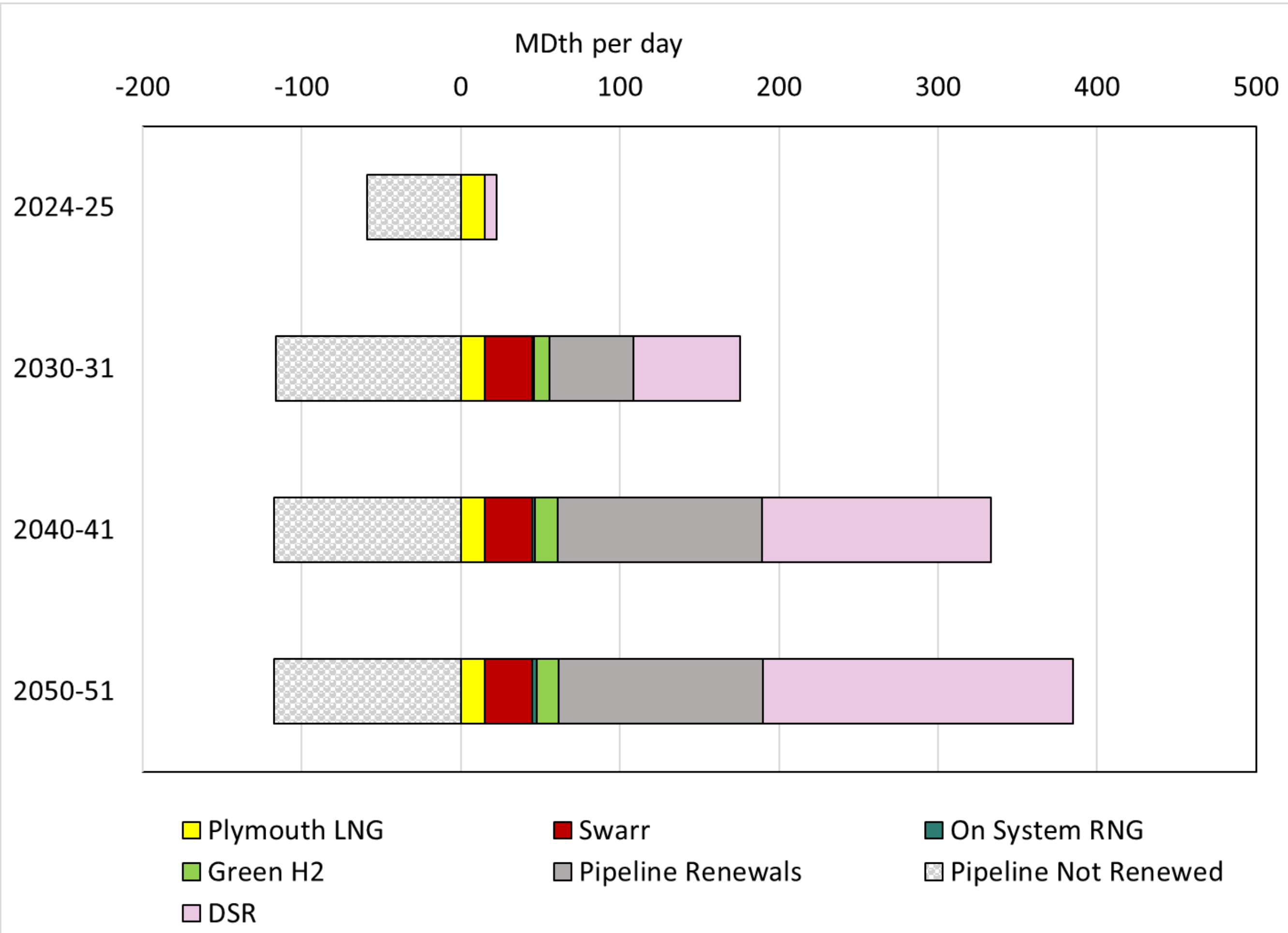
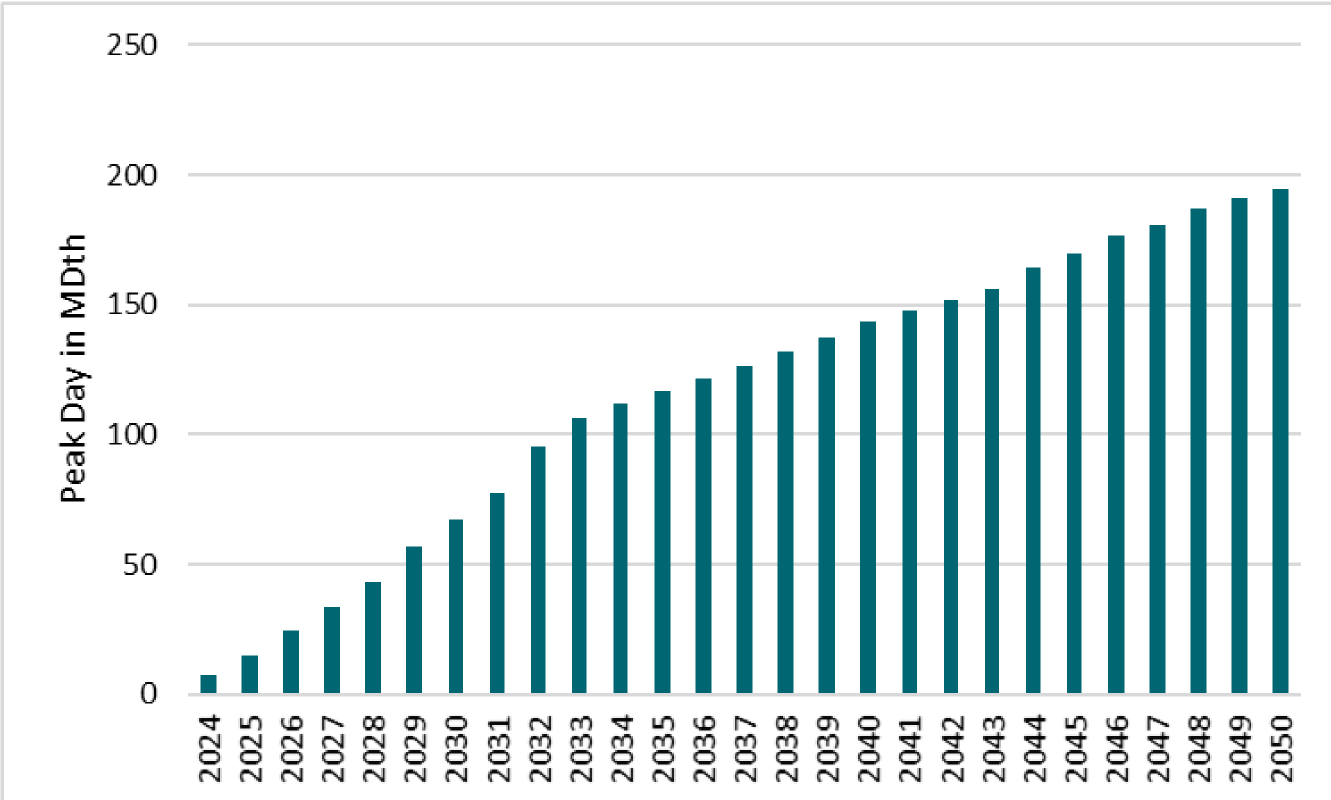
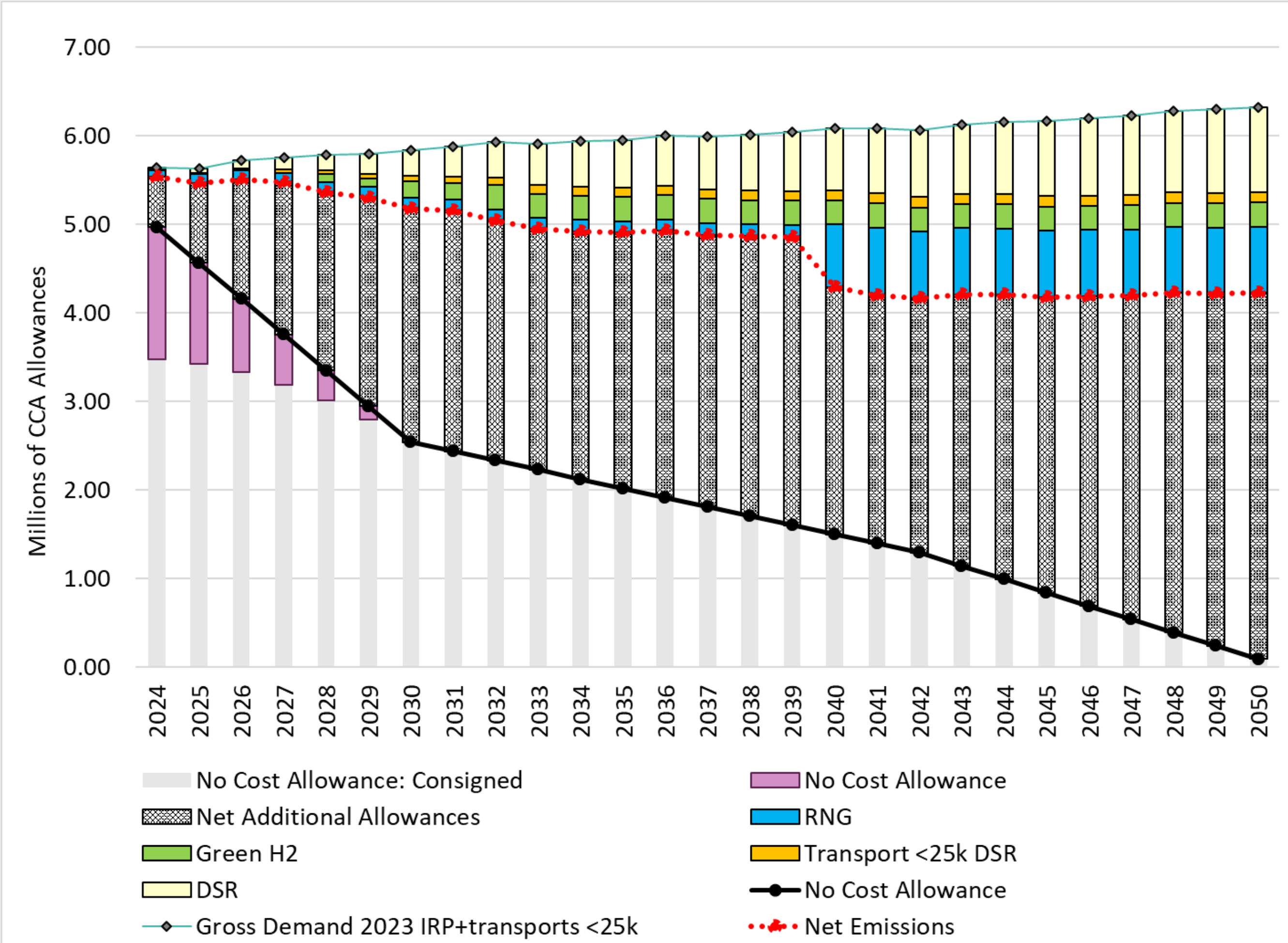


Figure F.17: Alternate Fuel Sourcing Not Limited to PNW — Demand-side Resources Additions



Data for portfolio additions is in the output data files on the 2023 Gas Utility IRP website. We based the emissions profile for the portfolios on the least-cost portfolio in that scenario or sensitivity.

Figure F.18: Alternate Fuel Sourcing Not Limited to PNW — CCA emissions



E — Hybrid Heat Pump Adoption Policy

This sensitivity models a policy where the hybrid heat pump is the preferred technology to electrify existing gas space heating loads at the end of the equipment life of PSE residential customers. The other end uses in residential and non-residential sectors will be electrified.

Figure F.19: Hybrid Heat Pump Adoption Policy Portfolio Additions

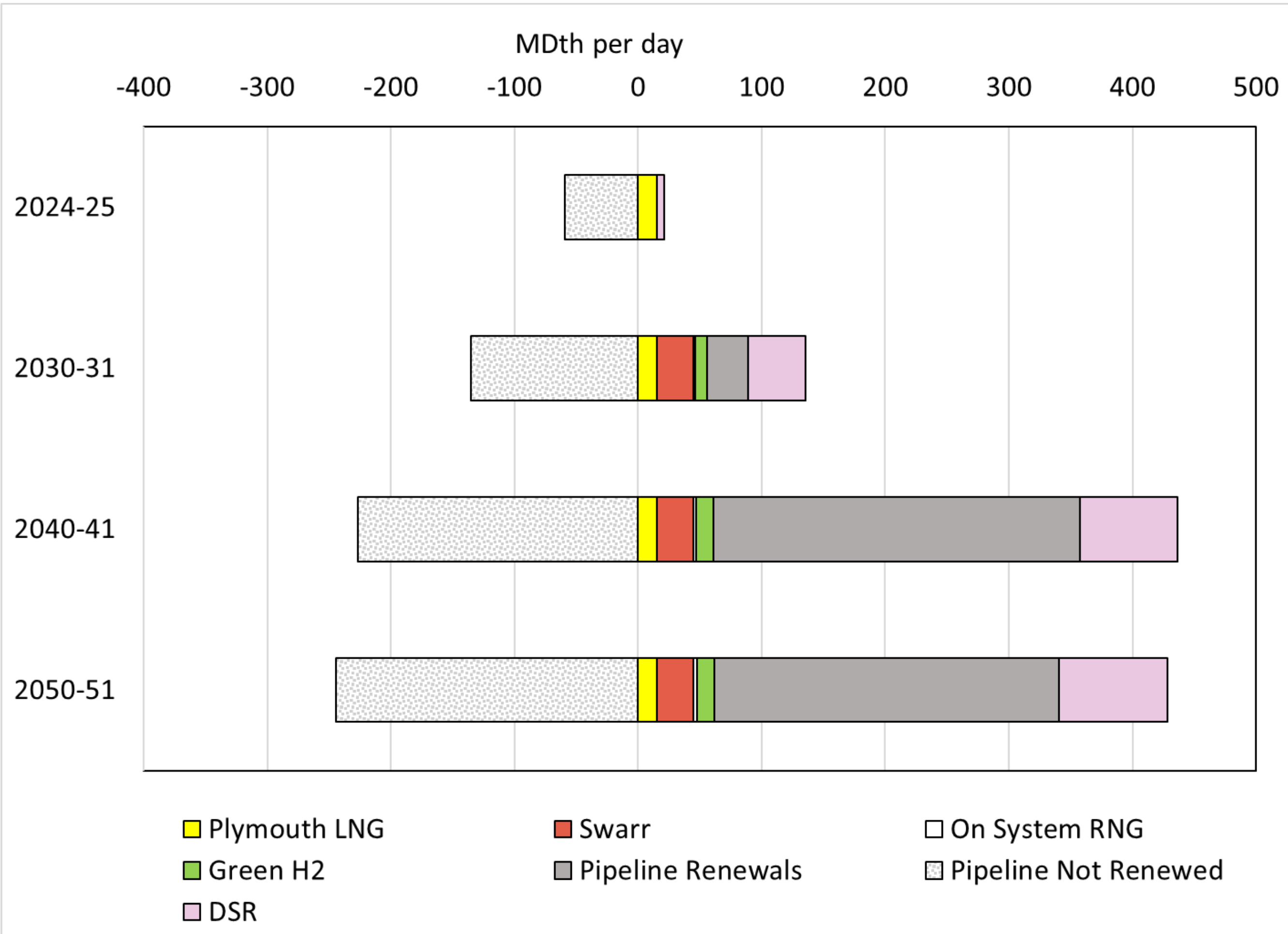
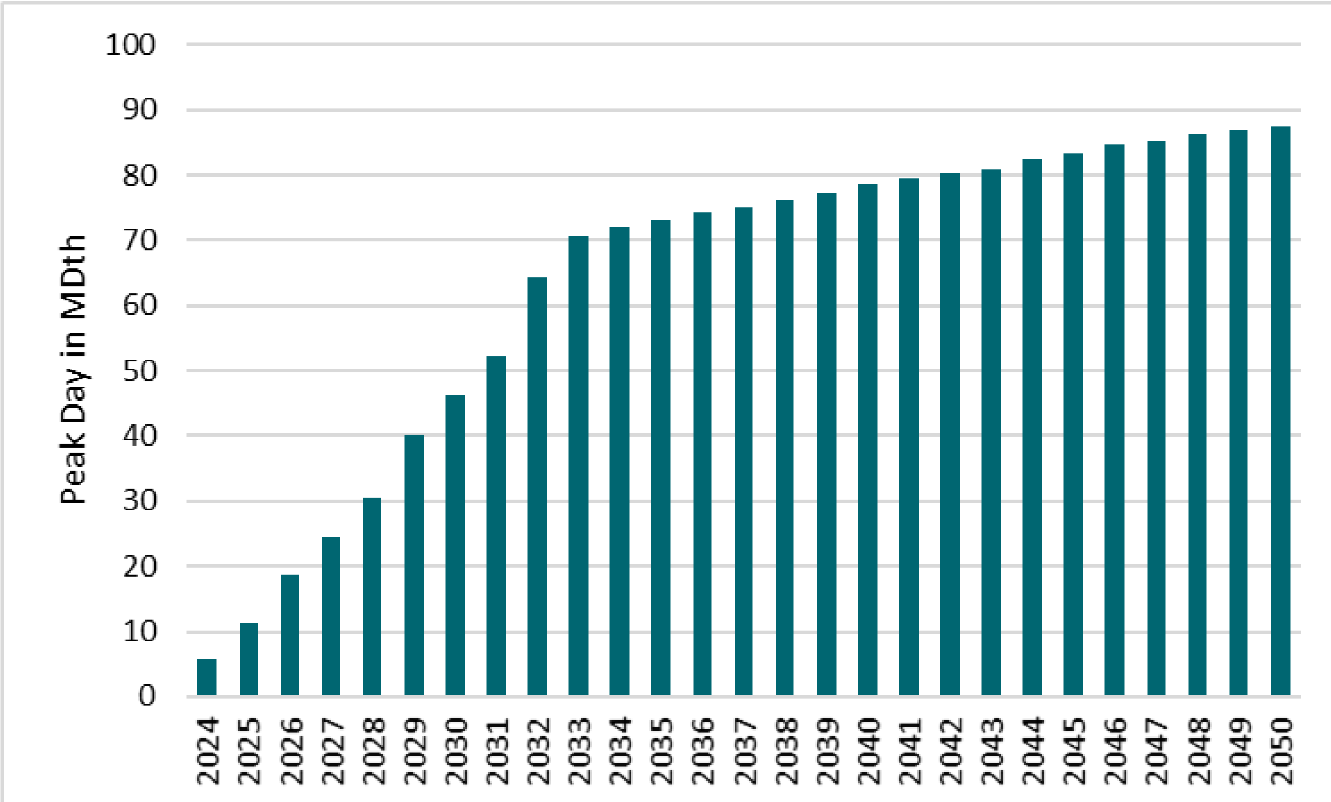
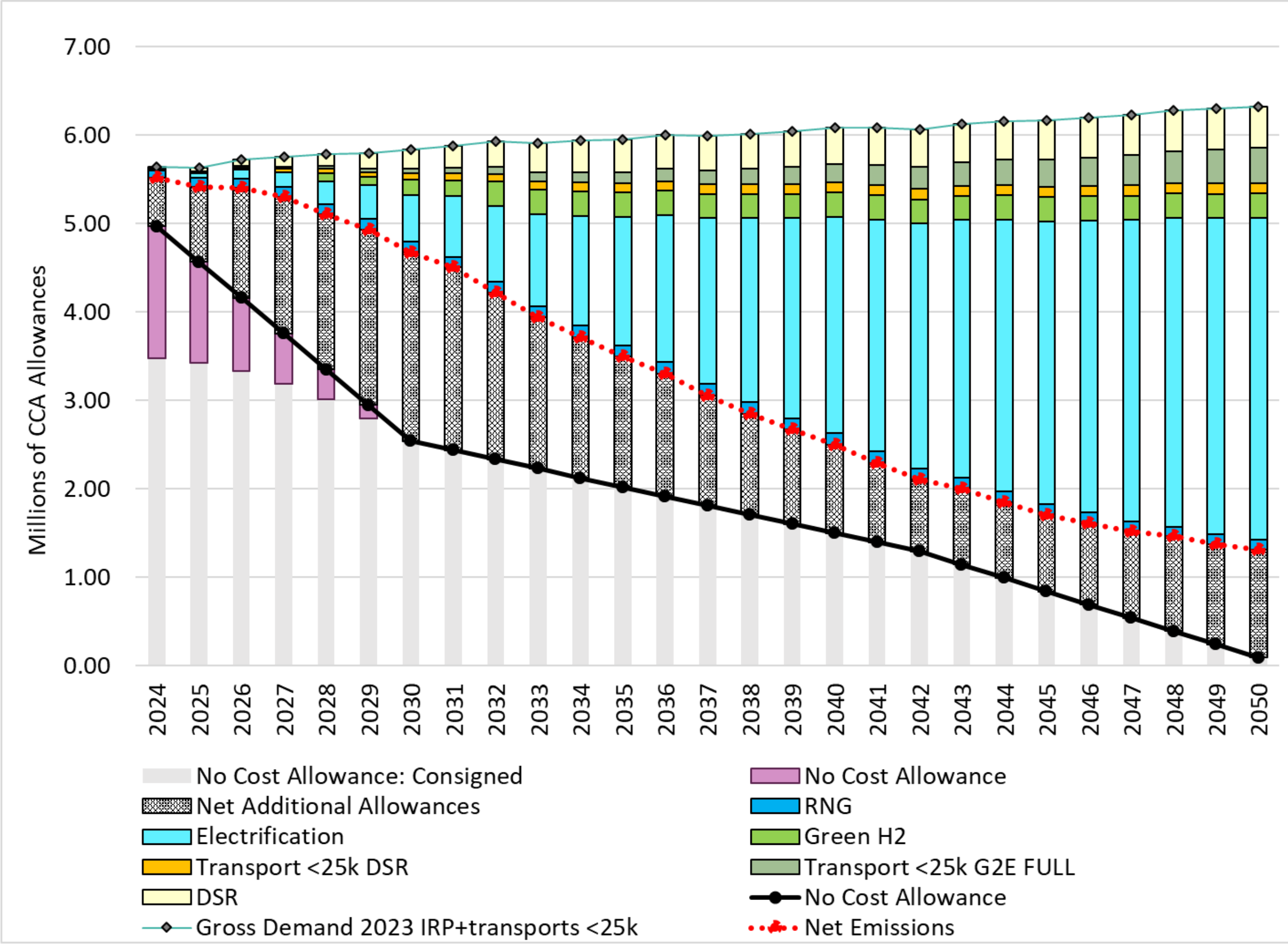


Figure F.20: Hybrid Heat Pump Adoption Policy — Demand-side Additions



Data for portfolio additions is in the output data files on the 2023 Gas Utility IRP website. We based the emissions profile for the portfolios on the least-cost portfolio in that scenario or sensitivity.

Figure F.21: Hybrid Heat Pump Adoption Policy — CCA Emissions



F — Zero Gas Growth

This sensitivity looks at the impact of zero-gas customer growth. Portfolio additions represent the least cost builds for that scenario or sensitivity.

Figure F.22: Zero Gas Growth — Portfolio Additions

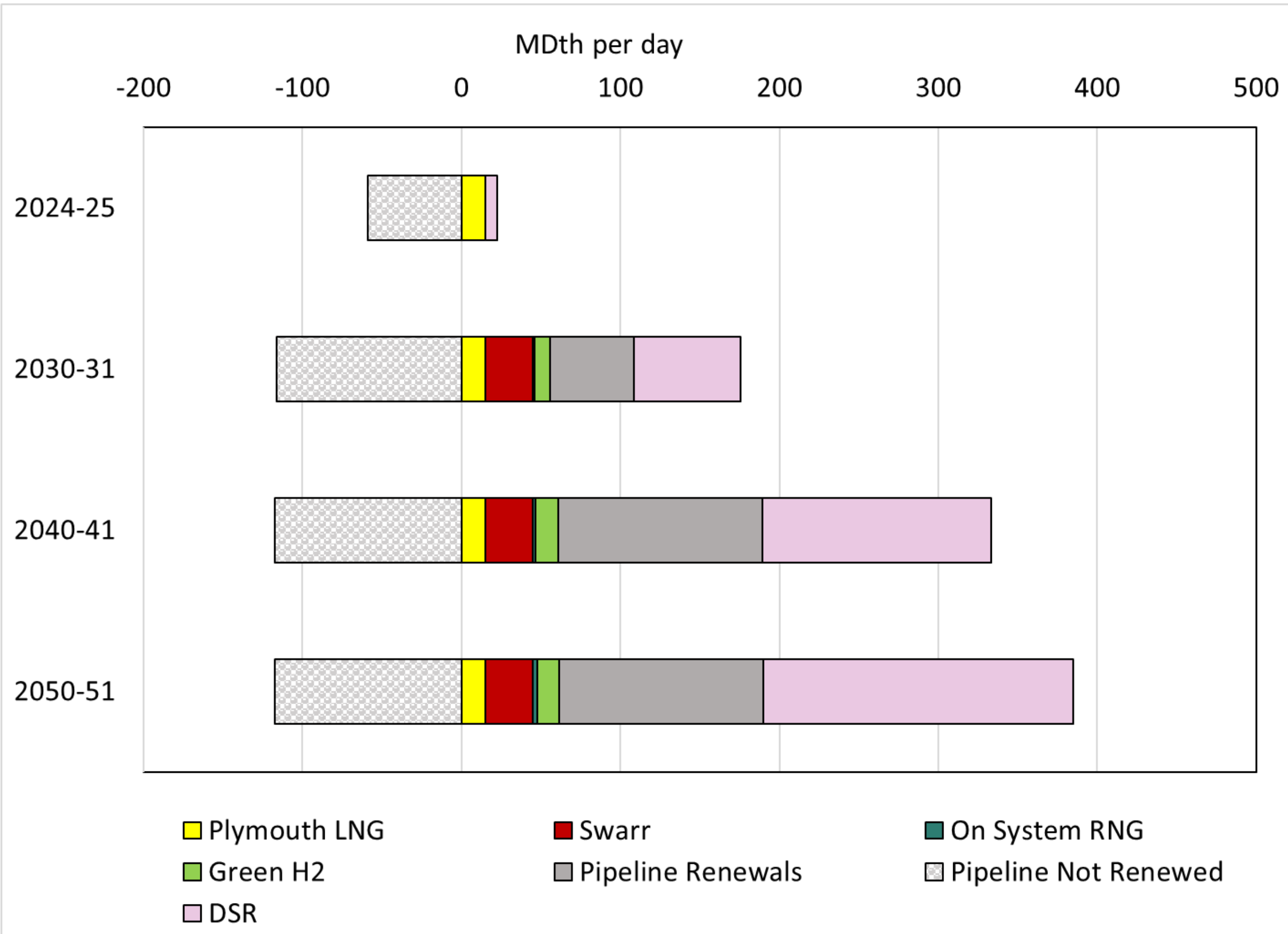
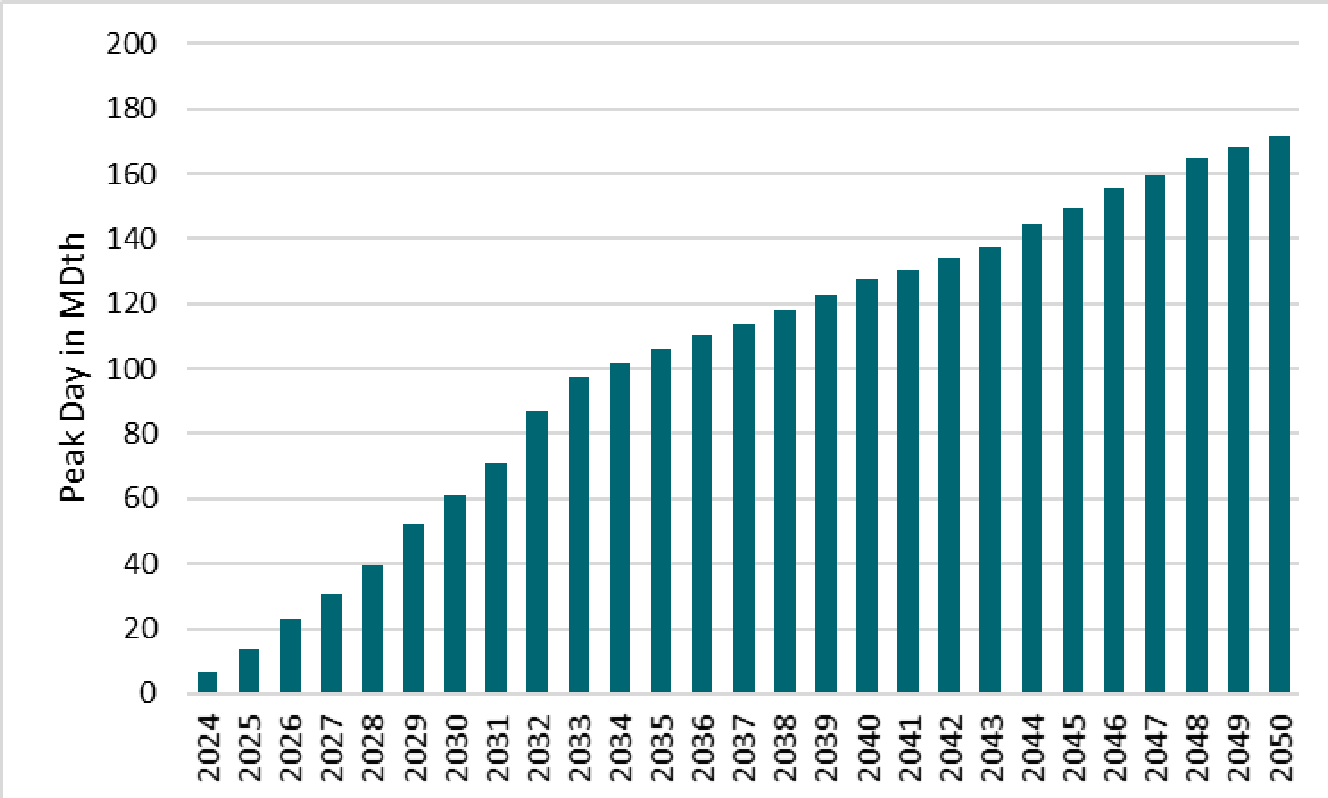
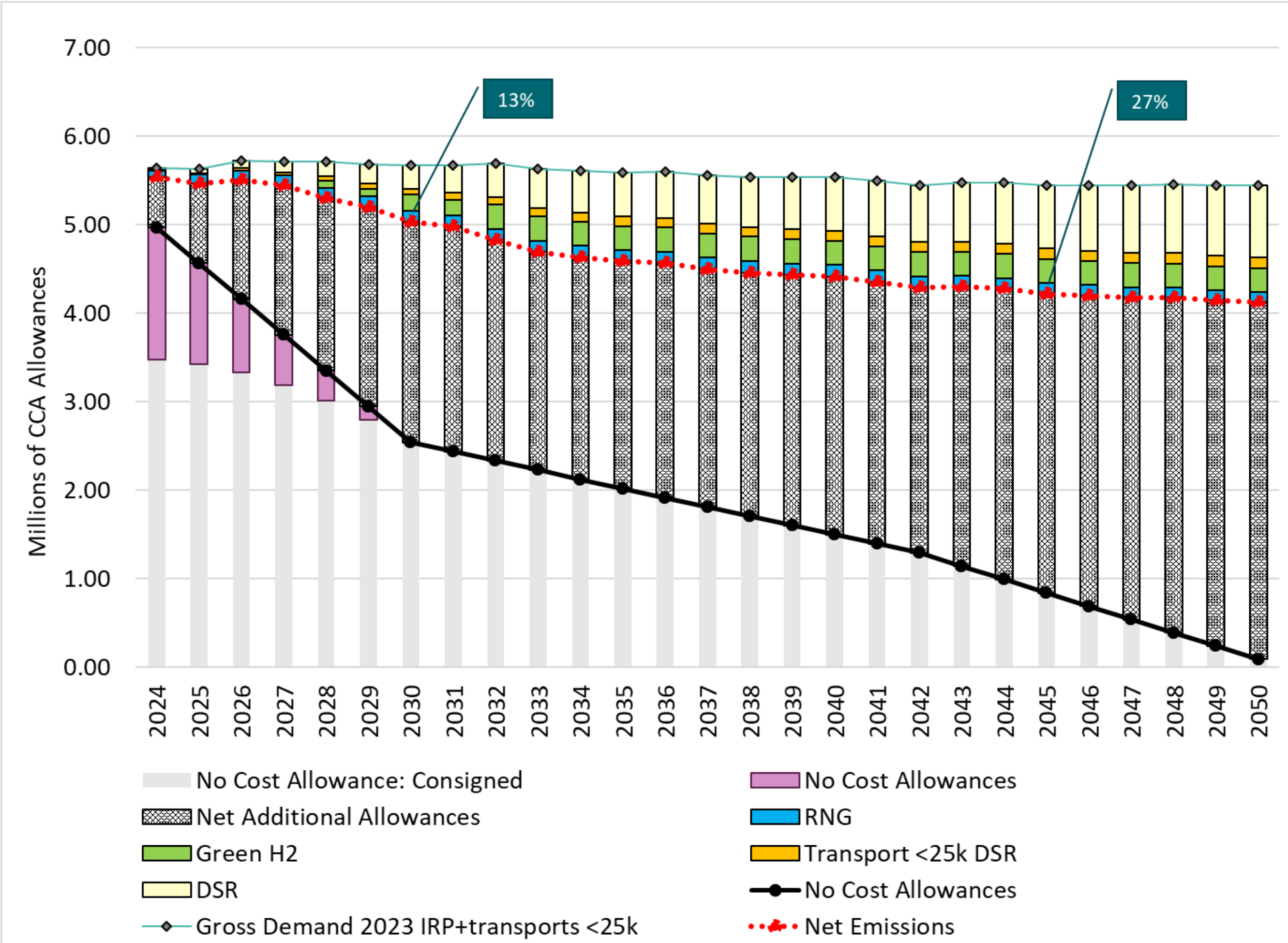


Figure F.23: Zero Gas Growth — Demand-side Resources Additions



Data for portfolio additions is in the output data files on the 2023 Gas Utility IRP website. We based the emissions profile for the portfolios on the least-cost portfolio in that scenario or sensitivity.

Figure F.24: Zero Gas Growth – CCA Emissions



G — High Gas Prices

Portfolio additions represent the least cost builds for that scenario or sensitivity.

Figure F.25: High Gas Prices - Portfolio Additions

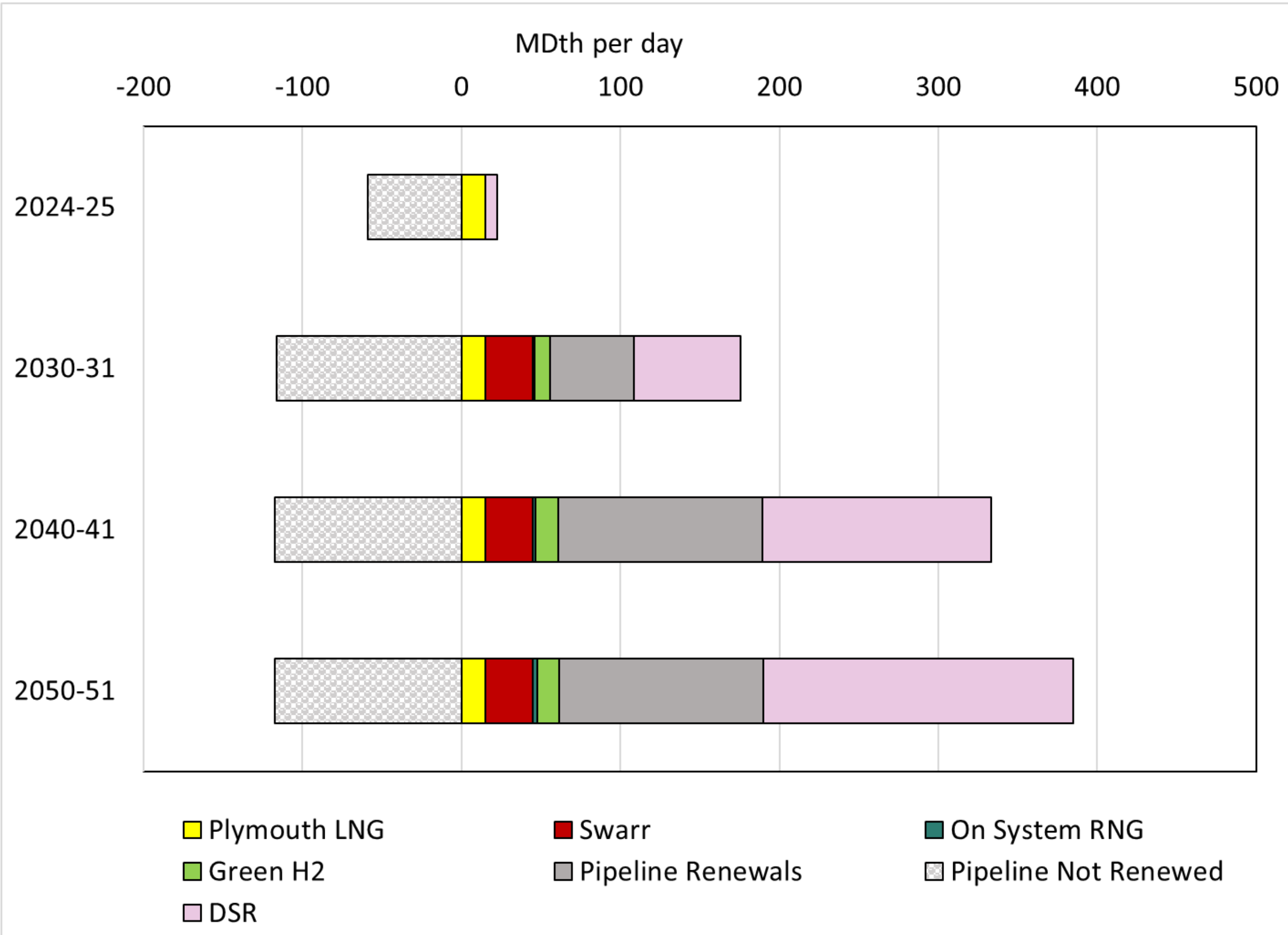
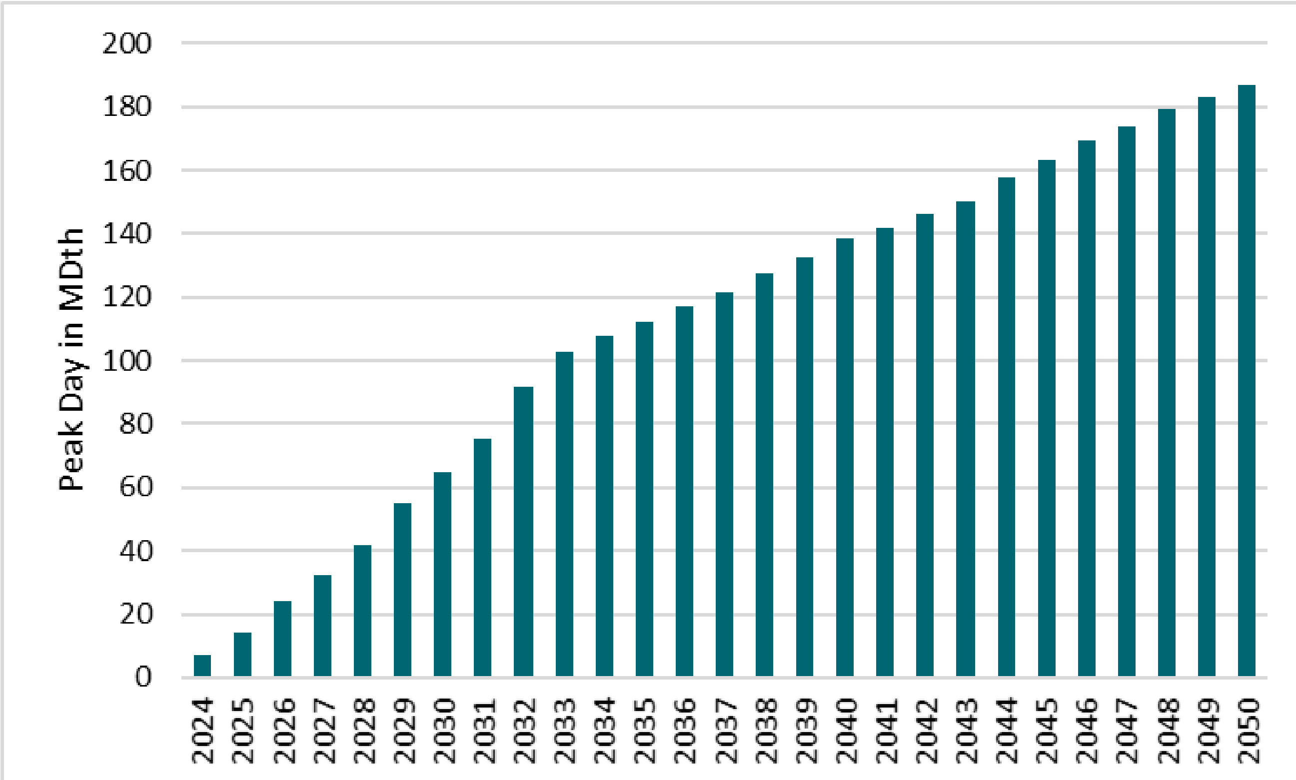


Figure F.26: High Gas Prices - Demand Side Resources Additions



Data for portfolio additions is in the output data files uploaded to the 2023 Gas Utility IRP website. We based the emissions profile for the portfolios on the least-cost portfolio in that scenario or sensitivity.

Figure F.27: High Gas Prices — CCA Emissions