2024 Economic Study

Additional Policy Scenario & Stakeholder-Requested Scenario Sensitivities

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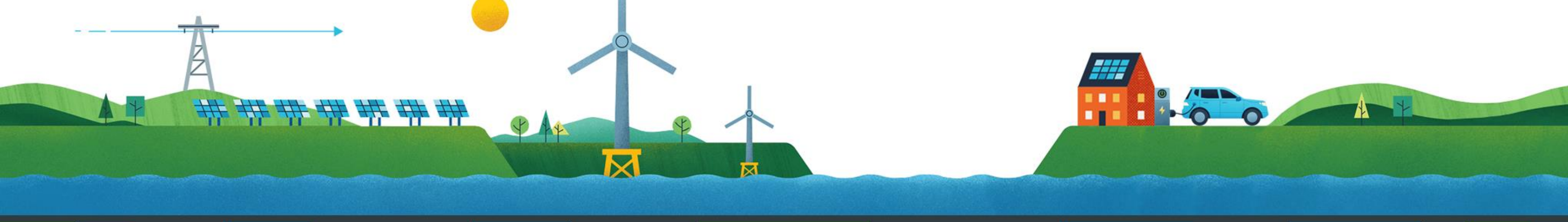
ECONOMIC STUDIES & ENVIRONMENTAL OUTLOOK



Overview of Presentation

- Overview of the 2024 Economic Study
- Policy Scenario Sensitivity: Flexible Demand
- Policy Scenario Sensitivity: Reduced Electric Sector Decarbonization and Electrification
- Stakeholder-Requested Scenario Sensitivity: Reduced Small Modular Reactor (SMR) and 100-Hour Batteries (BESS100) Capital Costs
- Timeline and Next Steps
- Appendix A: Flexible Demand Sensitivity – Additional Capacity Expansion Results
- Appendix B: Flexible Demand Sensitivity – Additional MWY Results
- Appendix C: Reduced Decarbonization Sensitivity – Additional Capacity Expansion Results
- Appendix D: Stakeholder-Requested Scenario Sensitivity Additional Results

OVERVIEW OF THE 2024 ECONOMIC STUDY

Previous Presentations

Date	Presentation (with Link)
Jan 18, 2024	Initiation of the 2024 Economic Study
Mar 20, 2024	Stakeholder-Requested Scenario Timeline & Benchmark Scenario Assumptions
Jun 20, 2024	Preliminary Benchmark Scenario Results & Review of Stakeholder Requested Scenario Proposals
Aug 21, 2024	Final Benchmark Scenario Results, Publishing of the Public Benchmark Scenario, & Policy Scenario Assumptions
Oct 23, 2024	Interregional Model Assumptions / High Level Results
Nov 20, 2024	Preliminary Policy Scenario Results & Stakeholder-Requested Scenario Assumptions
Jan 23, 2025	Final Policy Scenario Results
Feb 26, 2025	Preliminary Stakeholder-Requested Scenario Results
Mar 19, 2025	Policy Scenario Sensitivities & Follow-Up to Stakeholder-Requested Scenario
May 14, 2025	Policy Scenario Sensitivities & Stakeholder-Requested Scenario Final Results

Objective of the Economic Study Process

- Provide information to stakeholders to facilitate the evaluation of economic and environmental impacts of New England regional policies, federal policies, and various resource technologies on satisfying future resource needs in the region
  - Identify system efficiency issues on the Pool Transmission Facilities (PTF) portion of the New England Transmission System and, as applicable, evaluate competitive solutions to alleviate identified system efficiency needs
- The 2024 Economic Study is anticipated to conclude by December 2025, but timeline may vary depending on outcomes of the System Efficiency Needs Scenario (SENS)

Economic Study Reference Scenarios

Benchmark Scenario – Model the previous calendar year and compare it to historical system performance. This scenario's purpose is to test the fidelity of models against historical performance and improve the models for future scenarios

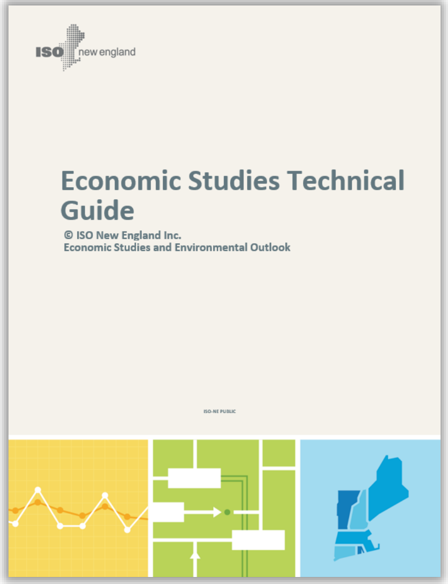
Policy Scenario – Model future years (>10-year planning horizon) based on satisfying New England region and other energy policies and goals

System Efficiency Needs Scenario – Model a future year (10-year planning horizon) based on the ISO's existing planning criteria to identify system efficiency issues that could meet the threshold of a System Efficiency Needs Assessment and move on to the competitive solution process for System Efficiency Transmission Upgrades

Stakeholder-Requested Scenario – Scenario with a region-wide scope that is requested by stakeholders and not covered by the other 3 scenarios or potential sensitivities on those 3 scenarios

Economic Studies Technical Guide

- The ISO published the first version of the Economic Studies Technical Guide (ESTG) on March 25, 2024
  - Revision 1.1 of the ESTG will be issued on July 30, 2025
- The ESTG seeks to provide stakeholders, policymakers, and the public with a comprehensive document that describes the Economic Study process
  - Please refer to the ESTG for detailed questions about assumptions and study procedures



POLICY SCENARIO SENSITIVITY

Flexible Demand

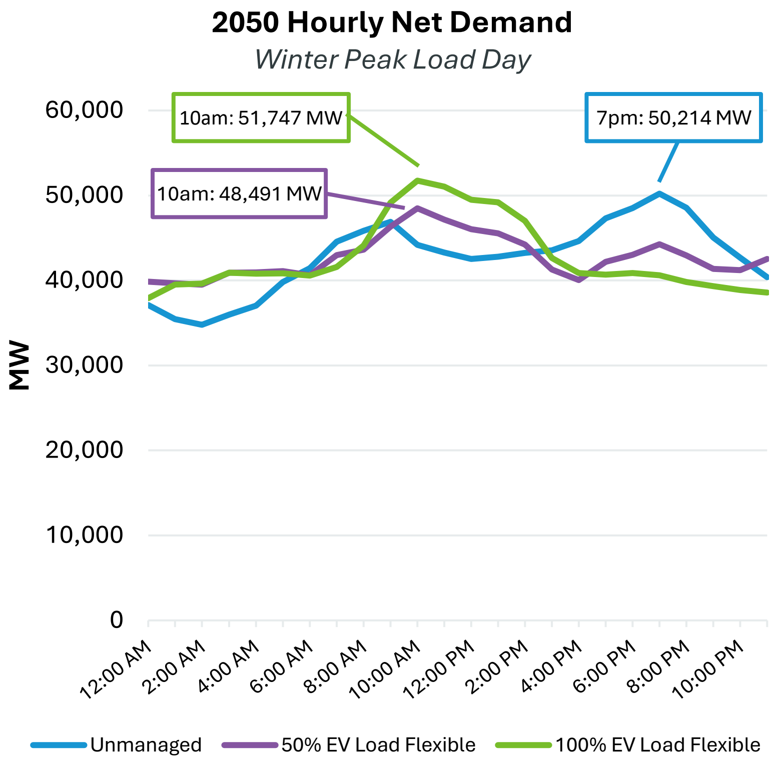
Flexible Demand Overview

- The Economic Studies typically model only existing active demand response (ADR) based on the 2024 Forecast Report of Capacity, Energy, Loads, and Transmission (CELT Report), with high dispatch costs limiting its operations to the highest demand hours
- The following sensitivities explore the potential benefits of a **conceptual flexible demand program, where PLEXOS can shift the timing of a portion of baseload or electric vehicle (EV) load within each day to reduce the overall cost of serving demand**
  - This represents a broader range of potential future technologies that increase the attribute of flexibility on the system
- The purpose of these sensitivities is to **assess whether increased demand-side flexibility can reduce inefficiencies in the reference buildout** such as high costs, large capacity requirements, misalignment of supply and demand, and reliance on stored fuels for a small portion of winter days

Preliminary Results: Optimized Demand Profiles

- Preliminary production cost results for 2050 showed production cost savings from implementing flexible demand in the model, but **they also showed potential increases in peak demand**

- From the model's perspective, the most economic way to reduce production cost is to shift as much demand as possible onto the midday hours when photovoltaic (PV) production is at its peak. This can increase transmission and capacity costs, but the model has no insight into these costs



Load Assumptions and Peak Load Constraint

- The ISO's 2050 Transmission Study[1] found that **increases in peak load above ~51 GW become significantly more expensive with regard to transmission costs**
  - Transmission costs increase by roughly $1.5 billion per GW of load added from 51 GW to 57 GW
  - Higher peak loads → more transmission overloads → more transmission upgrades needed → increased transmission costs

- Based on the 2050 Transmission Study finding, **a 51 GW peak load constraint was implemented in the flexible demand sensitivity capacity expansion and production cost models**. All results will reflect this change

- The peak load constraint is applied to net load because behind-the-meter photovoltaics (BTM-PV) reduce the demand that must be served by the bulk power system
  - Storage charging load is excluded from the constraint based on the assumption that storage is a highly controllable resource and its charging can be shifted in real-time to avoid contributing to system peaks.

[1] https://www.iso-ne.com/static-assets/documents/100008/2024_02_14_pac_2050_transmission_study_final.pdf

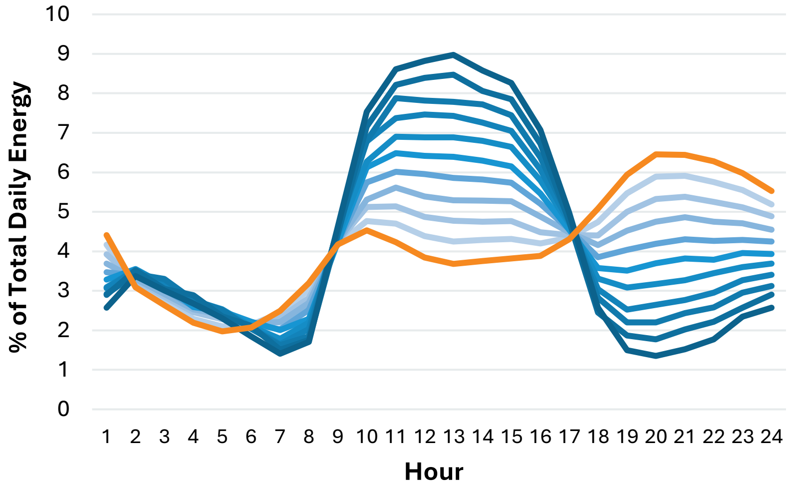
FLEXIBLE DEMAND IN CAPACITY EXPANSION

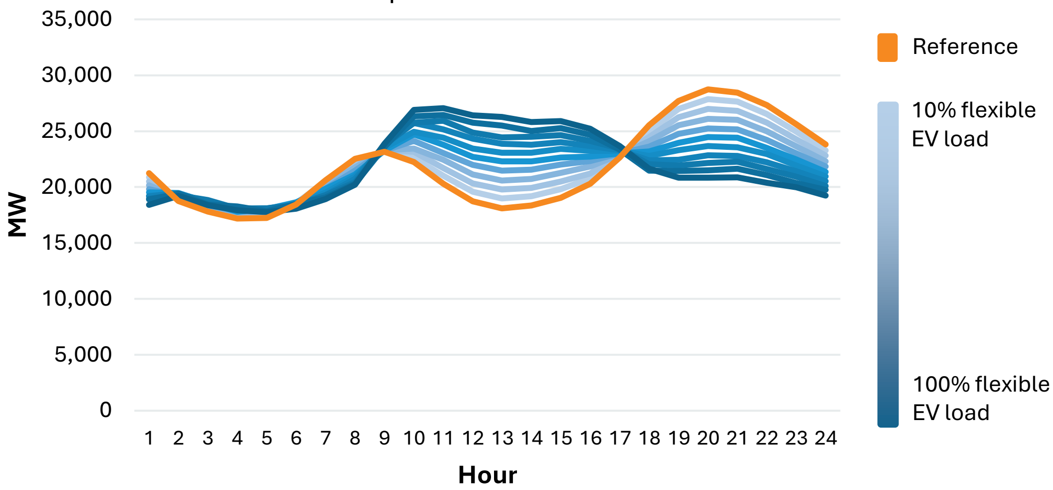
2019 Weather Year

Takeaways: Flexible Demand in Capacity Expansion

- As renewable penetration increases, the most efficient way, given the approach and assumptions, to shift demand is to increase demand midday when solar generation (both utility and BTM-PV) is high and decrease it during evening or winter morning peaks when solar generation is low
- Capital costs savings increase linearly with increasing demand-side flexibility, as represented in this analysis by EV and baseload shifting
  - Flexibility reduces reliance on expensive resources that are only needed for short durations
- Additionally, battery buildouts decline linearly because flexible demand increasingly substitutes for batteries in performing load shifting

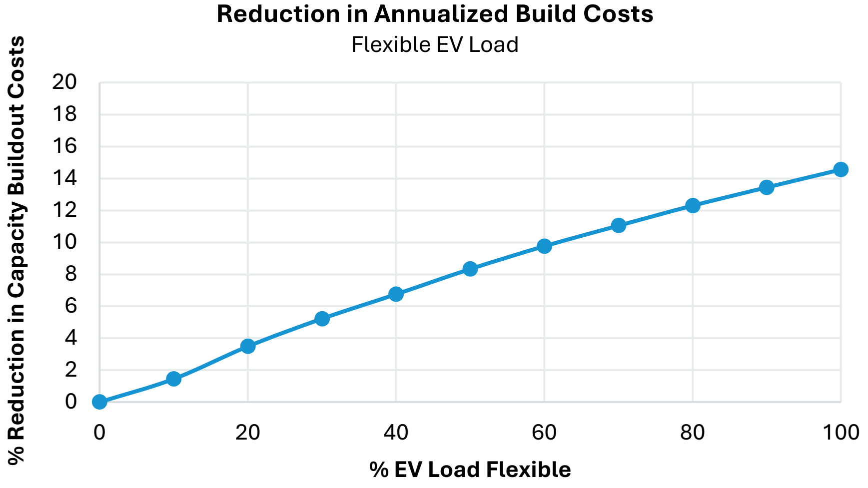
Optimized Profiles: EV Load

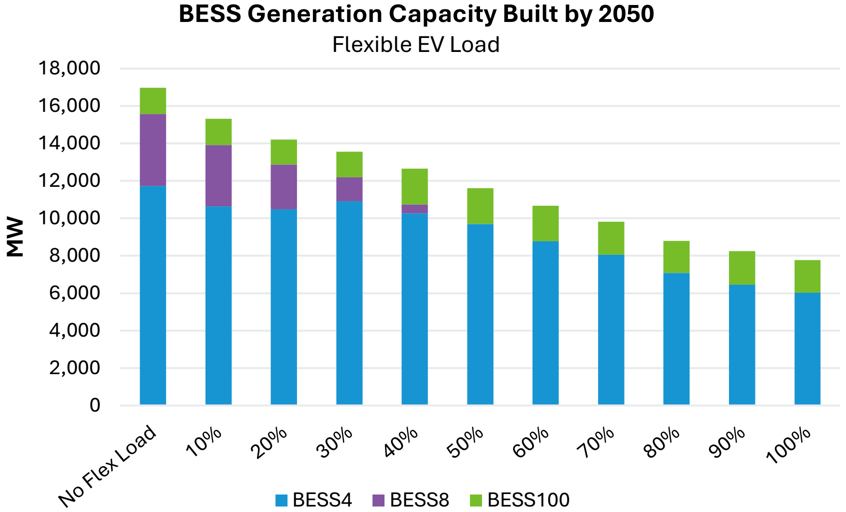




- Profiles are optimized to minimize production cost by shifting load onto low or negative locational marginal price (LMP) hours
- Optimal charging times appear to shift to midday as the system is decarbonized
  - Additionally, as heating electrification increases, winter peak loads may occur in the morning rather than evening, so the traditional 'on-peak' vs 'off-peak' managed EV charging may vary by season
  - See Appendix A for additional optimized EV and baseload profile results including seasonal average profiles. Note that winter profiles shift load away from morning hours

Capacity Expansion Results: EV Load Flexibility





- Total build costs can be reduced up to 14.6% using optimally managed EV charging and 17.4% using optimally managed baseload, which makes up a larger portion of total load
  - See Appendix A for capacity expansion results of flexible baseload, capacity buildout results for flexible EV load cases, MWh associated with each component in 2050, and 2050 production costs
- Flexible load replaces the role of short-duration batteries in shifting demand within each day, so the total battery energy storage system (BESS) buildout is reduced as more load is allowed to flex
  - Unlike batteries, flexible demand was not modeled with an associated cost for shifting load, making it a more economic solution, under these modeling assumptions, for addressing mismatches between supply and demand

FLEXIBLE DEMAND MULTIPLE WEATHER YEAR (MWY) ANALYSIS

2050 MWY Analysis

Multiple Weather Year Analysis Overview

- The Policy Scenario reference case uses the 2019 weather year load profile, which peaks at 50.2 GW. To investigate how effective demand shifting programs could be in reducing peak loads above 51 GW, **the ISO performed additional 2050 production cost runs with 20 weather year profiles**
  - This analysis assumes a fixed percentage of total daily load is flexible, rather than separating by load component. Results include total MW of load that need to be shifted but do not attribute this flexibility to specific load components
- The resource mix evaluated in **this analysis uses the Policy Scenario reference case buildout**
  - This approach isolates the impact of flexible demand on system performance and peak loads without conflating results with differences in resource mix
  - Using the reference buildout represents a more realistic planning scenario in which the grid is not explicitly designed to rely on demand flexibility

2050 Peak Loads Across 20 Weather Years

- The goal of this analysis is to determine
  1. How much flexible demand is required to maintain a 51 GW peak load?
  2. How do system costs change when demand shifting programs are implemented?
  3. To what extent can demand-side flexibility reduce system inefficiencies?

- Across the 20 years of load and weather data, the 2004 weather year has the highest peak net demand at 59,490 MW, requiring **14.3%** load flexibility to reduce the peak to 51GW
  - During the peak hour, this is equivalent to 44% baseload flexibility or 78% EV load flexibility. Distributing load shifting participation across multiple load components reduces stress on any single component
  - This analysis is limited to only 20 years of historic weather data. Extreme weather events could produce even higher peak loads which would require more demand flexibility

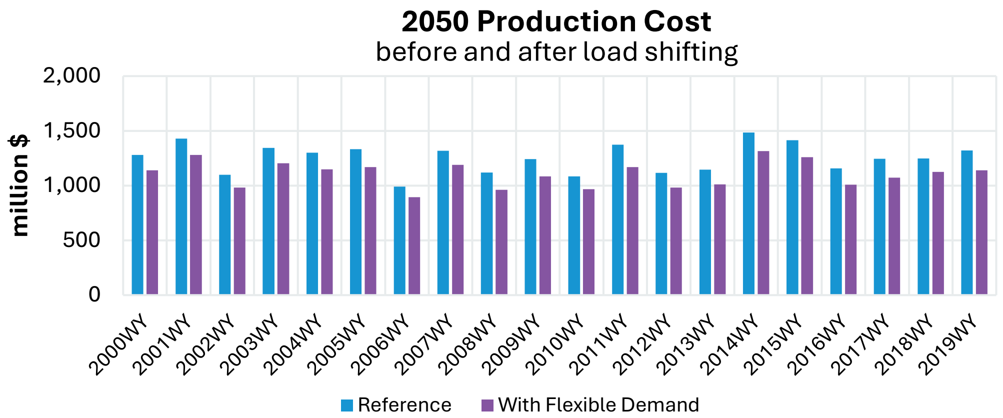
Weather Year	Peak Net Load (MW)	Peak Load Reduction Needed (MW)
2000	48,633	0
2001	42,890	0
2002	44,064	0
2003	50,727	0
2004	59,490	8,490
2005	52,197	1,197
2006	41,697	0
2007	52,170	1,170
2008	46,702	0
2009	54,340	3,340
2010	43,963	0
2011	54,958	3,958
2012	40,934	0
2013	48,879	0
2014	50,512	0
2015	54,199	3,199
2016	52,861	1,861
2017	50,089	0
2018	50,366	0
2019	50,214	0

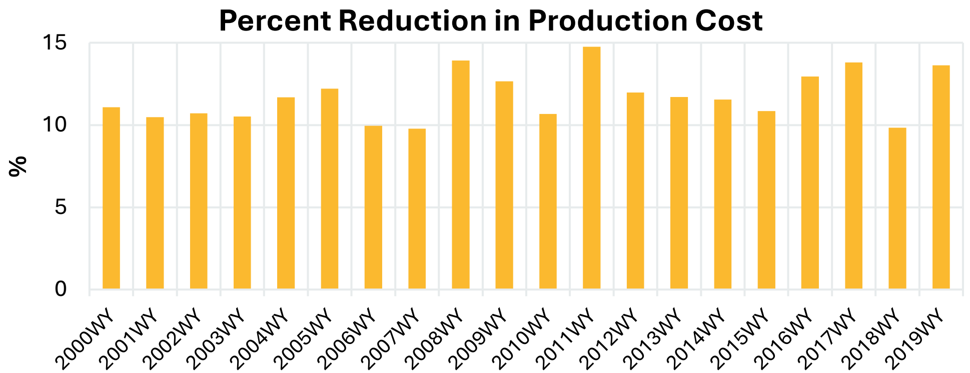
Takeaways: Economic and Operational Impacts of Flexible Demand

- Demand-side flexibility **reduces production costs** by moving load to lower-cost hours
- Demand shifting **can be used to maintain a 51 GW peak load,** even in severe weather years, by rescheduling load to off-peak hours
  - Peak load reductions can avoid costly transmission upgrades, as identified in the 2050 Transmission Study
- Operationally, demand-side flexibility improves the alignment of real-time generation with hourly demand, **reducing reliance on stored fuels and batteries and lowering the risk of winter energy shortfalls**

Economic Impacts of Flexible Demand

Production Cost Savings

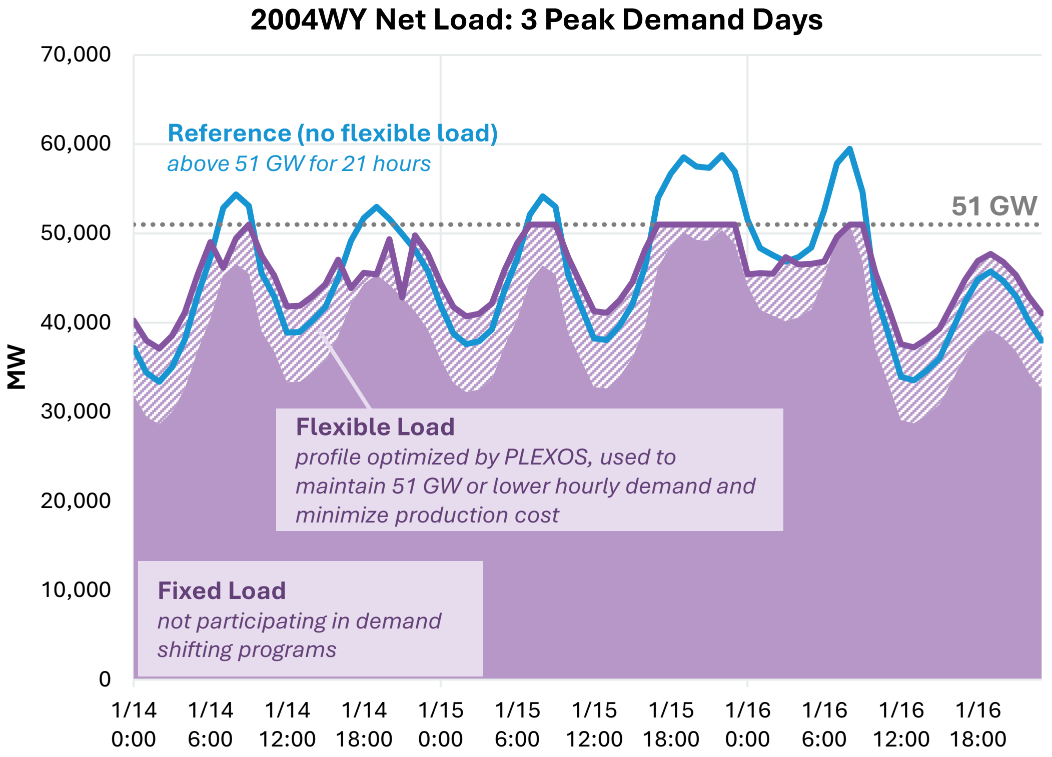




- Flexible demand reduces costs by shifting load away from high-cost hours, improving overall system efficiency. Across the 20 modeled weather years, implementing demand-side flexibility resulted in **production cost savings ranging from 10-15% relative to the reference case**
  - See Appendix B for detailed annual production cost savings and annual energy shifted
  - Note that PLEXOS has perfect foresight and total control over flexible load. In practice, load shifting needs are less predictable and less precise, so these modeled cost savings may be inflated from actual operational savings

Operational Impacts of Flexible Demand

Reductions in Peak Load

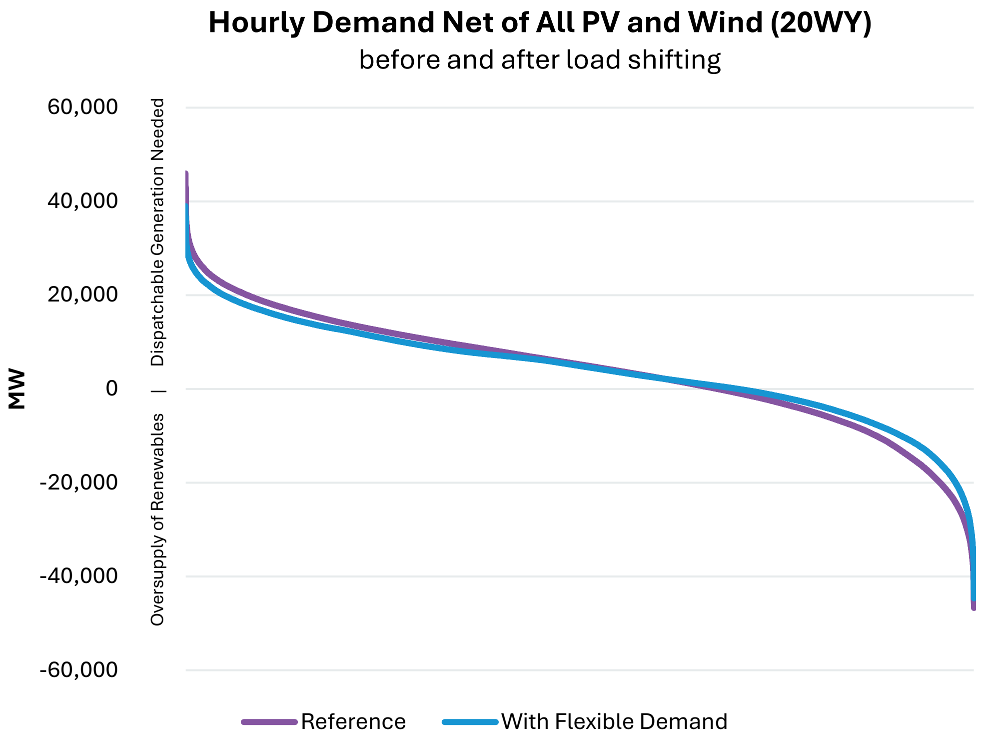


- This graph shows a snapshot of the 2004 weather year peak demand days before and after demand shifting
- With demand shifting, the portion of load that is flexible is strategically rescheduled to off-peak hours, either early morning or midday, which reduces peak demand to 51 GW
  - Total daily demand is still served within each day, but the profile shape is optimized to flatten peaks and improve usage of available renewables
- As identified in the 2050 Transmission Study, transmission costs increase by roughly $1.5 billion per GW of load added from 51 GW to 57 GW
  - The modeled reductions in peak load from demand-side flexibility demonstrate how demand shifting can contribute to significant avoided transmission investment

Operational Impacts of Flexible Demand

Improved Alignment of Supply and Demand

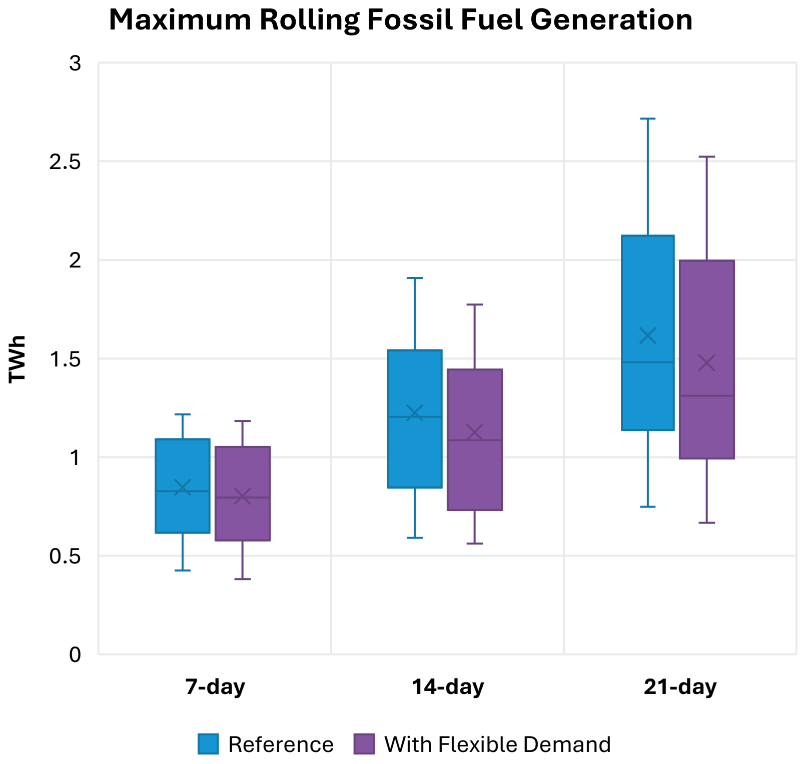
- In a highly decarbonized system, intermittent renewable generation and load both vary drastically. Demand shifting can aid in better coordination between hourly supply and demand
  - Lower peak net demand means less dispatchable generation is needed, reducing emissions
  - Less oversupply of renewables means resources are being used more efficiently with less curtailment



Operational Impacts of Flexible Demand

Winter Energy Deficits: Fossil Fuel Generation

- In order to analyze the potential benefits of flexible demand in reducing winter energy deficits, this analysis calculates the maximum 7-, 14-, and 21-day rolling generation from fossil fuels over 19 winters (Oct-Apr)
  - This analysis does not model fuel constraints
- Results show that **demand shifting consistently reduces fossil fuel drawdowns regardless of weather conditions**
  - Demand shifting reduces morning heating and evening peak loads, which is when fossil fuel generation is most likely to be needed
- Historic[1] (2008-2024) maximum rolling fossil fuel generation is significantly higher than 2050 fossil generation, even in the reference case
  - 7-day: 1.73 TWh
  - 14-day: 3.15 TWh
  - 21-day: 4.56 TWh

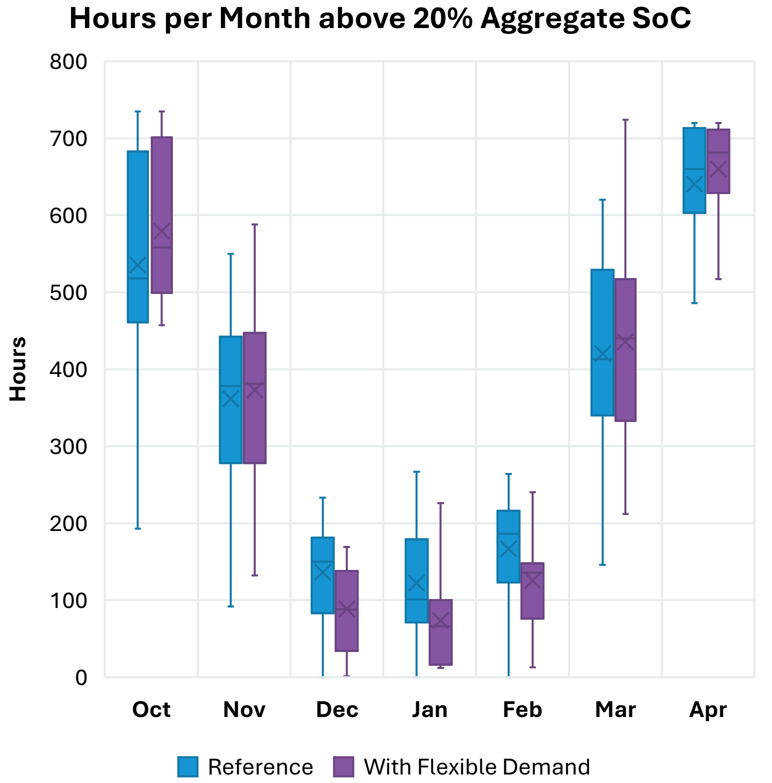


[1] https://www.iso-ne.com/isoexpress/web/reports/operations/-/tree/daily-gen-fuel-type

Operational Impacts of Flexible Demand

Winter Energy Deficits: BESS Drawdown

- Results to date show that battery storage is heavily drawn down in the winter, when surplus renewable generation is limited
  - It's often more economic for the model to leave batteries near empty than to charge them using generators with positive operating costs
- **With demand shifting, winter state of charge levels decline further due to improved alignment of supply and demand**, leaving fewer hours with excess energy available for charging
  - This does not necessarily indicate a higher risk of winter energy shortfalls. Rather, it reflects that **the system is relying less on all forms of stored energy, both from fuels and batteries, because demand is being served more efficiently from real-time generation**
  - The model will still cycle batteries as needed for the most economic dispatch



POLICY SCENARIO SENSITIVITY

Reduced Electric Sector Decarbonization and Electrification

Reduced Decarbonization Sensitivity Overview

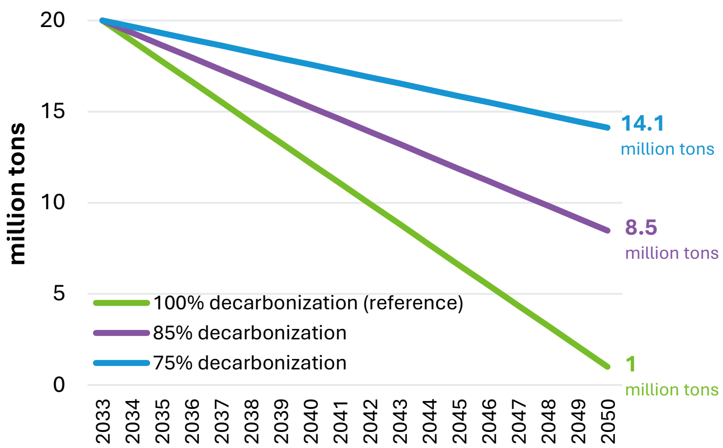
- While the Policy Scenario reference case models economy-wide decarbonization by 2050, these sensitivities explore how the system may evolve under different assumptions about emissions accounting. The ISO does not model carbon offsetting technologies, which could allow states to achieve net-zero emissions even when modeled emissions remain above zero. **These varied targets are meant to demonstrate a range of possible outcomes based on different interpretations of what constitutes "100%" decarbonization**
  - Electric sector decarbonization is reduced by relaxing the carbon constraint in the capacity expansion model, representing alternate assumptions about emissions targets and accounting. Decarbonization levels are measured against historic state baselines
  - Heating and transportation sector electrification is reduced by lowering demand from heat pumps and EVs
  - The sensitivities test 75% and 85% decarbonization levels for the electric sector alone and in combination with reduced electrification of the heating and transportation sectors

- **These sensitivities are not policy recommendations. Rather, they serve to identify common economic pathways for investment across a range of alternative futures, including different approaches to defining and achieving net-zero emissions**

2050 Energy by Component (TWh)

Electrification	Base	EV	HP
100%	120.2	56.4	30.6
85%	120.2	47.9	26.0
75%	120.2	42.3	23.0

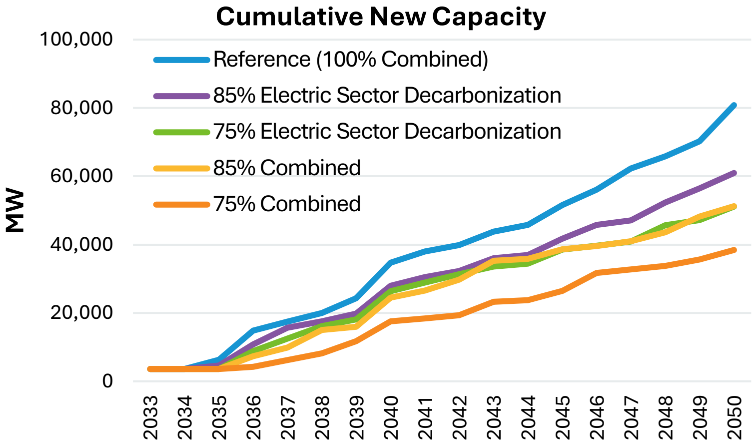
Annual CO_2 Limit



Reduced Decarbonization Takeaways

- Buildout costs are significantly reduced as decarbonization levels decrease
  - This aligns with previous results showing that the majority of buildout costs are concentrated to the last 5 years of the planning horizon. By that point, most emissions from spring and fall have been eliminated, so expensive resources like small modular reactors (SMRs) are needed to abate emissions in more challenging hours
- Despite the reduced decarbonization targets, many takeaways from the reference case still apply
  - Inexpensive resources like PV, land-based wind (LBW), and short-duration batteries facilitate substantial low-cost decarbonization in the next 10-15 years, providing the majority of early emission reductions
  - LBW remains the most economic resource to build
  - Emissions continue to follow seasonal trends, with elevated levels during winter months

Capacity Expansion Results



2033-2050 Total New Capacity (MW)

	Reference	85% Electric Sector Decarb	75% Electric Sector Decarb	85% Combined	75% Combined
PV	38,000	32,235	28,011	27,191	22,532
LBW	3,600	3,600	3,600	3,600	3,600
OSW	17,848	12,000	10,880	11,075	6,564
SMR	5,117	3,091	1,800	1,976	900
Li-ion BESS	14,811	10,042	6,849	7,414	4,840
100-hr BESS	1,451	0	0	0	0
Total	**80,826**	**60,967**	**51,141**	**51,256**	**38,436**
Delta from Reference		-19,859	-29,685	-29,570	-42,390
% Change		-24.57	-36.73	-36.59	-52.45

*Note: 'Combined' refers to the decarbonization level of electric sector **and** electrification levels of heating and transportation. Each case applies a consistent level across all sectors: 100% (reference), 85%, or 75%. This terminology is used throughout all slides and figures*

- Relative to the reference case, the total new capacity needed is up to 36% lower with reduced electric sector decarbonization levels and up to 52% lower with reduced decarbonization and electrification levels
  - Besides 100-hour batteries, which are only built in the reference case, SMRs show the largest percentage reduction in capacity built between the reference and reduced decarbonization sensitivities. This is consistent with previous findings that SMRs are primarily built to decarbonize the last 15-25% of emissions, which are the most expensive to abate
- Across all cases, 3.6GW of LBW are built in 2033 because the production cost savings from new LBW outweigh the increased capital costs

2050 Total Costs

	Reference	85% Electric Sector Decarbonization	75% Electric Sector Decarbonization	85% Combined	75% Combined
2050 Capital Costs ($B)	20.49	13.32	10.44	10.86	6.71
2050 Fixed O&M Costs ($B)	4.10	3.21	2.81	2.87	2.28
2050 Production Cost ($B)	1.32	2.68	3.68	2.61	3.90
2050 Total Cost ($B)	**25.91**	**19.22**	**16.93**	**16.33**	**12.89**
Delta from Reference ($B)		-6.69	-8.98	-9.57	-13.01
% Change		-25.83	-34.65	-36.96	-50.24

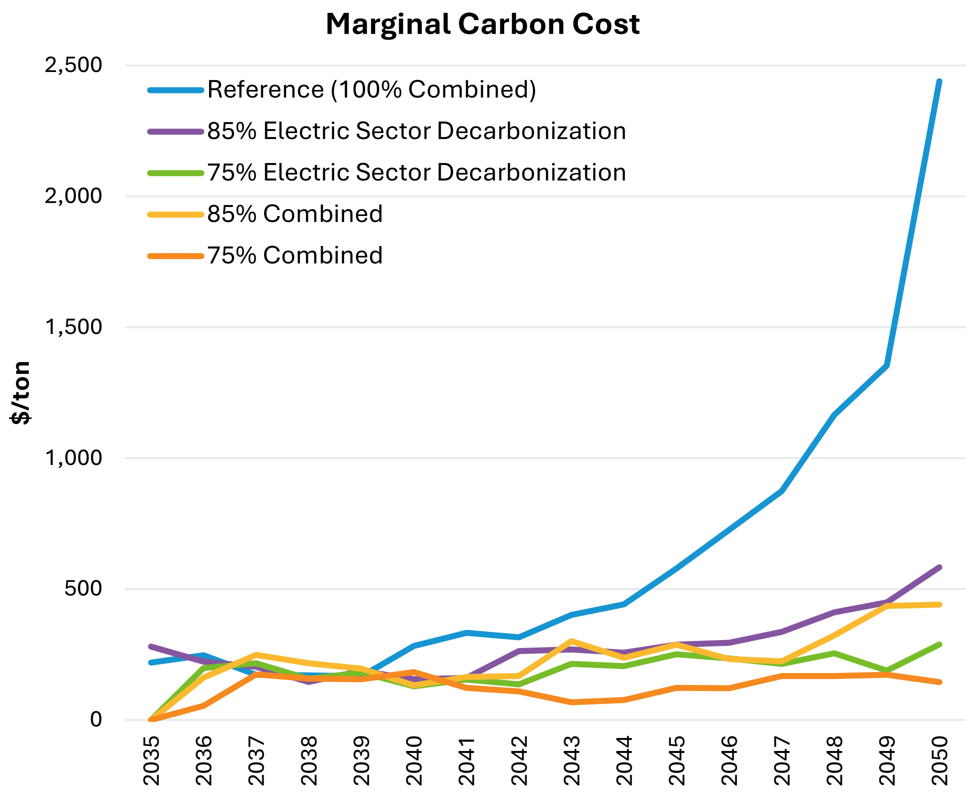
- Total electric sector costs decline across all reduced decarbonization cases, primarily driven by lower capital costs
  - While capital costs decrease, production costs increase due to reduced buildouts of wind and PV, which have no operating costs
  - The 75% combined case shows a 50% reduction in total 2050 costs relative to the reference case
- These results reflect electric sector costs only

2050 Economic and Operational Metrics

	Reference	85% Electric Sector Decarbonization	75% Electric Sector Decarbonization	85% Combined	75% Combined
Avg LMP ($/MWh)	25.57	64.21	82.59	69.93	97.00
Hours with LMP≤$0/MWh	4,527	3,015	2,785	3,161	2,500
SMR Capacity Factor (%)	20.72	47.02	65.53	48.97	57.92
Energy Curtailed (GWh)	30,979	17,479	14,480	16,869	10,660
% Generation from Renewables	69.26	59.13	55.45	58.40	49.98
Peak Emitting Generation (MW)	16,235	17,890	19,349	17,840	18,072

- The reduced decarbonization sensitivities use new resources more efficiently
  - Fewer hours with negative LMPs result in more frequent economic dispatch of SMRs, although this reflects higher energy market costs
  - Renewable curtailment is reduced by up to 65%, as fewer clean resources are built to address decarbonization needs during infrequent high-emission hours
- The reduced decarbonization buildouts have an increased reliance on legacy fossil fuel generation capacity because they have fewer new clean resources

Marginal Carbon Cost



- Marginal carbon cost is a measure of the costs associated with reducing emissions in a given year
  - The reference case found that as the system is decarbonized, low-cost resources like PV and short-duration batteries provide fewer emission reductions because residual emissions are concentrated during peak winter hours. To decarbonize those key hours, more expensive resources like SMRs and 100-hour batteries are built
- Relaxing decarbonization targets avoids the sharp increase in marginal carbon cost seen at high decarbonization levels
- The sensitivities that modify electric sector only decarbonization levels have slightly higher costs than the combined cases due to increased demand from heating and transportation sectors

2050 Monthly Electric Sector Emissions

2050 Monthly Emissions (thousand tons)

	Reference (100% Combined)	85% Electric Sector Decarbonization	75% Electric Sector Decarbonization	85% Combined	75% Combined	2024 Estimated[1]
Jan	939	2,228	2,947	2,017	2,860	2,172
Feb	446	1,313	1,978	1,235	1,942	1,657
Mar	194	685	1,201	719	1,167	1,939
Apr	13	99	250	114	288	1,511
May	0	12	82	21	144	1,709
Jun	0	43	147	75	269	2,318
Jul	13	215	519	319	870	3,102
Aug	50	283	637	386	962	2,806
Sep	0	104	289	150	499	2,294
Oct	10	203	447	245	557	2,517
Nov	178	829	1,362	856	1,479	2,245
Dec	762	1,954	2,624	1,829	2,508	2,228

- As decarbonization targets are relaxed, electric sector emissions increase but continue to follow a seasonal pattern
  - These results do not account for emissions from the heating and transportation sectors
- The reduced decarbonization and electrification sensitivities show lower winter electric sector emissions compared to the electric-sector only cases due to lower heating demand

[1] https://isonewswire.com/tag/monthly-prices/

Additional Capacity Expansion Results

- Building on previous sensitivities that showed cost savings from flexible demand and bifacial tracking PV panels, additional sensitivities were run for the 75% electric sector decarbonization and electrification case. The purpose is to **quantify how much combining these affordable decarbonization strategies can further reduce capacity buildout costs**
  - The ISO presented the results of the bifacial tracking PV sensitivity at the May PAC
- Results in the table below reflect capacity expansion results under the 75% decarbonization and electrification assumptions. Percent changes shown are relative to the 100% economy-wide reference case
  - Detailed buildout results are shown in Appendix C
- While the combined benefits are smaller than the sum of individual sensitivity cost savings, **stacking reduced decarbonization and electrification, flexible demand, and bifacial tracking PV can reduce capital costs up to 74%**

2033-2050 Annualized Build Cost versus Reference (% Change)

		Flexible Demand Level			
		No Flexible Load	20% Flexible EV Load	50% Flexible EV Load	100% Flexible EV Load
PV Panel Type	Monofacial Fixed Tilt	-65.63	-66.97	-69.68	-72.57
	Bifacial Single Axis Tracking	-67.00	-69.30	-71.63	-73.90

STAKEHOLDER-REQUESTED SCENARIO

Sensitivity Request

Stakeholder-Requested Scenario

- Stakeholders have the option to submit a Stakeholder-Requested Scenario proposal to be conducted within the framework of the Economic Studies
- Results of the Stakeholder-Requested Scenario are considered for informational purposes only
  - The Stakeholder-Requested Scenario/sensitivities **will not be** evaluated as system efficiency needs against the factors and metrics outlined in Attachment N of the Open Access Transmission Tariff (OATT)

Stakeholder-Requested Scenario Recap

- The ISO received one Stakeholder-Requested Scenario proposal to evaluate the operation of peaker generation plants under ISO forecasted heating and EV charging loads combined with expected growth in clean generation
  - Input assumptions mirrored the Policy Scenario with modifications to the electrification load and the amount of peaker generators from **2033 to 2040**
    - **The carbon constraint ends in 2040 at 12.2 million tons**
  - The ISO used a capacity expansion model to build resources **from 2033 to 2040**
  - The ISO ran production cost models in **2040** with the buildout resource mix from the capacity expansion
  - The ISO presented final results at the May 14, 2025 PAC[2]

https://www.iso-ne.com/static-assets/documents/100023/a02_2025_05_14_pac_2024_economic_study_additional_results.pdf

Stakeholder-Requested Scenario Sensitivity

- The ISO received a sensitivity request to lower the capital costs of SMR and BESS100 (100-hour batteries) such that it would enable these resources to be built in the mid-2030s timeframe
  - The results of this sensitivity would help stakeholders understand the economic requirements to facilitate and accelerate earlier adoption of these emerging technologies
- This sensitivity is focused on:
  - Reference Scenario
  - 50% Electrification Scenario
  - 100% Peaker Retired Scenario

Stakeholder-Requested Scenario Assumptions

- The ISO took SMR capital costs from NREL's 2024 Annual Technology Baseline Workbook (see Appendix D)
  - The ISO lowered cost assumptions from "conservative" (most expensive) to "moderate" and "advanced" (cheapest)
- The ISO took BESS100 capital costs from Form Energy's White Papers[3]
  - The ISO lowered cost assumptions from \$2,150/kW to \$1,900/kW (moderate) and \$1,700/kW (advanced)

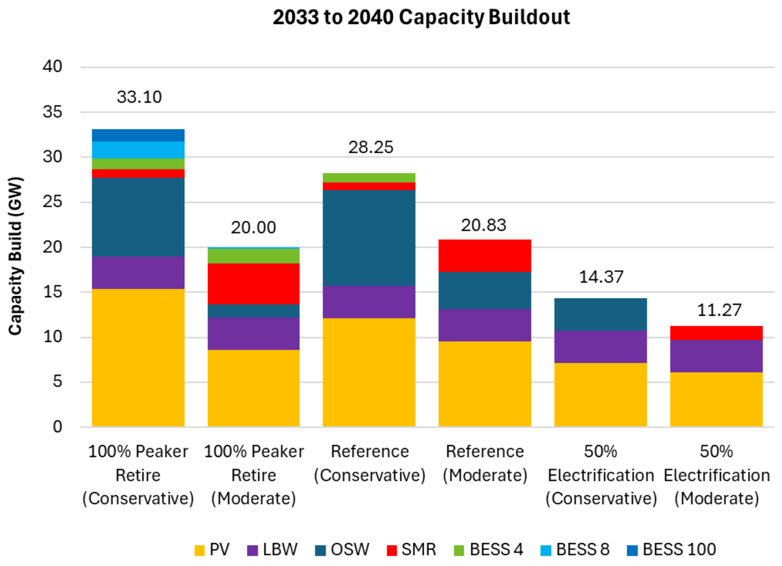
[3] https://formenergy.com/wp-content/uploads/2023/09/Form-ISO-New-England-whitepaper-09.27.23.pdf
https://www.edockets.state.mn.us/documents/%7B00AE3887-0000-C24C-BFC6-45EC1209A3DB%7D/download

Sensitivity Takeaways

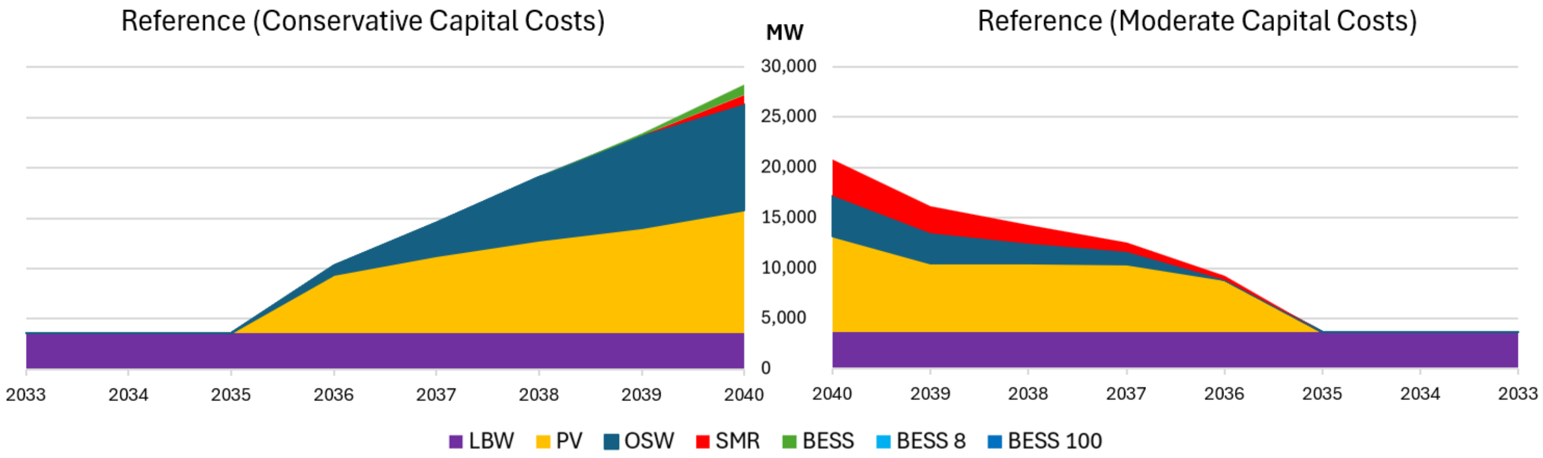
- Lower SMR cost assumptions have a greater impact on capacity expansion than BESS100
- The lower cost assumptions for SMR shifted its buildout from 2039 to mid-2030s and reduced the buildout of other non-emitting resources
- The model did not build any BESS100 in any of the scenarios despite lower cost assumptions

Capacity Buildout: Conservative vs. Moderate Capital Costs

- Moderate SMR capital costs resulted in greater buildout of SMR and less buildout of PV, OSW, and BESS
- Lower BESS100 capital costs did not incentivize earlier buildout
  - ISO ran a test case to exclusively model lowest BESS100 cost assumptions while keeping SMR costs conservative
    - The buildouts were identical to the base buildouts that used conservative capital costs
- **Lower SMR capital costs eliminated the need for BESS100 in the 100% Peaker Retired Scenario**

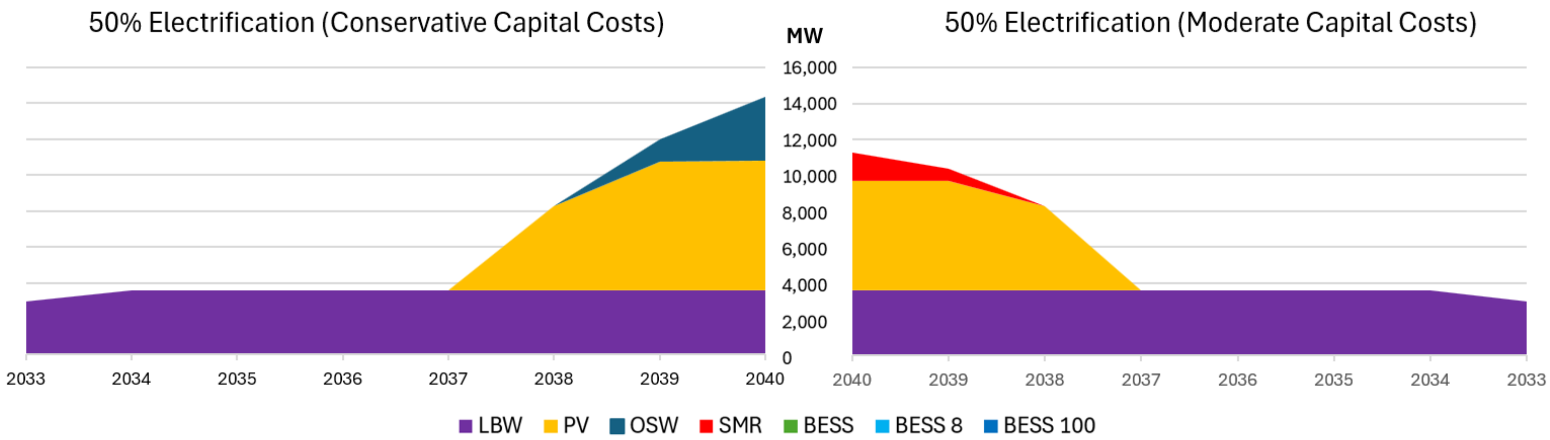


Cumulative Capacity Buildout: Reference Scenario



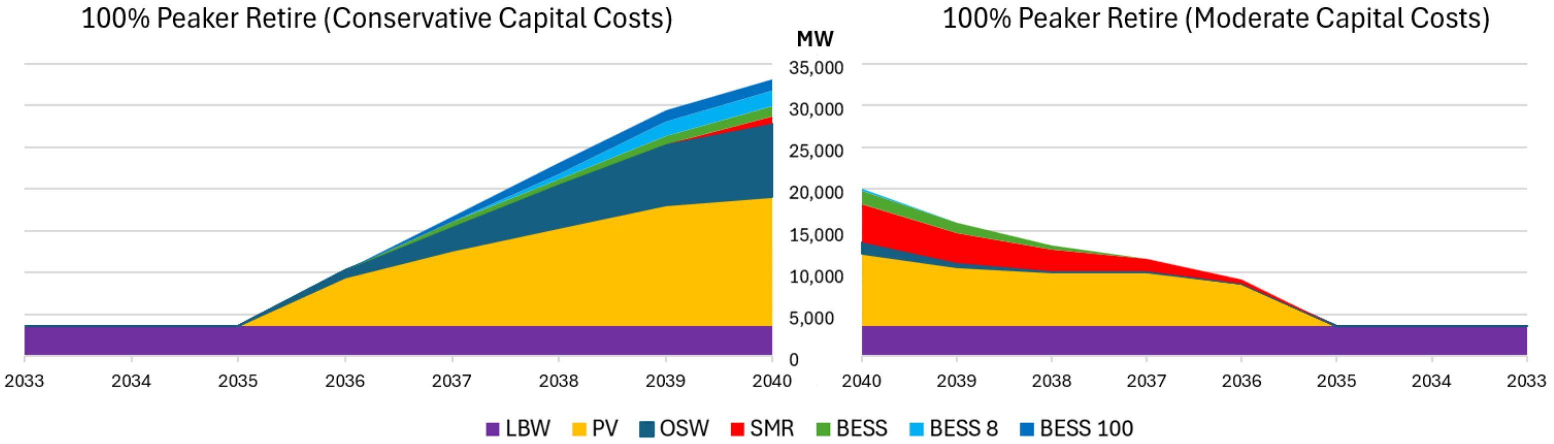
- Model still built maximum amount of LBW (3,600 MW) regardless of changes in SMR and BESS100 cost assumptions
- SMRs are built earlier under the lower cost assumptions, starting in 2036 instead of 2039 as SMRs are more cost effective for reducing emissions than OSW

Cumulative Capacity Buildout: 50% Electrification Scenario



- SMR replaced OSW under the "moderate" capital cost assumptions despite having higher build costs than OSW
- Since SMR is a dispatchable resource, the model doesn’t need to overbuild based on a wind profile, therefore, the SMR capacity buildout is less than OSW

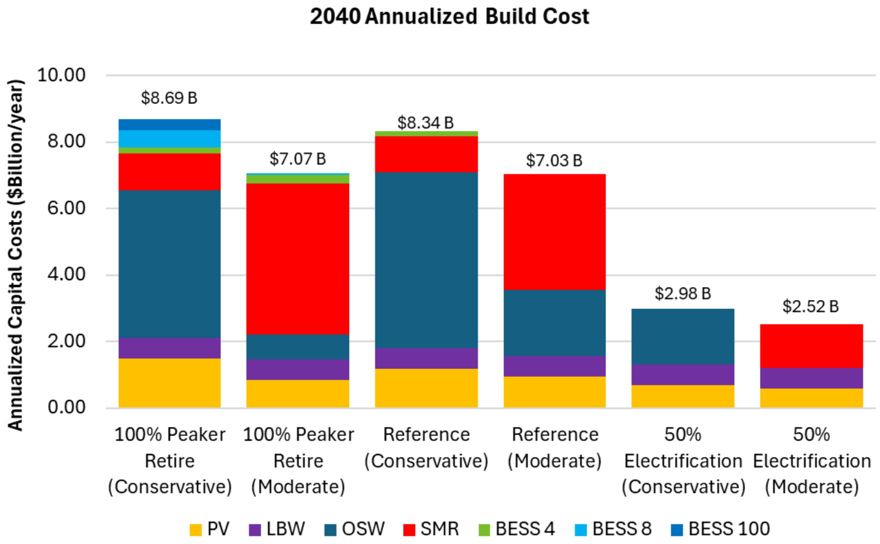
Cumulative Capacity Buildout: 100% Peaker Retired Scenario



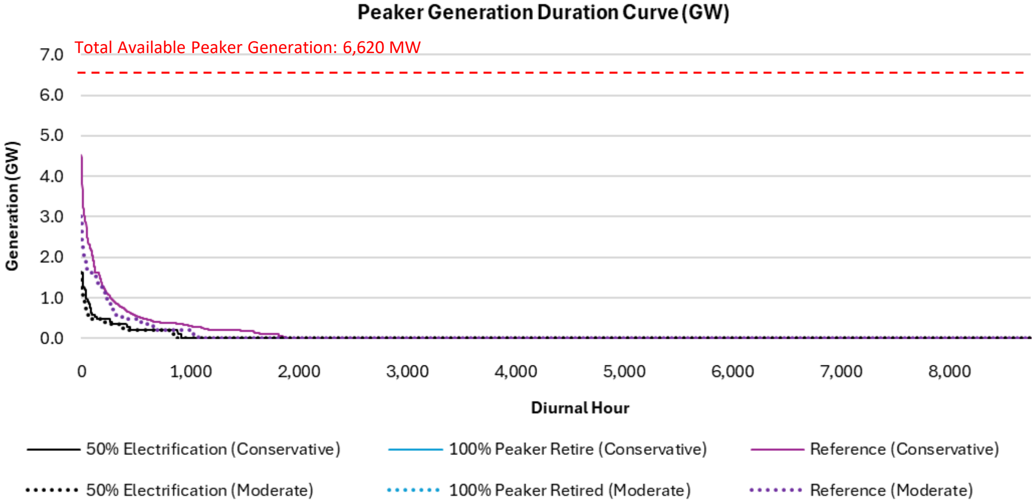
- This is the only scenario that built BESS100 to satisfy the need for additional dispatchable resources in the absence of peakers
  - BESS100 is no longer needed once SMR costs are lowered
- By lowering the SMR capital costs, the total buildout is nearly halved

Capacity Expansion Metrics: Conservative vs. Moderate Capital Costs

- The greater buildout of SMR under the "moderate" cost assumptions reduced the need for other non-emitting resources
- The reduction in capacity buildout resulted in lower total build costs



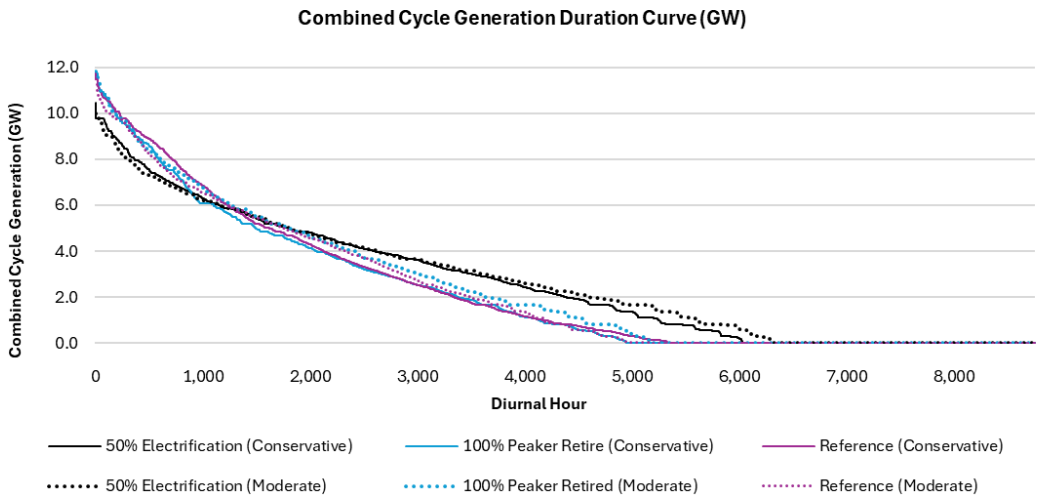
2040 Thermal Operations: Conservative vs. Moderate Capital Costs



Scenario	Capacity Factor (pu)
50% Electrification (conservative)	0.006
50% Electrification (moderate)	0.005
100% Peaker Retired (conservative)	0
100% Peaker Retired (moderate)	0
Reference (conservative)	0.018
Reference (moderate)	0.012

- Peaker generation drops when more SMRs are built and operated
- The Reference Scenario saw a greater reduction in emitting generation resulting in lower emissions under the "moderate" cost assumptions

2040 Thermal Operations : Conservative vs. Moderate Capital Costs



Scenario	Capacity Factor (pu)
50% Electrification (conservative)	0.48
50% Electrification (moderate)	0.49
100% Peaker Retired (conservative)	0.40
100% Peaker Retired (moderate)	0.45
Reference (conservative)	0.42
Reference (moderate)	0.42

- No change in combined cycle capacity factor for the Reference Scenario, regardless of SMR capacity
- The most significant change in combined cycle capacity factor was observed in the 100% Peaker Retired Scenario
  - There's an increased reliance on combined cycle units for additional capacity since the buildout is nearly halved under the lower SMR/LDES cost assumptions, this led to increased emissions

2040 Production Costs: Operational Metrics

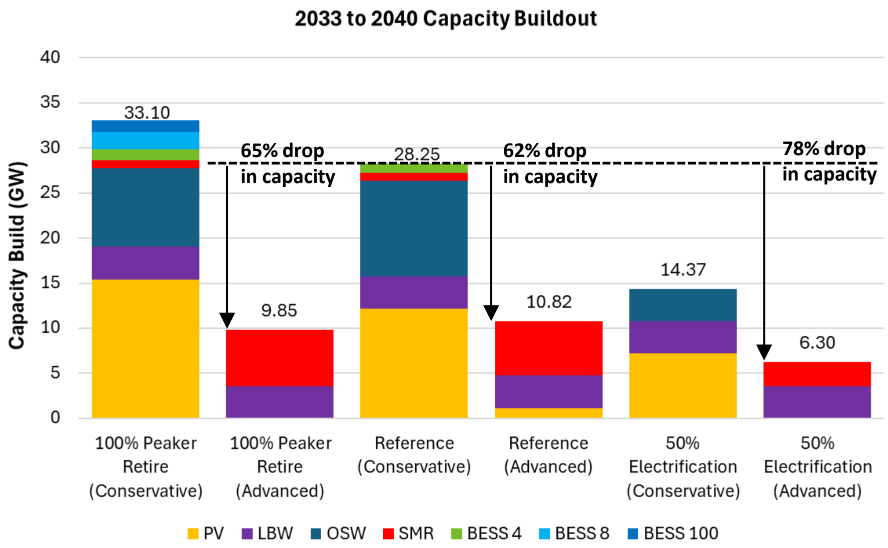
- **Curtailment is significantly reduced across all scenarios** since the model is not overbuilding PV and wind resources
- The greater buildout of SMRs replaced BESS buildout in the Reference Scenario, thereby, reducing the operating costs of BESS by half resulting in overall reduction in production cost
  - Similar BESS reduction was observed in the 100% Peaker Retired Scenario, but was offset by the higher SMR and combined cycle generation resulting in increased production cost
  - The 50% Electrification Scenario had higher production costs due to addition of SMRs, which were not built under the "conservative" cost assumptions

Metric*	100% Peaker Retired	Reference	50% Electrification
Curtailment	-81%	-69%	-57%
Carbon Emissions	+8%	-10%	+2%
Production Cost	+20%	-0.1%	+7%

**** Percent change from Conservative capital cost assumptions to Moderate capital cost assumptions (see Appendix D for more details)***

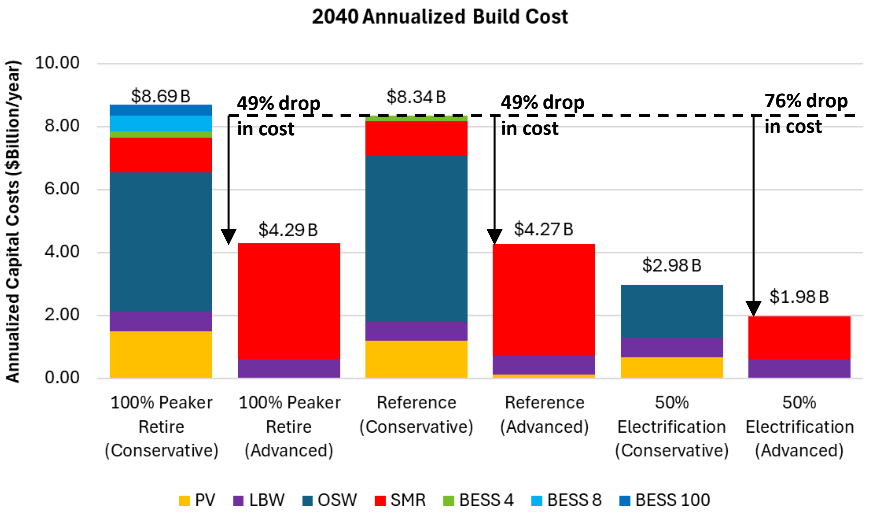
Capacity Buildout: Conservative vs. Advanced Capital Costs

- **Under the "advanced" (cheapest) capital cost assumptions, the model mainly builds SMR and LBW**
- The lowest cost assumptions for SMR significantly reduced total system buildout
- The 100% Peaker Retired Scenario has the largest SMR buildout (6.25 GW)
  - The Reference Scenario built 200 MW less SMR but is supplemented by 1.16 GW of PV

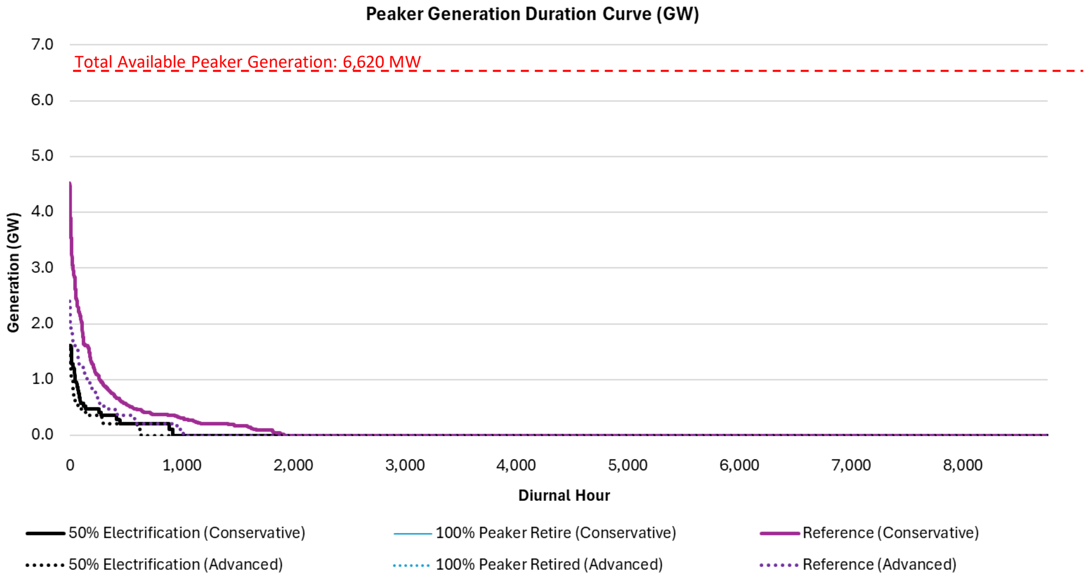


Capacity Expansion Metrics: Conservative vs. Advanced Capital Costs

- Even though the Reference Scenario built more capacity than the 100% Peaker Retired Scenario, the annualized cost is lower because PV is significantly cheaper to build than SMR
- While PV is cheaper than SMR, the 100% Peaker Retired Scenario chooses SMR over PV because it can provide dispatchable energy in the absence of peakers



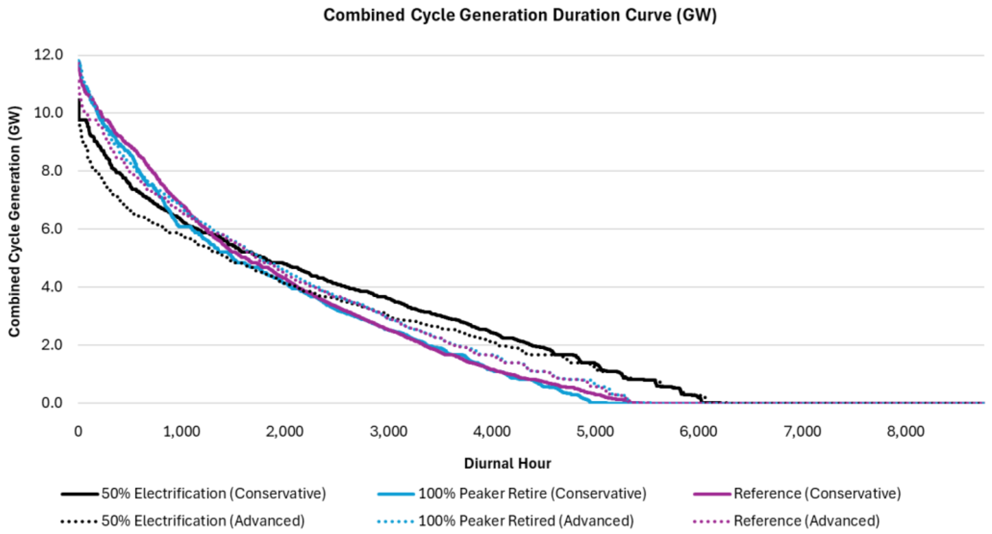
2040 Thermal Operations: Conservative vs. Advanced Capital Costs



Scenario	Capacity Factor (pu)
50% Electrification (conservative)	0.006
50% Electrification (advanced)	0.004
100% Peaker Retired (conservative)	0
100% Peaker Retired (advanced)	0
Reference (conservative)	0.018
Reference (advanced)	0.009

- The Reference Scenario saw the biggest drop in peaker capacity factor with greater buildout of SMRs (-49%)

2040 Thermal Operations: Conservative vs. Advanced Capital Costs



Scenario	Capacity Factor (pu)
50% Electrification (conservative)	0.48
50% Electrification (advanced)	0.43
100% Peaker Retired (conservative)	0.40
100% Peaker Retired (advanced)	0.44
Reference (conservative)	0.42
Reference (advanced)	0.43

- Combined cycle generators operate more frequently under the 100% Peaker Retired Scenario (advanced) because of the significant reduction in capacity buildout
- Inversely, the 50% Electrification Scenario (advanced) saw the biggest drop in combined cycle capacity factor with increased buildout of SMR

2040 Production Cost: Operational Metrics

- **The 100% Peaker Retired (advanced) scenario was the only scenario that had ADR operating, which indicates that not enough new capacity was built**
  - The model became more reliant on existing dispatchable generation (i.e. emitting generation), resulting in higher emissions
- The 50% Electrification Scenario (advanced) saw a reduction in production costs due to a significant drop in combined cycle generation and to a lesser extent, reduced peaker operations
- The 100% Peaker Retired and Reference Scenarios (advanced) had higher production costs due to increased operation of combined cycle and SMR resources

Metric*	100% Peaker Retired	Reference	50% Electrification
Curtailment	-97%	-98%	-89%
Carbon Emissions	+8%	-8%	-13%
Production Cost	+27%	+11%	-1%

**** Percent change from conservative capital cost assumptions to advanced capital cost assumptions (see Appendix D for more details)***

NEXT STEPS

2024 Economic Studies Report

- The ISO will publish the 2024 Economic Studies Report this September
- The report will include the Policy, Stakeholder-Requested, and Benchmark Scenarios
- Due to timing constraints from implementation of recent Tariff changes—which affect how the System Efficiency Needs Scenario (SENS) is conducted—and resource limitations from the ongoing LTTP effort, SENS will not be included in the report
  - Instead, the ISO will present SENS results during the August PAC

Next Steps

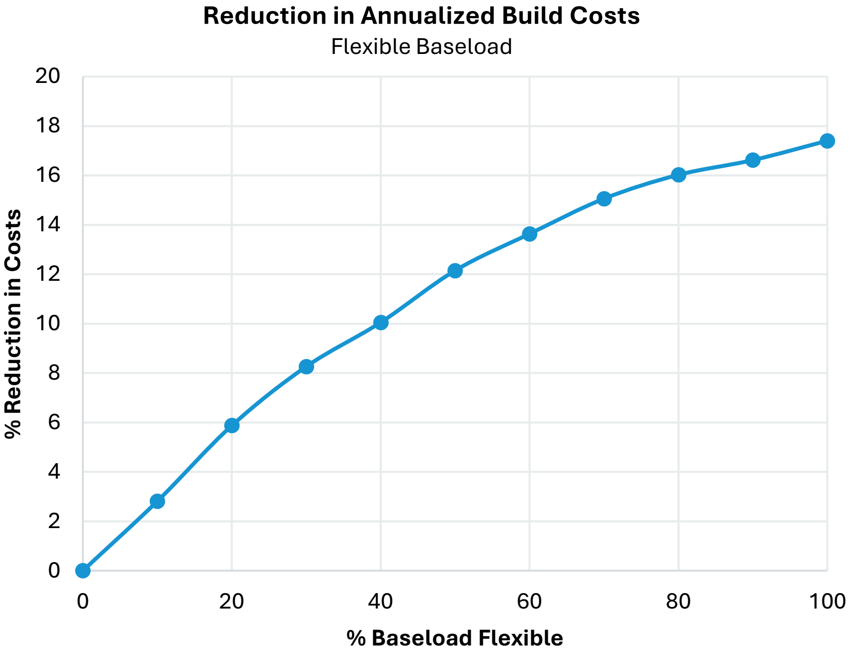
- The ISO will present the results for the SENS at the August PAC
- The ISO will publish Revision 1.1 of the ESTG to the ISO website on July 30, 2025
  - The PAC will be notified once the ESTG is posted
- The ISO will notify the PAC when it publishes the 2024 Economic Studies Report later this Quarter

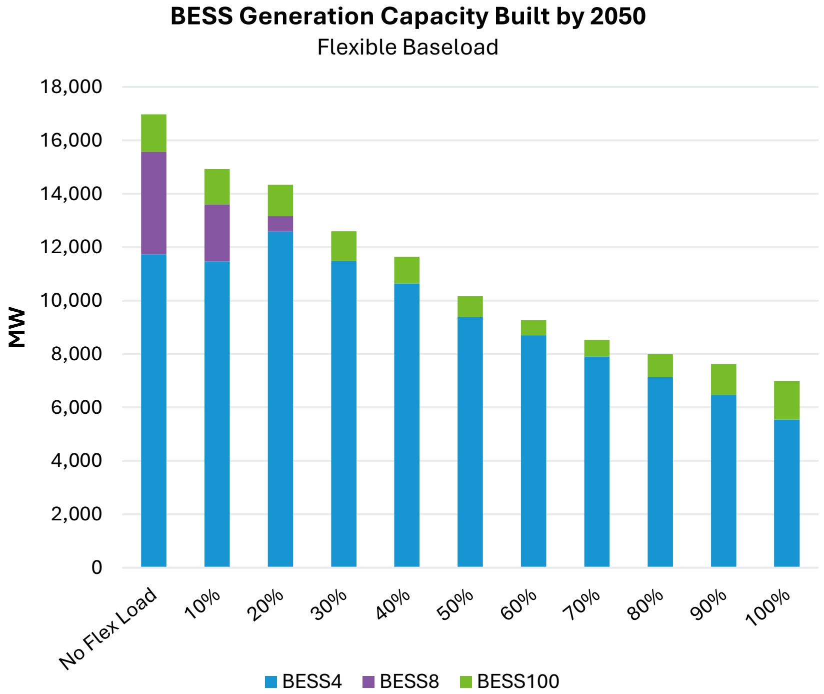
Questions

APPENDIX A

Flexible Demand Sensitivities – Additional Capacity Expansion Results

Capacity Expansion Results: Baseload Flexibility





- Total build costs can be reduced up to 17.4% using managed baseload

Capacity Expansion Buildout Results: Flexible Baseload

	No Flex Load	10% Flexible Baseload	20% Flexible Baseload	30% Flexible Baseload	40% Flexible Baseload	50% Flexible Baseload	60% Flexible Baseload	70% Flexible Baseload	80% Flexible Baseload	90% Flexible Baseload	100% Flexible Baseload
PV (MW)	38,173	36,758	36,905	36,284	37,149	36,758	37,414	38,965	39,371	41,691	43,000
LBW (MW)	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600
OSW (MW)	17,277	17,327	17,356	17,633	18,058	17,169	16,625	16,189	16,250	17,006	17,021
SMR (MW)	5,400	5,400	5,400	5,400	5,179	5,349	5,400	5,400	5,231	4,726	4,574
Li-ion BESS (MW)	15,570	13,612	13,169	11,488	10,643	9,381	8,703	7,908	7,136	6,476	5,548
Iron-air BESS (MW)	1,410	1,313	1,165	1,107	1,000	783	563	631	858	1,152	1,446
Total (MW)	**81,430**	**78,010**	**77,595**	**75,511**	**75,630**	**73,040**	**72,305**	**72,692**	**72,445**	**74,651**	**75,190**
Delta (MW)	0	-3,420	-3,835	-5,919	-5,800	-8,390	-9,124	-8,738	-8,984	-6,779	-6,239
% Change	0.00	-4.20	-4.71	-7.27	-7.12	-10.30	-11.21	-10.73	-11.03	-8.32	-7.66

- Unlike capital costs, capacity buildouts don't always decrease linearly with the portion of load flexibility. Buildouts will be larger if the resource mix includes more low-cost resource types, especially PV
- Note that the No Flex Load reference results slightly differ from previous versions because this analysis uses fixed representative sample days for capacity expansion modeling across all load flexibility levels. This approach, used in the Stakeholder-Requested Scenario, ensures consistent comparisons across sensitivities with different load profiles

Capacity Expansion Buildout Results: Flexible EV Load

	No Flex Load	10% Flexible EV Load	20% Flexible EV Load	30% Flexible EV Load	40% Flexible EV Load	50% Flexible EV Load	60% Flexible EV Load	70% Flexible EV Load	80% Flexible EV Load	90% Flexible EV Load	100% Flexible EV Load
PV (MW)	38,173	37,534	37,286	37,413	37,581	37,693	38,078	39,000	39,000	39,612	40,577
LBW (MW)	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600
OSW (MW)	17,277	17,101	17,053	17,063	17,309	17,176	17,171	17,477	17,523	17,672	17,659
SMR (MW)	5,400	5,400	5,400	5,400	5,400	5,400	5,354	5,157	5,111	4,945	4,794
Li-ion BESS (MW)	15,570	13,915	12,870	12,194	10,748	9,696	8,775	8,056	7,083	6,456	6,026
Iron-air BESS (MW)	1,410	1,398	1,330	1,358	1,906	1,917	1,890	1,771	1,702	1,795	1,743
Total (MW)	**81,430**	**78,949**	**77,539**	**77,028**	**76,543**	**75,481**	**74,868**	**75,061**	**74,019**	**74,080**	**74,400**
Delta (MW)	0	-2,481	-3,890	-4,402	-4,886	-5,948	-6,561	-6,369	-7,411	-7,349	-7,030
% Change	0.00	-3.05	-4.78	-5.41	-6.00	-7.30	-8.06	-7.82	-9.10	-9.03	-8.63

- See previous slide for notes on capacity expansion buildout results

2050 Load Components: 2019 Weather Year

	Base	EV	Heat Pump	Total
Peak (MW)	25,794	14,946	25,495	50,214
Energy (GWh)	120,239	56,367	30,636	207,242

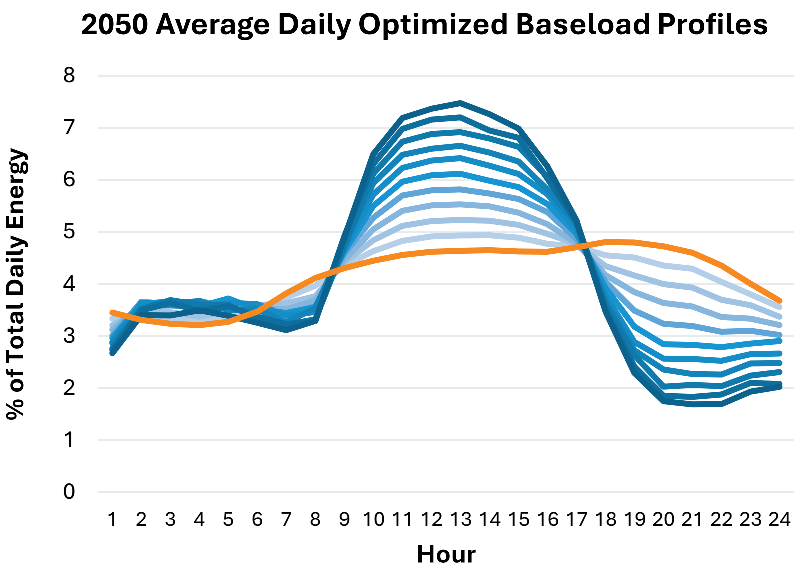
2050 Production Cost Results

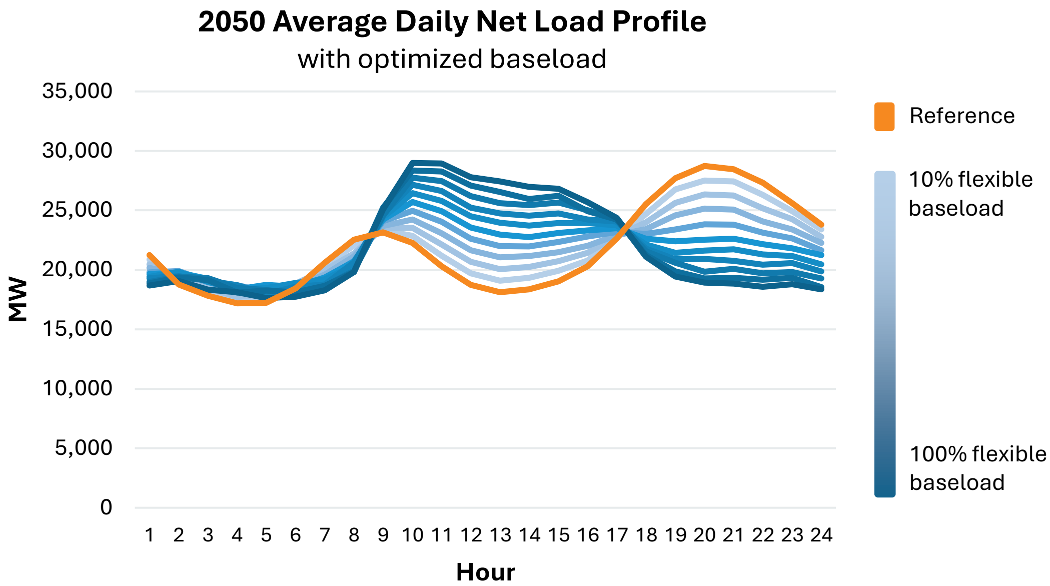
% Baseload Flexible	2050 Production Cost ($M)	Change from Reference ($M)
0	1,320	0
10	1,268	-51
20	1,221	-98
30	1,164	-156
40	1,122	-197
50	1,133	-187
60	1,129	-191
70	1,134	-186
80	1,126	-194
90	1,091	-228
100	1,088	-232

% EV Load Flexible	2050 Production Cost ($M)	Change from Reference ($M)
0	1,320	0
10	1,284	-36
20	1,268	-51
30	1,239	-80
40	1,185	-135
50	1,174	-146
60	1,152	-168
70	1,128	-191
80	1,110	-210
90	1,105	-214
100	1,096	-224

- 2050 production costs are dependent on the resource mix built by the capacity expansion model, but generally an increase in load flexibility reduces production costs
- Flexible demand shifts load away from high cost hours, typically during peaks or low renewable output, and onto lower cost hours with higher production from renewables

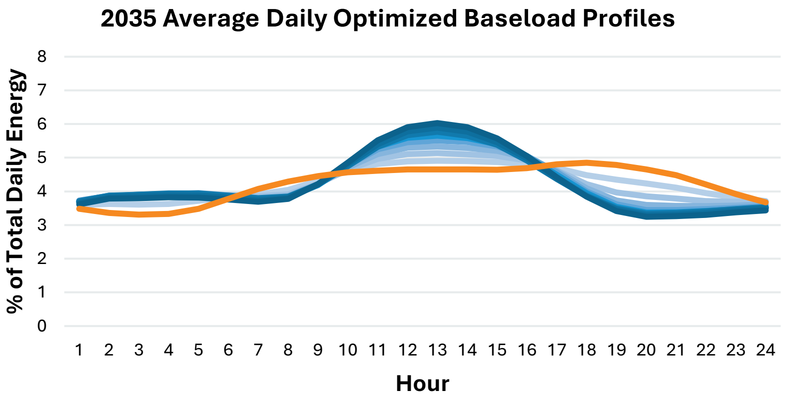
Optimized Profiles: Baseload

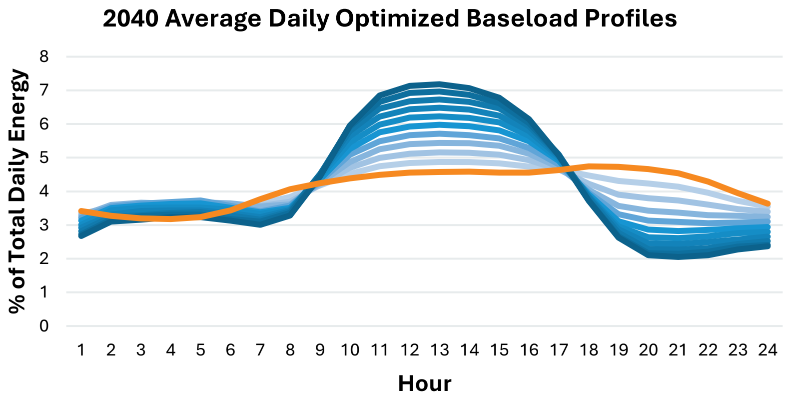


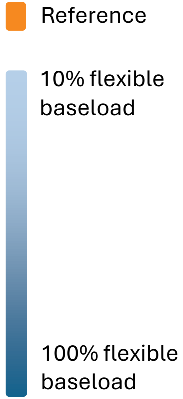


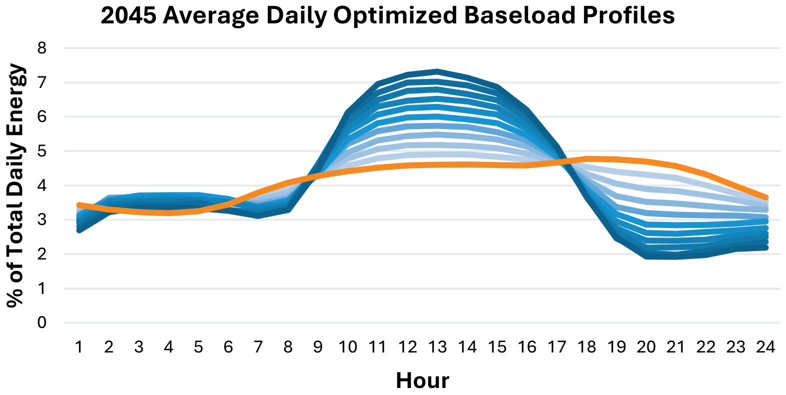
- Profiles are optimized to minimize production cost by shifting load onto low or negative LMP hours
- Usage of baseload appliances like dishwashers, laundry machines, and dryers can be shifted within each day. Customers with BTM-BESS can further support demand shifting by charging during low-cost periods and discharging during peaks

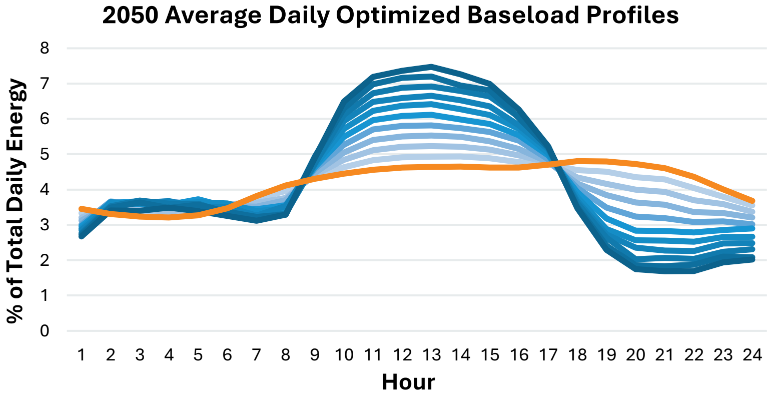
Baseload Shifting Profiles: 2035, 2040, 2045, 2050



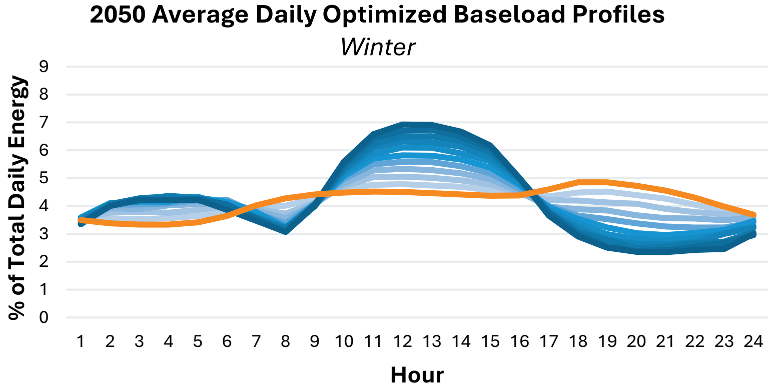


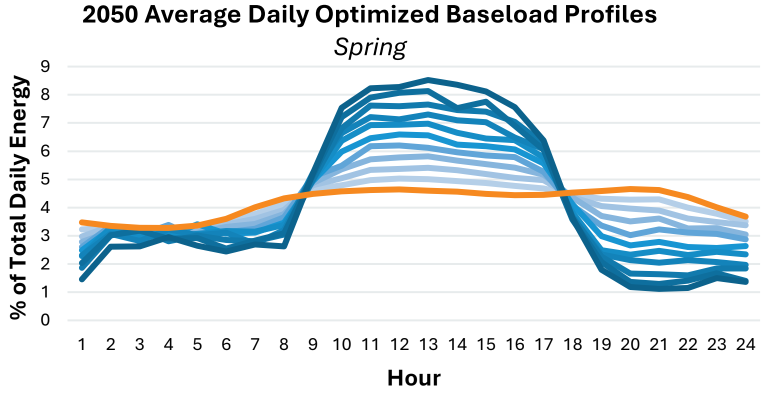


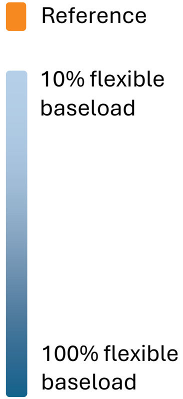


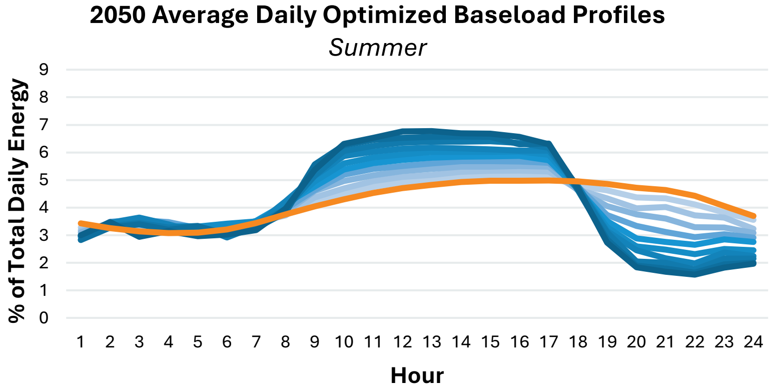


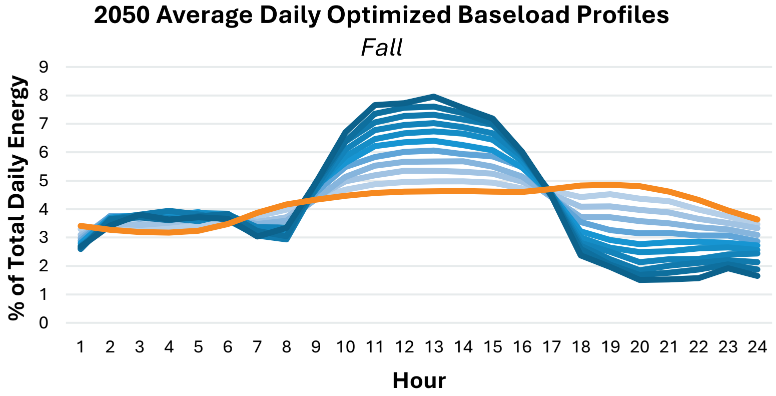
Baseload Shifting Profiles: 2050 by Season



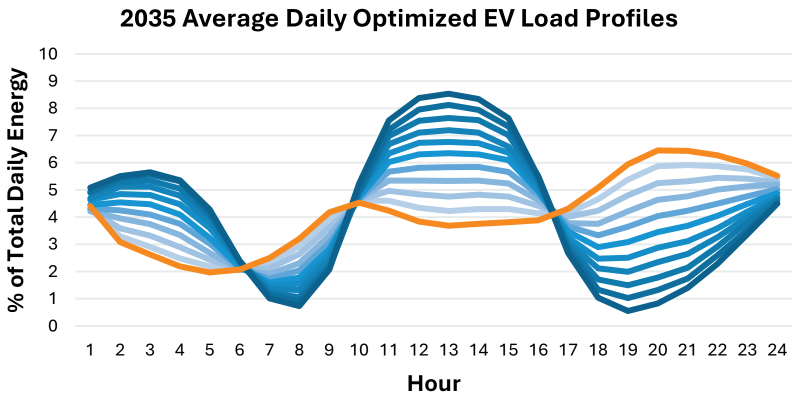


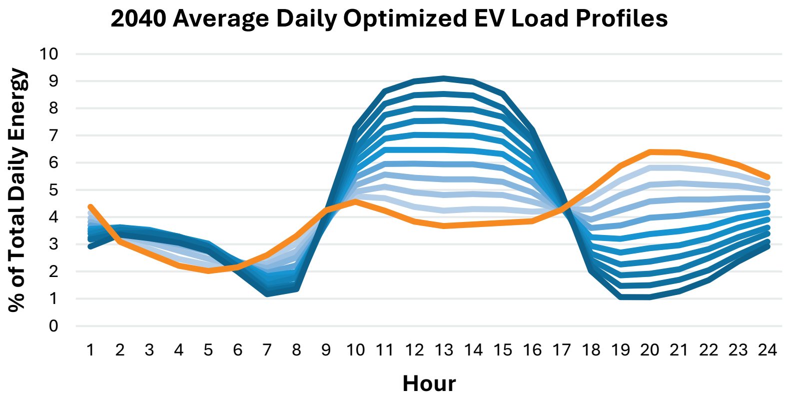


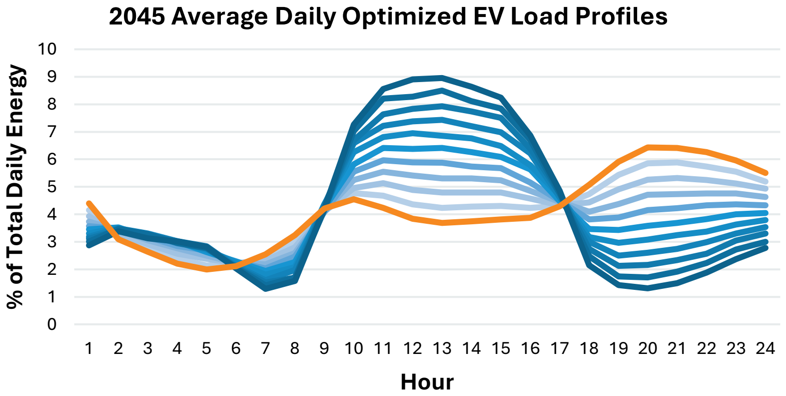


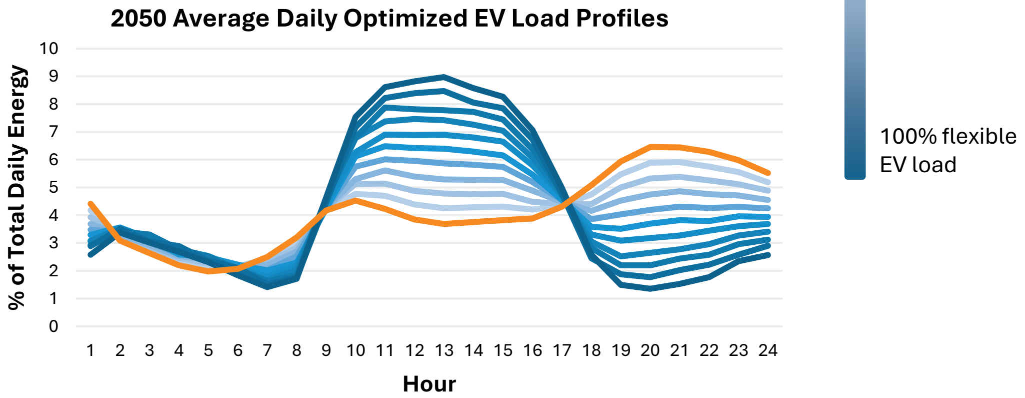


EV Load Shifting Profiles: 2035, 2040, 2045, 2050

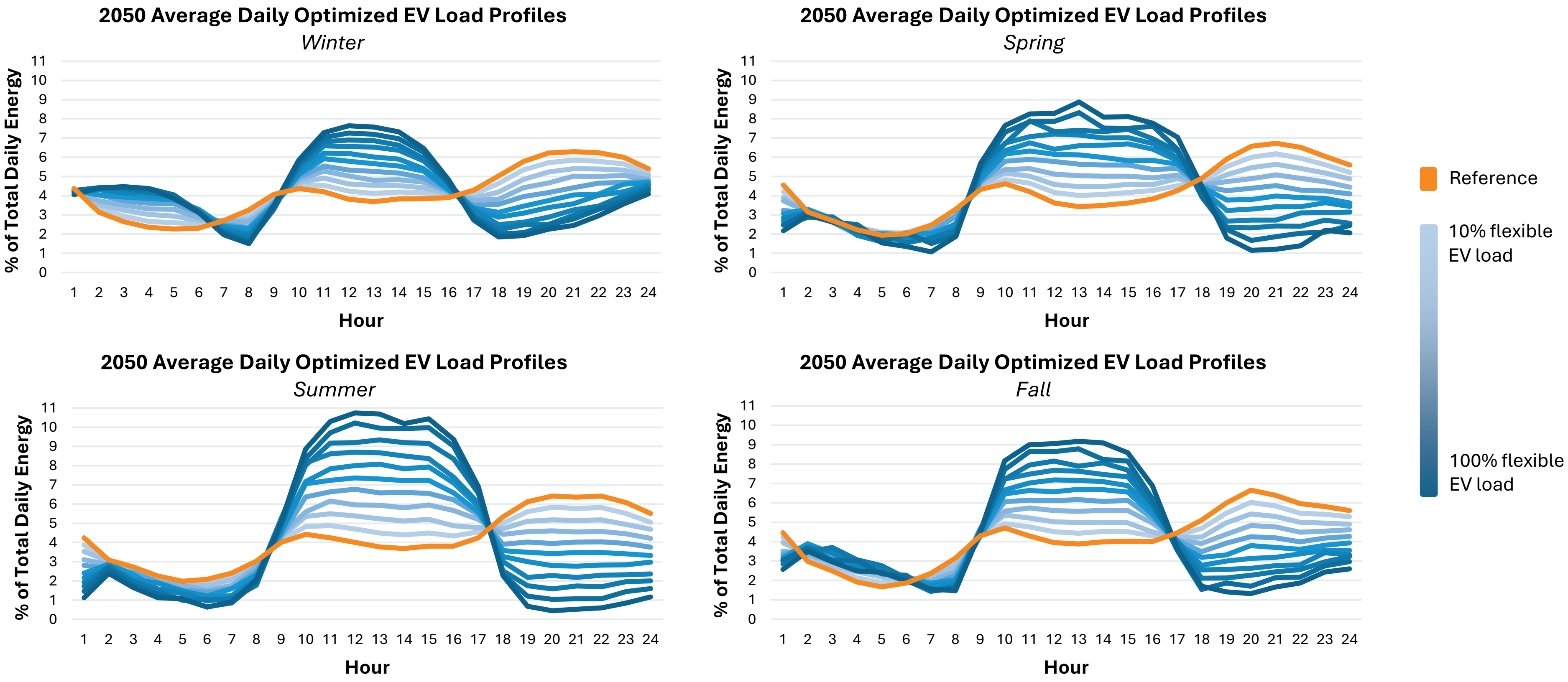








EV Load Shifting Profiles: 2050 by Season



APPENDIX B

Flexible Demand Sensitivities – Additional MWY Results

Economic Impacts of Flexible Demand: 20 Weather Years

Weather Year	Production Cost without Demand Shifting ($M)	Production Cost with Demand Shifting ($M)	Production Cost Savings ($M)	Total Energy Shifted (GWh)
2000	1,281	1,139	142	19,777
2001	1,429	1,279	150	20,581
2002	1,100	982	118	20,264
2003	1,345	1,204	142	19,897
2004	1,300	1,148	152	21,077
2005	1,332	1,169	163	21,064
2006	992	893	99	20,137
2007	1,318	1,189	129	21,240
2008	1,119	963	156	20,561
2009	1,243	1,085	157	20,731
2010	1,083	968	116	20,917
2011	1,373	1,170	203	20,566
2012	1,116	982	134	20,447
2013	1,145	1,011	134	20,656
2014	1,486	1,314	172	20,794
2015	1,413	1,260	153	21,115
2016	1,158	1,008	150	21,351
2017	1,246	1,074	172	20,541
2018	1,249	1,126	123	20,315
2019	1,320	1,140	180	20,680

APPENDIX C

Reduced Decarbonization Sensitivity – Additional Capacity Expansion Results

75% Decarbonization and Electrification Combination Cases: Buildout Capacity Results

2033-2050 Total New Capacity (MW)

	Monofacial Fixed-Tilt PV				Bifacial Single-Axis Tracking PV			
	No Flexible Load	20% Flexible EV Load	50% Flexible EV Load	100% Flexible EV Load	No Flexible Load	20% Flexible EV Load	50% Flexible EV Load	100% Flexible EV Load
PV	22,532	23,054	24,119	28,824	23,025	23,000	24,074	29,548
LBW	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600
OSW	6,564	6,212	5,416	3,506	4,388	4,182	3,633	2,788
SMR	900	900	900	900	900	900	900	384
Li-ion BESS	4,840	3,034	984	0	5,090	3,616	1,482	0
100-hr BESS	0	0	0	0	0	0	0	0
Total	**38,436**	**36,800**	**35,019**	**36,830**	**37,003**	**35,298**	**33,689**	**36,321**
Delta from Reference	-42,994	-44,630	-46,411	-44,600	-44,427	-46,132	-47,741	-45,110
% Change	-52.80	-54.81	-56.99	-54.77	-54.56	-56.65	-58.63	-55.40

- Unlike capital costs, capacity buildouts don't always decrease linearly with the portion of load flexibility. Buildouts will be larger if the resource mix includes more low-cost resource types, especially PV
- Note that the reference results slightly differ from previous versions because this analysis uses fixed representative sample days for capacity expansion modeling across all load flexibility levels. This approach, used in the Stakeholder-Requested Scenario, ensures consistent comparisons across sensitivities with different load profiles

75% Decarbonization and Electrification Combination Cases: Buildout Cost Results

2033-2050 Annualized Build Costs ($B)

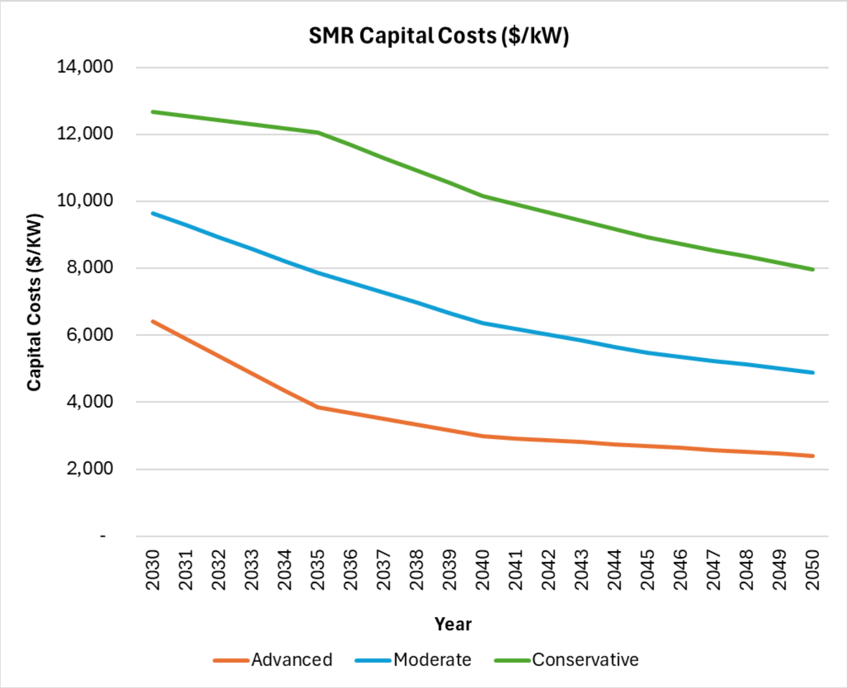
	Monofacial Fixed-Tilt PV				Bifacial Single-Axis Tracking PV			
	No Flexible Load	20% Flexible EV Load	50% Flexible EV Load	100% Flexible EV Load	No Flexible Load	20% Flexible EV Load	50% Flexible EV Load	100% Flexible EV Load
PV	16.44	17.34	18.91	22.47	20.29	20.87	22.07	24.94
LBW	9.38	9.38	9.38	9.38	9.38	9.38	9.38	9.38
OSW	20.47	18.29	14.19	6.49	13.13	11.06	8.70	3.41
SMR	1.80	2.39	2.35	2.39	1.97	2.02	1.56	1.02
Li-ion BESS	2.95	1.65	0.19	0.00	4.23	2.25	0.41	0.00
100-hr BESS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**51.04**	**49.04**	**45.02**	**40.73**	**48.99**	**45.58**	**42.12**	**38.74**
Delta from Reference	-97.43	-99.43	-103.45	-107.74	-99.48	-102.89	-106.35	-109.73
% Change	-65.63	-66.97	-69.68	-72.57	-67.00	-69.30	-71.63	-73.90

APPENDIX D

Stakeholder-Requested Scenario Sensitivity – Additional Results

SMR Capital Costs

Year	SMR Conservative $/kW	SMR Moderate $/kW	SMR Advanced $/kW
2033	12,304	8,578	4,870
2034	12,179	8,220	4,354
2035	12,053	7,863	3,839
2036	11,677	7,565	3,667
2037	11,300	7,267	3,495
2038	10,923	6,969	3,323
2039	10,547	6,672	3,151
2040	10,170	6,374	2,979
2041	9,919	6,195	2,922
2042	9,668	6,016	2,865
2043	9,417	5,838	2,807
2044	9,166	5,659	2,750
2045	8,914	5,480	2,693
2046	8,726	5,361	2,635
2047	8,538	5,242	2,578
2048	8,349	5,123	2,521
2049	8,161	5,004	2,464
2050	7,973	4,885	2,406



2040 Production Cost: Operational Metrics

Metric	100% Peaker Retired Moderate	100% Peaker Retired Conservative	Reference Moderate	Reference Conservative	50% Electrification Moderate	50% Electrification Conservative
Generation (TWh)	160	162	160	160	132	132
Non-Emitting Generation (TWh)	112.5	120.2	114.2	118.6	81.6	83.5
Emitting Generation (TWh)	21.5	19.4	20.9	21.3	24.0	23.4
Imports (TWh)	23.6	20.5	22.5	18.8	23.1	22.0
Carbon Emissions (million tons)	9.7	8.9	9.5	10.6	10.6	10.4
Hours with Emitting Generation	5,907	5,381	5,817	6,088	7,177	6,780
Curtailment (TWh)	1.5	7.9	4.0	12.8	2.4	5.6
Storage Generation (TWh)	7.0	12.0	4.8	7.2	3.9	4.0
Storage Load (TWh)	8.5	15.3	6.1	8.8	4.9	5.0
Production Cost ($Million)	2,439	2,031	2,311	2,313	2,391	2,236

2040 Production Cost: Operational Metrics

Metric	100% Peaker Retired Advanced	100% Peaker Retired Conservative	Reference Advanced	Reference Conservative	50% Electrification Advanced	50% Electrification Conservative
Generation (TWh)	160	162	160	160	132	132
Non-Emitting Generation (TWh)	111.5	120.2	111.6	118.6	84.1	83.5
Emitting Generation (TWh)	21.4	19.4	21.5	21.3	20.8	23.4
Imports (TWh)	24.3	20.5	24.2	18.8	24.0	22.0
Carbon Emissions (million tons)	9.6	8.9	9.7	10.6	9.1	10.4
Hours with Emitting Generation	6,024	5,381	5,946	6,088	6,644	6,780
Curtailment (TWh)	0.2	7.9	0.3	12.8	0.6	5.6
Storage Generation (TWh)	4.0	12.0	4.0	7.2	3.3	4.0
Storage Load (TWh)	5.0	15.3	5.1	8.8	4.1	5.0
Production Cost ($Million)	2,574	2,031	2,557	2,313	2,208	2,236