MAY 14, 2025 | PAC WEBEX

2024 Economic Study

Policy Scenario Sensitivities & Stakeholder-Requested Scenario Final Results

Ellie Ross, Kim Quach, & Richard Kornitsky
ECONOMIC STUDIES & ENVIRONMENTAL OUTLOOK

Overview of Presentation

- Overview of the 2024 Economic Study
- Policy Scenario Sensitivity: Bifacial Tracking PV
- Policy Scenario Sensitivity: Accelerated Decarbonization
- Stakeholder-Requested Scenario Final Results
- Timeline and Next Steps
- Appendix: Policy Scenario Additional Results

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

OVERVIEW OF THE 2024 ECONOMIC STUDY

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 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 or when FERC acts on the SENS Tariff revisions

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

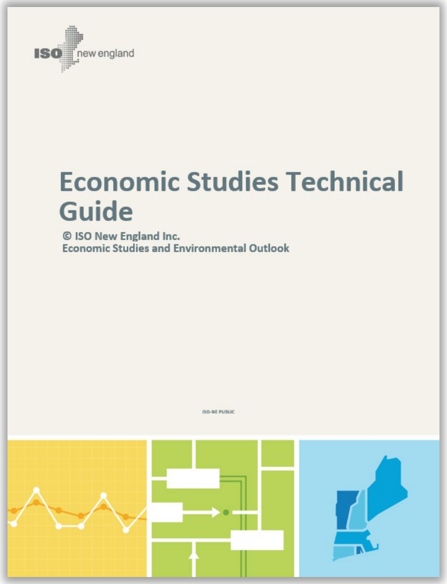
Policy Scenario – Model future years (>10-year planning horizon) based on satisfying New England region and other energy policies and goals

System Efficiency Needs Scenario (SENS) – 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 these 3 scenarios

Economic Studies Technical Guide

- The ISO published the first version of the Economic Studies Technical Guide (ESTG) on March 25, 2024
- This Technical Guide seeks to provide stakeholders, policy makers, and the public with a comprehensive document that describes the Economic Study process
  - Please refer to this document for detailed questions about assumptions and study procedures



Policy Scenario Recap and Updates

- The Policy Scenario uses a capacity expansion model followed by a production cost model. The objective of the scenario is to build a system that meets state emission reduction goals with lowest net present value (NPV)
  - Results in 2024 Economic Study to-date show that from 2033-2040, the capacity expansion model builds PV, wind, and short-duration batteries
  - The cost of reducing carbon emissions increases exponentially in 2045-2050 as the system is decarbonized and more expensive resources are needed to serve load while meeting the carbon constraint
    - Small modular reactors (SMRs) and long duration energy storage (LDES) are most effective for emission reductions from 2045-2050

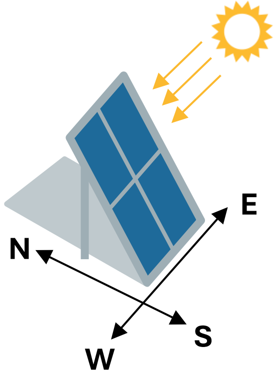
- Updates have been made to the Policy Scenario Reference case since the March PAC and the following results reflect those changes
  - Correction of PV capital cost assumptions to correlate with fixed-tilt monofacial PV generation profiles. Previous results used single-axis tracking bifacial PV cost assumptions with the fixed-tilt monofacial generation profiles
  - Increase in land-based wind (LBW) availability to 3,600 MW from 3,000 MW

POLICY SCENARIO SENSITIVITY

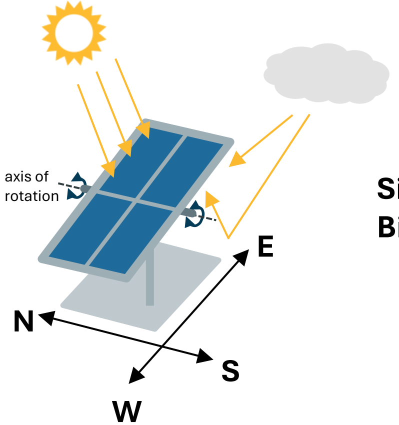
Bifacial Tracking PV

Fixed-Tilt vs. Single-Axis Tracking Bifacial PV

- The Policy Scenario Reference case uses cost assumptions and generation profiles correlating to fixed-tilt monofacial PV resources
  - Fixed-tilt PV is typically South-facing
  - Monofacial panels can only generate from the front of the panel. Any light that hits the back of the panel is reflected
- The ISO has received a sensitivity request to model all candidate PV resources as single-axis tracking bifacial panels
  - Single-axis tracking PV is typically on a horizontal axis of rotation that is oriented from North to South
  - Bifacial panels can generate from both the front and back of the panel. Light hits the back of the panels when it is scattered by clouds or reflected off the ground

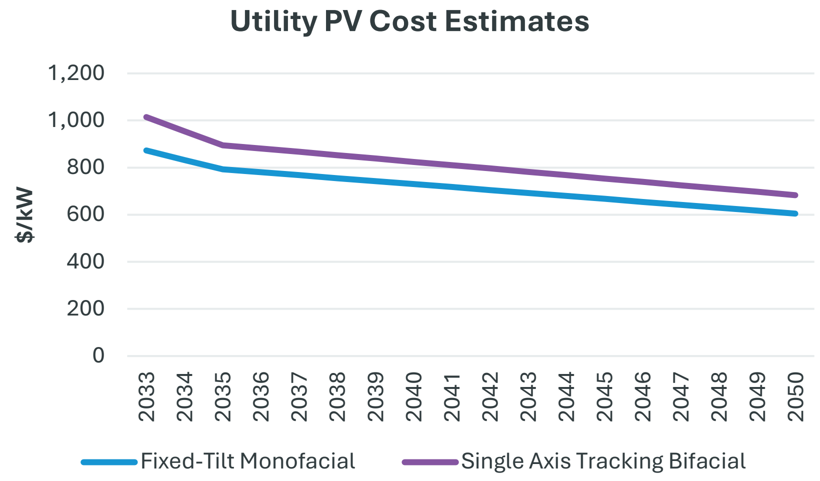


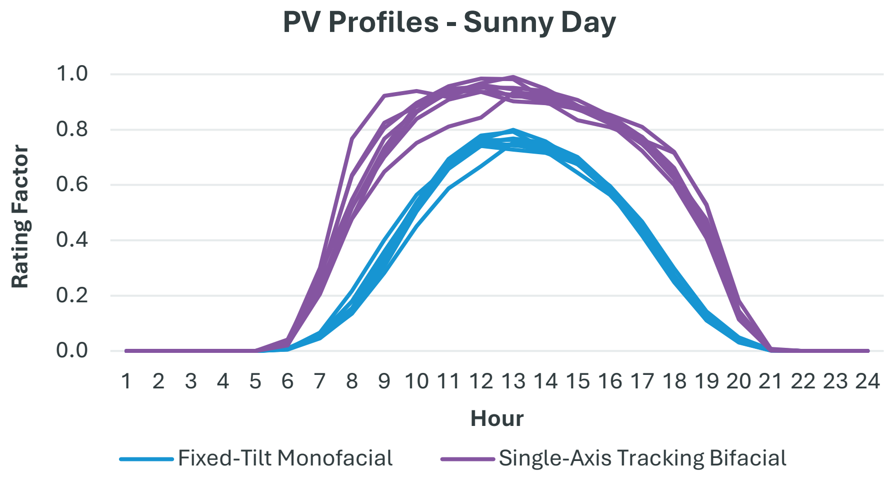
Fixed-Tilt Monofacial Panel



Singe-Axis Tracking Bifacial Panel

Bifacial Tracking PV Assumptions





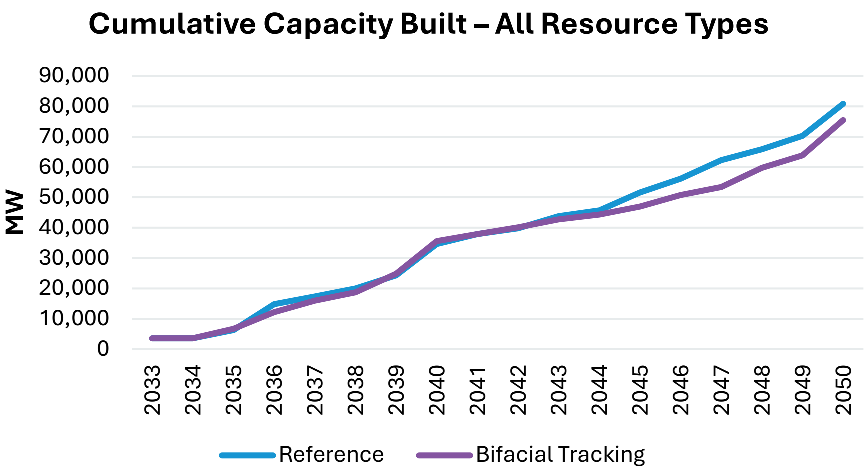
- According to the National Renewable Energy Laboratories Annual Technology Baseline (NREL ATB), single-axis tracking bifacial panels are assumed to be ~15% more expensive than fixed-tilt monofacial panels
- Hourly generation profiles for single-axis tracking bifacial panels are based on existing DNV solar datasets that have been scaled by load zone. Single-axis tracking bifacial PV generates ~45% more than fixed-tilt monofacial

Bifacial Tracking PV Takeaways

- Modeling candidate PV resources as single-axis tracking bifacial **PV reduces overall capacity buildout by 5.4 GW**
  - PV capacity built is reduced by 3.7 GW due to the higher capacity factor of single-axis tracking bifacial PV
  - Total **build costs are reduced by 2.5%**
- **Bifacial tracking PV has an economic advantage over fixed-tilt monofacial PV** for reducing carbon production until 2045
  - At high-levels of renewable penetration, new PV resources are curtailed frequently regardless of panel type which diminishes the benefits from the additional production of bifacial tracking panels

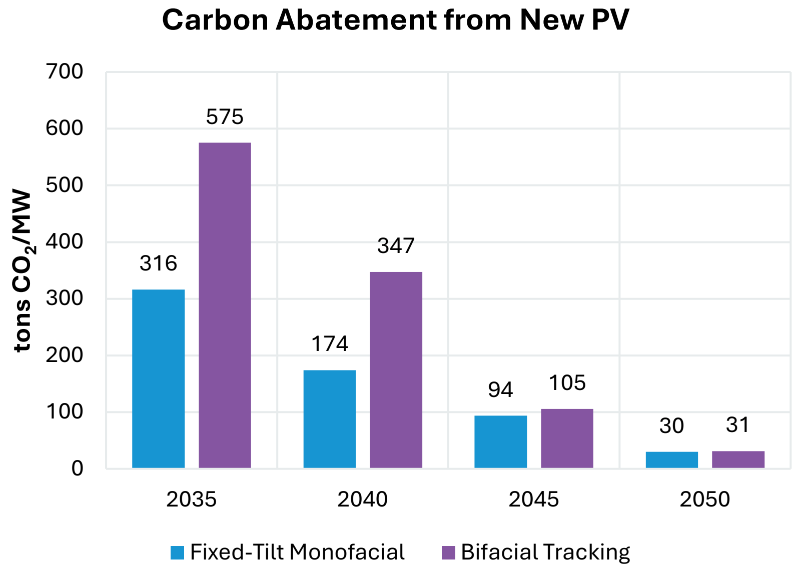
Bifacial Tracking PV: Capacity Buildout

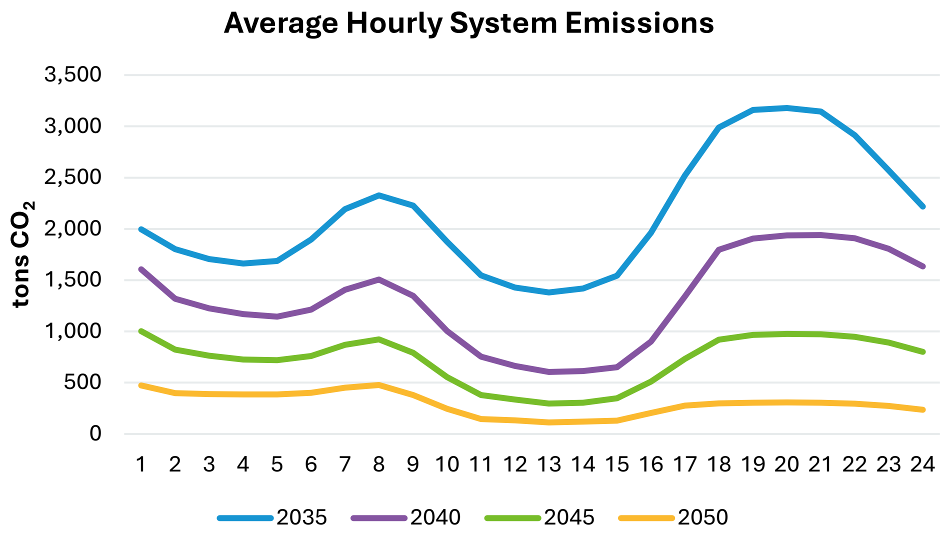
Type	Reference	Bifacial Tracking	Delta
PV	38,000	34,278	-3,722
LBW	3,600	3,600	0
OSW	17,848	18,648	+801
SMR	5,117	4,658	-459
Li-ion BESS	14,811	12,446	-2,364
Iron-air BESS	1,451	1,834	+384
Total (MW)	**80,826**	**75,465**	**-5,361**



- The total capacity of new resources is reduced by 5.4 GW when new PV is modeled as single-axis tracking bifacial
  - The buildouts of PV and short-duration batteries are reduced because of the increased production from bifacial tracking PV

Bifacial Tracking PV: Carbon Abatement

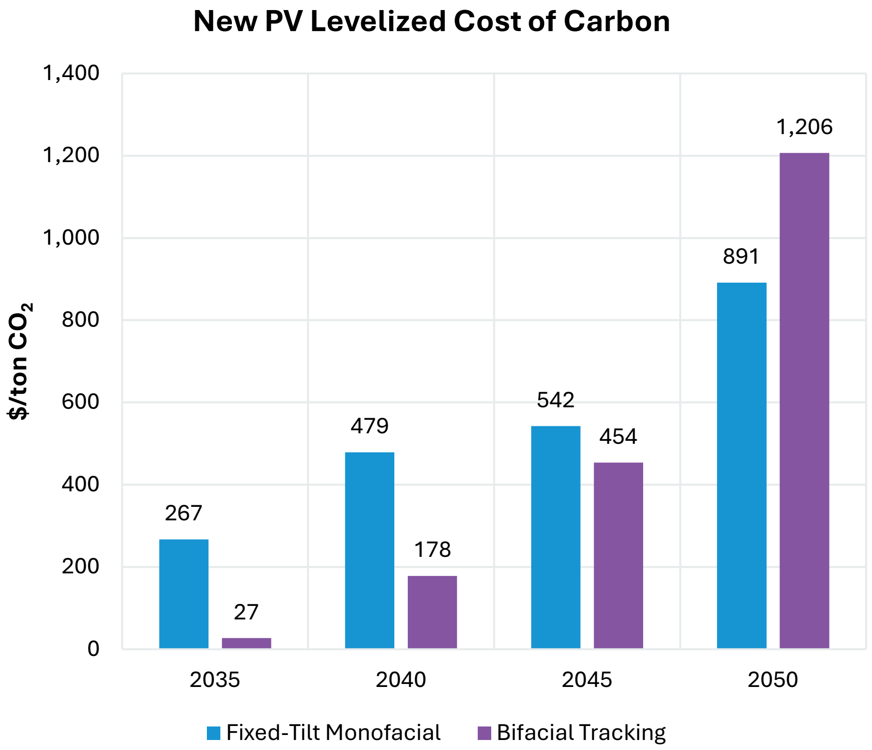




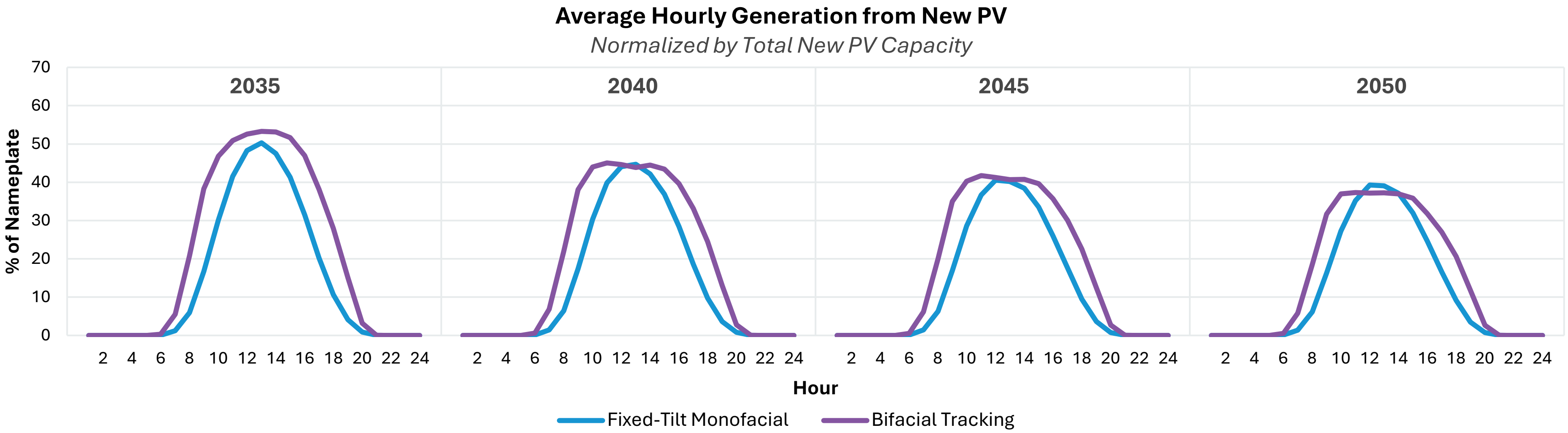
- In 2045 and 2050, bifacial tracking PV has less of an advantage over fixed-tilt PV at reducing emissions
  - Midday hours are mostly decarbonized by 2045, so new PV will be curtailed most days of the year, regardless of the panel type

Bifacial Tracking PV: Levelized Cost of Carbon

- Levelized cost of carbon (LCOC) is a measure of the cost of reducing carbon emissions using different resource types
  - The costs associated with new resources include both capital costs and production costs
  - LCOC for all resource types in the reference case can be found in the Appendix
- After 2045, the cost of bifacial tracking PV outweighs the benefits of the increased capacity factor
  - Fixed-tilt monofacial becomes more economic than bifacial tracking after 2045



Bifacial Tracking PV: Hourly Generation



- Bifacial tracking PV has an advantage over fixed-tilt monofacial PV during the shoulder hours because of its ability to generate when the sun is lower in the sky
  - During the midday hours, bifacial tracking PV is curtailed in larger amounts than monofacial fixed-tilt PV, especially as the system becomes more saturated with PV
- Contributions from new PV resources decrease over time as an increasing number of days each year already experience curtailment during peak solar generation hours

Bifacial Tracking PV: 2050 Operational Metrics

	Reference	Bifacial Tracking	Delta
Production Cost ($M)	1,316	1,276	-40
Avg LMP ($/MWh)	25.57	21.40	-4.17
Hours with LMP≤$0/MWh	4,527	5,180	+653
Total System Curtailment (GWh)	30,979	45,079	+14,100
New PV Capacity Factor (%)	12.03	15.39	+3.36
New PV Curtailment Factor (%)	17.95	25.99	+8.04

- The bifacial tracking sensitivity buildout has slightly lower energy market costs in 2050 because there is more energy coming from zero cost resources
- Bifacial tracking PV has a higher capacity factor than fixed-tilt monofacial PV, but it is also curtailed at a higher rate

$$Capacity\ Factor\ [\%] = 100 * \frac{Annual\ Energy\ Produced\ [MWh]}{Nameplate\ Capacity\ [MW] * 8{,}760\ [h]}$$

$$Curtailment\ Factor\ [\%] = 100 * \frac{Annual\ Energy\ Curtailed\ [GWh]}{Annual\ Energy\ Curtailed\ [GWh] + Annual\ Energy\ Produced\ [GWh]}$$

POLICY SCENARIO SENSITIVITY

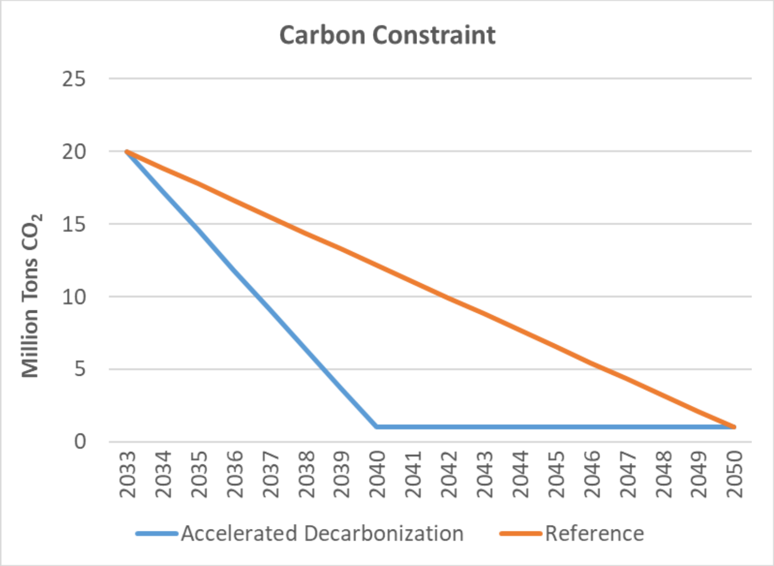
Accelerated Decarbonization

Policy Sensitivity Overview – Accelerated Decarbonization

- In the Policy Reference Scenario, a carbon constraint was enforced to enable the model to build enough zero-carbon resources to meet the region's decarbonization goals by 2050
  - The carbon constraint followed a glide path starting at 20 million tons of CO_2 in 2033 and ending at 1 million tons in 2050
- The ISO received a sensitivity request to model a future system under an accelerated decarbonization timeline, in which the region meets their decarbonization goals in 2040 instead of 2050
  - The results of this sensitivity would help states understand the required investments and consumer cost impacts of more aggressive decarbonization policies

Accelerated Decarbonization - Assumptions

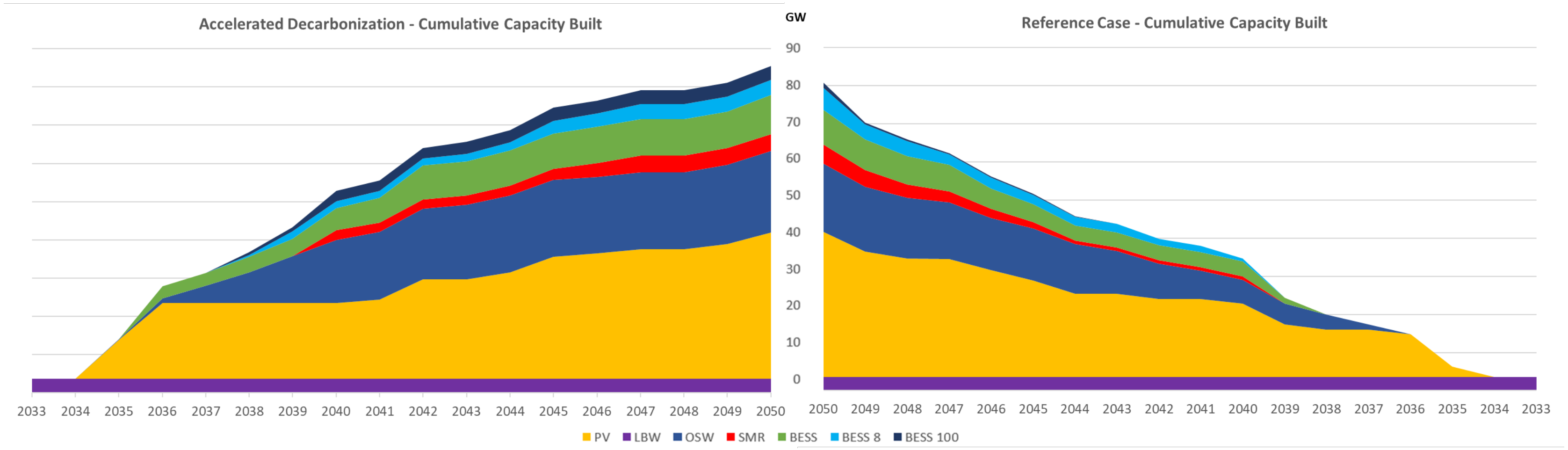
- The carbon constraint from the Policy Reference Scenario was updated to reflect a glide path that **ends at 1 million tons in 2040 instead of 2050 and continues to constrain at 1 million tons from 2040-2050**
  - This sensitivity **does not** consider accelerated decarbonization of the transportation and heating sectors, so load growth assumptions are unchanged from the Reference Scenario



Accelerated Decarbonization Takeaways

- The buildout of resources under an accelerated decarbonization timeframe would be **more extensive and expensive** compared to the Reference buildout
- The accelerated decarbonization scenario **continued to build resources after meeting the carbon constraint in 2040 to meet increasing electrification load** between 2040-2050
- The marginal cost of carbon under the accelerated decarbonization timeframe **increased much faster** than under the Reference Scenario

Accelerated Decarbonization: Capacity Buildout



- The accelerated decarbonization model built 85.4 GW of capacity, **6% more** than the Reference which built 80.8 GW
  - Both models built the maximum amount of LBW in the first year as it was the lowest cost resource to build
- The bulk of the SMR buildout occurred in 2040 when the 1 million ton carbon constraint was first enforced, whereas the Reference model gradually built SMRS over the last decade

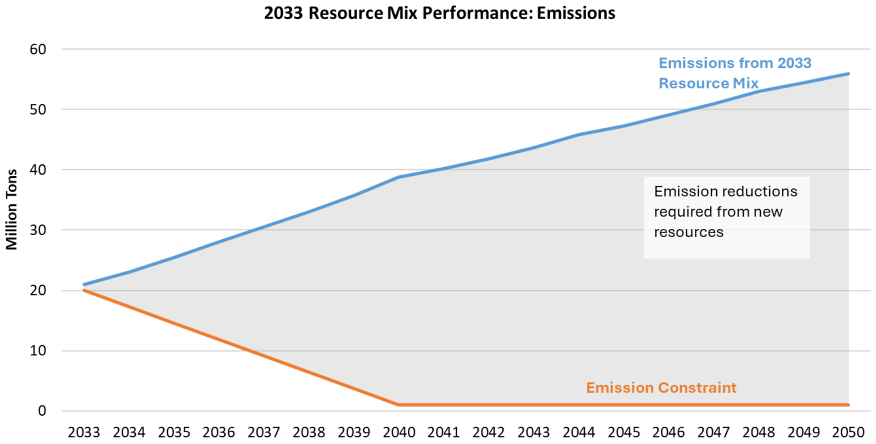
Accelerated Decarbonization: Capacity Buildout

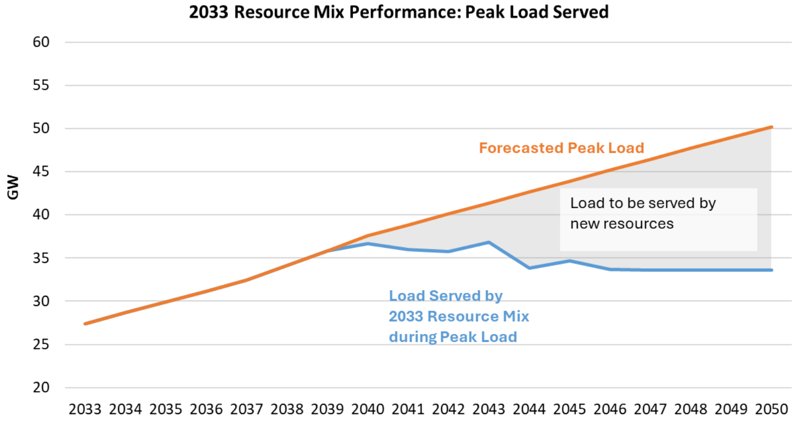
- The accelerated decarbonization **model built less SMRs overall compared to the Reference model** because SMRs were not needed as much in the last decade once the carbon constraint has been satisfied in 2040
  - The SMR capital costs start to steeply decline **after** 2040 and the cost difference between OSW and SMRs become less drastic, therefore, **more SMRs are built between 2040-2050 in the Reference model**
- The accelerated decarbonization model built more 100 hour batteries due to the greater buildout of renewables that would incentivize long duration storage and the accelerated decarbonization

Cumulative Capacity (GW)

Resource Type	Accelerated Decarbonization	Reference
PV	38.3	38.0
LBW	3.6	3.6
OSW	21.3	17.8
SMR	4.5	5.1
BESS 4	10.2	9.1
BESS 8	3.9	5.7
BESS 100	3.6	1.5

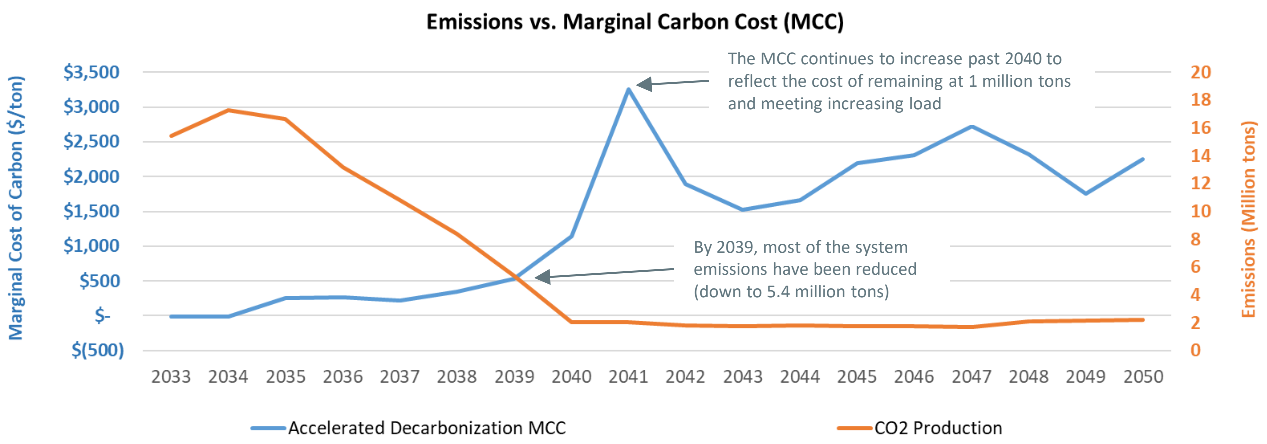
Accelerated Decarbonization: Carbon Constraint vs Load Growth





- The two factors driving capacity expansion are the **emission constraint** and **load growth**
  - The 2033 resource mix **cannot** meet the emission constraint without building new resources early on
  - The 2033 resource mix **can serve** the forecasted load in a moderate weather year until 2040 without needing new resources
    - This is why the model continues building new resources after meeting the carbon constraint in 2040

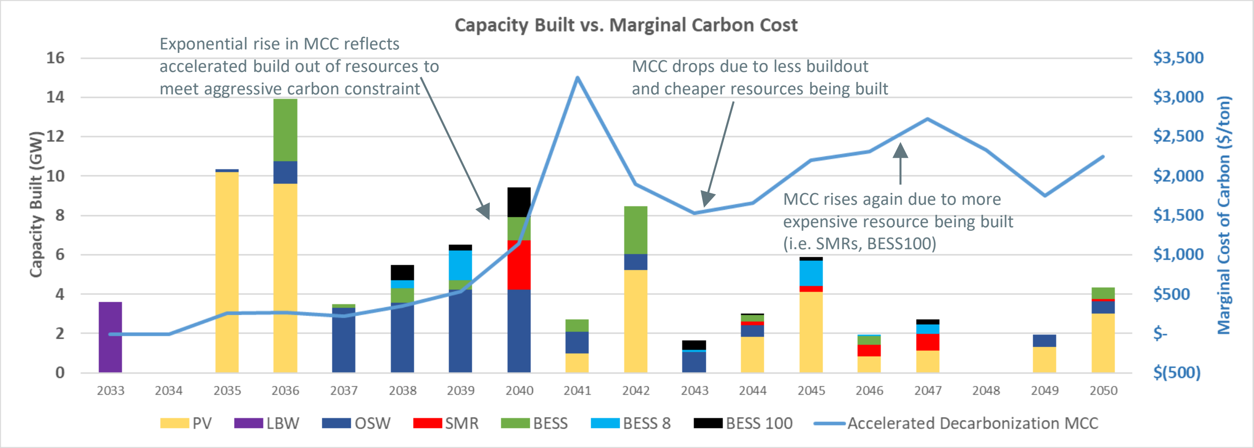
Accelerated Decarbonization: Marginal Carbon Cost



Marginal Carbon Cost (MCC) = Cost of reducing the next additional ton of carbon emission

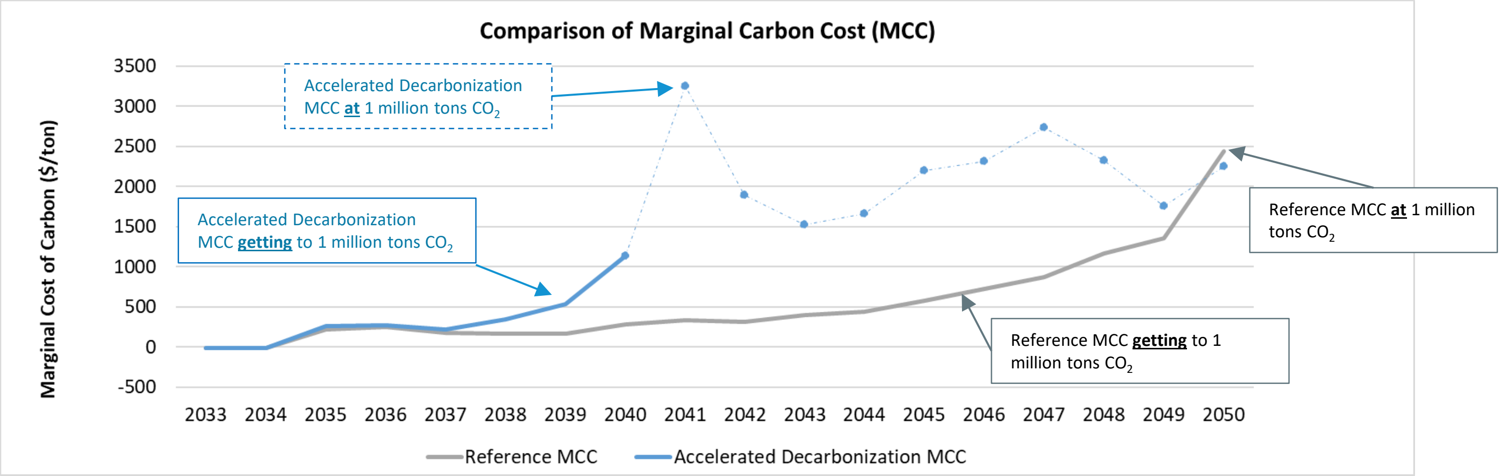
- **Between 2033-2039, the MCC is stable and has small incremental increases year-over-year** since the model primarily builds cheaper resources like PV, LBW, and OSW to achieve most of the system emissions
- The MCC accelerates between 2039-2040 as the model quickly builds more expensive resources (i.e. SMRs, 100-hour batteries) to further reduce emissions by 4.4 million tons
  - The MCC continues to rise after 2040

Accelerated Decarbonization: Marginal Carbon Cost



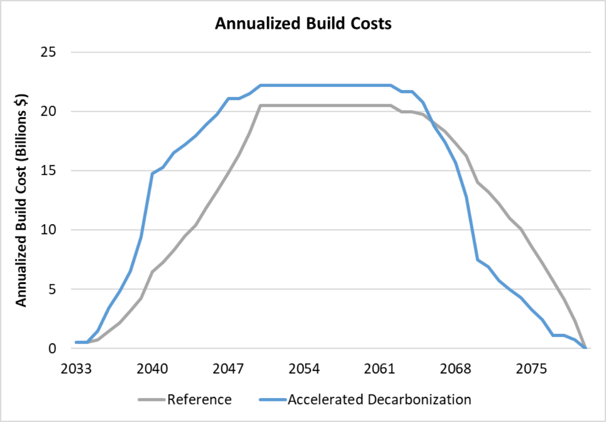
- The MCC fluctuates between 2041-2050 within the range of approx. $1,500/ton and $3,000/ton
  - The model continues to build new resources after 2040 to meet the increasing electrification load and the **fluctuation in the MCC reflects the change in production cost, build costs, and FOM corresponding to the type and quantity of resources that are built for that year**

Accelerated Decarbonization: Comparison of Costs



- **The accelerated decarbonization timeline causes the MCC to escalate much faster than the Reference MCC**
  - By 2041, the MCC peaks at $3,254/ton compared to $332/ton in the Reference Scenario for the same year
  - The 2050 MCCs for both scenarios are relatively the same: $2,252/ton for the accelerated decarbonization scenario and $2,440/ton for the Reference

Accelerated Decarbonization: Comparison of Costs



Reference Total Build Costs	Accelerated Decarbonization Total Build Costs
$615 billion	$666 billion

- The annualized build costs only account for the costs up to the last year of the model's time horizon, therefore, **to get the total cost of the buildout when every unit has been paid off the costs were projected 30 years (i.e. the economic life of a unit) past 2050**
  - For example, if a unit was built in 2050, the annualized build costs will be zero in 2080 as the unit is paid off after 30 years
- The buildout of non-emitting resources to meet the accelerated carbon constraint is **8% more expensive** than the Reference
  - Resource build costs are assumed to decrease over time as the technology matures, therefore, building resources before 2040 increases costs that would have been built later in the Reference Scenario when costs were lower
  - Similar to the MCC, the annualized build costs escalates much faster and has a higher peak than the Reference

Accelerated Decarbonization: 2040 Operational Metrics

	Reference	Accelerated Decarbonization	Delta
Production Cost ($M)	$2,600	$861	-$1,739
Avg LMP ($/MWh)	$78.60	$16.78	-$61.82
Hours with LMP≤$0/MWh	2,359	5,107	+2,748
Total Curtailment (GWh)	8,752	26,452	+17,700
Emissions (million tons)	11.6	2.0	-9.6
Hours of Emitting Generation (hr)	6,282	1,782	-4,500

- In 2040, the accelerated decarbonization scenario is building more resources than it can use resulting in **significant curtailment, three times more than in the Reference**

Accelerated Decarbonization: 2050 Operational Metrics

	Reference	Accelerated Decarbonization	Delta
Production Cost ($M)	$1,316	$1,202	-$114
Avg LMP ($/MWh)	$25.57	$18.04	-$7.53
Hours with LMP≤$0/MWh	4,527	5,184	+657
Total Curtailment (GWh)	30,979	36,994	+6,015
Emissions (million tons)	2.6	2.2	-0.4
Hours of Emitting Generation (hr)	1,705	1,381	-324

- The accelerated decarbonization model builds more non-emitting resources to meet the aggressive carbon constraint resulting in greater curtailment and more hours of zero/negative LMPs than the Reference
- **Production cost and average LMPs are lower compared to the Reference** due to less generation from high cost emitting resources and SMRs

STAKEHOLDER REQUESTED SCENARIO

Final Results

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 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**
  - A capacity expansion model was used to build resources **from 2033 to 2040**
  - Production cost models were run in **2040** with the buildout resource mix from the capacity expansion
  - Preliminary modelling only focused on adjustments of electrification **or** peaker capacity and results were presented at the February 26, 2025 PAC[1]

[1] https://www.iso-ne.com/static-assets/documents/100020/a09_2025_02_26_pac_2024_economic_studies_preliminary_stakeholder_requested_scenario_results.pdf

Stakeholder Requested Scenario Updates

- Today's presentation provides final results for the varying levels of
  - Electrification only (with the addition of a new 50% electrification scenario)
  - Peaker retirement only
  - Electrification **and** peaker retirement
- Updates have been made to the Stakeholder Requested Scenario model since the February PAC
  - Incorporated updates made to the Policy Scenario Reference case
  - Revised electrification scaling methodology to better align with the Policy Scenario Reference case
  - Locked in representative sample days rather than sampling random days to reduce variability in the capacity expansion model and allow for a more correlated buildout of resources at varying load levels

STAKEHOLDER REQUESTED SCENARIO

Final Results – Modified Electrification

Modified Electrification Takeaways

- New capacity expansion and build costs **increase** with increasing electrification
- The low electrification scenarios only built PV and wind resources and more expensive resources like SMRs are built in the higher electrification scenarios with additional capacity of PV, wind, and batteries
- Peaker generation remained relatively similar between scenarios while combined cycle generation **decreases with increasing electrification**

Changes to Electrification Assumptions

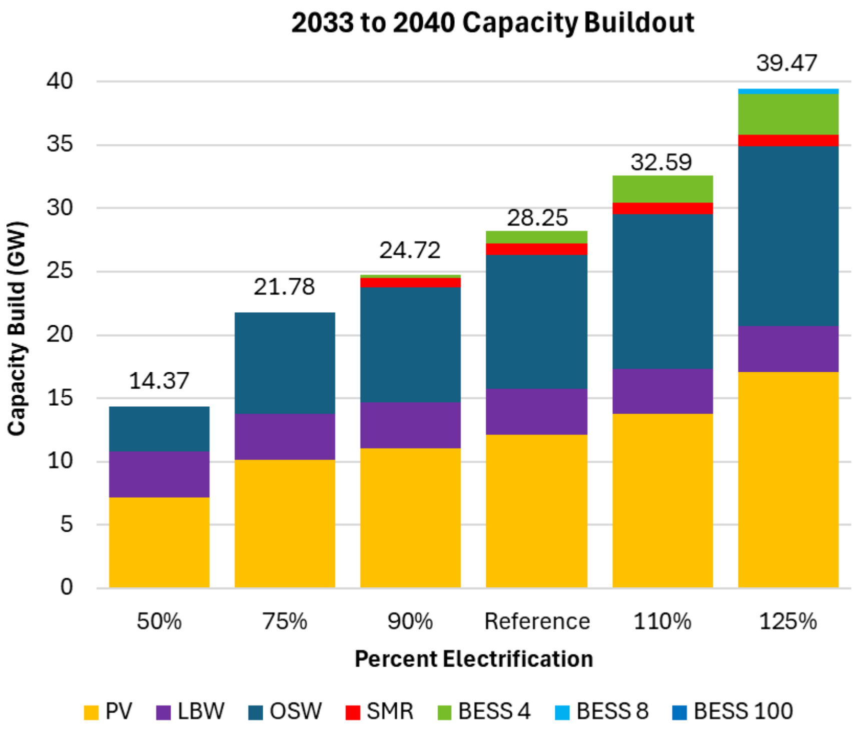
- The electrification assumptions have changed since the preliminary results
  - Initially, electrification forecasts for 2033 to 2040 were adjusted by ±10% and ±25% of peak load
- Electrification forecasts between 2033 and 2040 are now linearly interpolated based on the 2033 and 2040 electrification values then multiplied by the percent corresponding to the electrification
- This analysis is not intended to reflect the ISO Load Forecast but serves as a directional analysis of slower or faster paced electrification

2033 Values	50% Electrification	75% Electrification	90% Electrification	Reference	110% Electrification	125% Electrification
Peak EV (MW)	1,245	1,867	2,240	2,489	2,738	3,112
Peak HP (MW)	1,076	1,615	1,938	2,153	2,368	2,691
Electrification Energy (TWh)	6.3	9.5	11.4	12.7	14.0	15.9

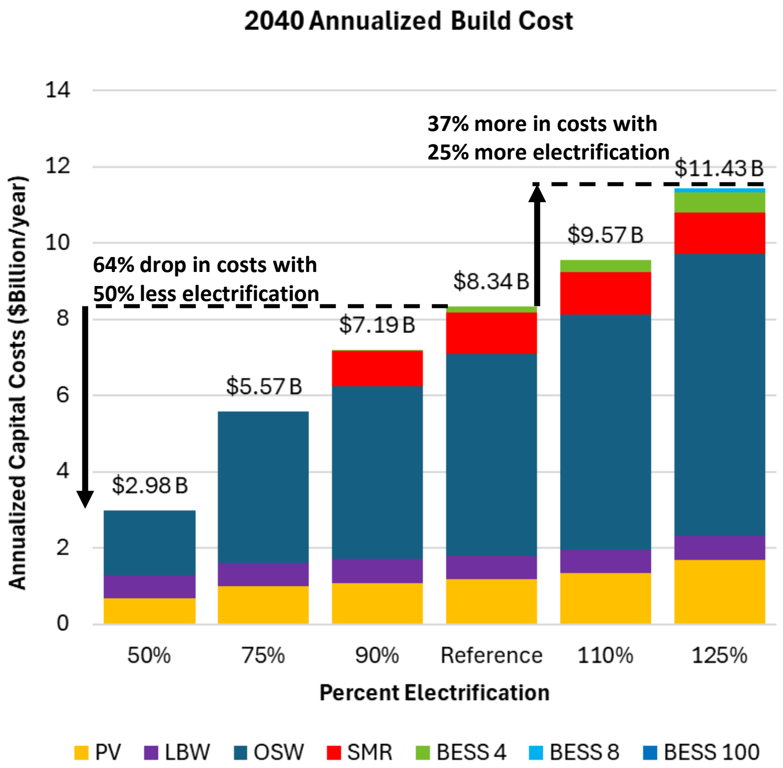
2040 Values	50% Electrification	75% Electrification	90% Electrification	Reference	110% Electrification	125% Electrification
Peak EV (MW)	5,078	7,616	9,140	10,155	11,171	12,694
Peak HP (MW)	7,332	10,997	13,197	14,663	16,129	18,329
Electrification Energy (TWh)	27.9	41.9	50.3	55.9	61.5	69.8

Modified Electrification: Capacity Buildout

- **Capacity buildouts increased with increasing electrification**
- Buildout of land-based wind maxed out at 3,600 MW across all electrification scenarios as it was the most economical resource to build first
- SMRs started getting built at 90% electrification with 762 MW built
  - The higher electrification scenarios each built 900 MW of SMRs in 2040 (125% electrification scenario built SMRs earlier in 2039)
- Only 400 MW of 8-hour batteries were built in total and were only present in the 125% electrification scenario
- **None of the electrification scenarios built 100-hour batteries**
  - Past modelling showed that the buildout of 100-hour batteries were typically economical **after** 2040



Modified Electrification: Capacity Expansion Metrics



- **2040 capital costs increased with increasing electrification** due to more capacity buildout
- The capacity expansion model built cheaper resources like PV and wind first, which were sufficient for the lower electrification scenarios (i.e. 50% and 75% electrification)
- For the higher electrification scenarios, starting with the 90% electrification, the bulk of the expensive resources like SMRs were built towards the end of the modelling horizon in 2039 and 2040

2040 Production Cost: Operational Metrics

Metric	50% Electrification	75% Electrification	90% Electrification	Reference	110% Electrification	125% Electrification
Generation (TWh)	132	146	155	160	166	175
Non-Emitting Generation (TWh)	83	102	111	119	126	137
Emitting Generation (TWh)	23.4	23.1	22.3	21.3	20.3	19.1
Imports (TWh)	22.0	19.1	19.2	18.8	18.1	17.2
Storage Generation (TWh)	4.0	5.2	6.0	7.2	8.7	11.3
Storage Load (TWh)	5.0	6.6	7.4	8.8	10.6	13.6

- As electrification increases, storage operation also increases while emitting generation decreases

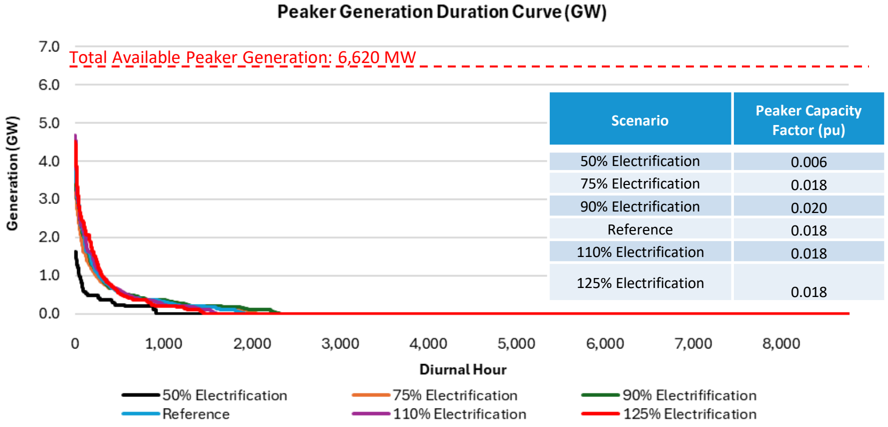
2040 Production Cost: Operational Metrics (cont.)

Metric	50% Electrification	75% Electrification	90% Electrification	Reference	110% Electrification	125% Electrification
Carbon Emissions (tons)	10.4	11.4	11.1	10.6	9.9	9.3
Hours with Emitting Generation	6,780	6,668	6,528	6,088	5,463	4,964
Curtailment (TWh)	5.6	11.8	11.7	12.8	14.7	17.7

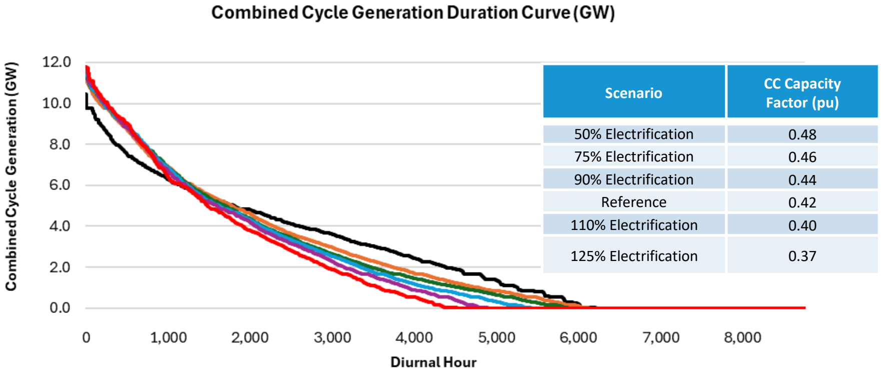
- Emissions generally decrease as electrification increases due to more non-emitting generation displacing emitting generation
- Capacity expansion builds more non-emitting resources than is needed for most of the year resulting in significant curtailment

2040 Thermal Operation

- Peaker generation does not vary significantly between scenarios
  - The only noticeable difference is lower peaker generation in the 50% Electrification which has the lowest load
  - Peaker generation never reaches 100% output
- More variations are seen in combined cycle generation which generally decreases as more non-emitting resources are built and operated in the higher electrification scenarios



Scenario	Peaker Capacity Factor (pu)
50% Electrification	0.006
75% Electrification	0.018
90% Electrification	0.020
Reference	0.018
110% Electrification	0.018
125% Electrification	0.018



Scenario	CC Capacity Factor (pu)
50% Electrification	0.48
75% Electrification	0.46
90% Electrification	0.44
Reference	0.42
110% Electrification	0.40
125% Electrification	0.37

STAKEHOLDER REQUESTED SCENARIO

Final Results – Modified Peaker Retirement

Modified Peaker Retirement Takeaways

- The resource buildouts are relatively the same for the Reference and low peaker retirement scenarios
- With all peakers retired, 100-hour batteries are built to provide generation that was once delivered by the peaker units
- Peaker capacity factor decreases as more peakers retire while combined cycle generation had little to no change in output
  - Note that **gas constraints were not enforced** and results could be different if constraints continue to exist

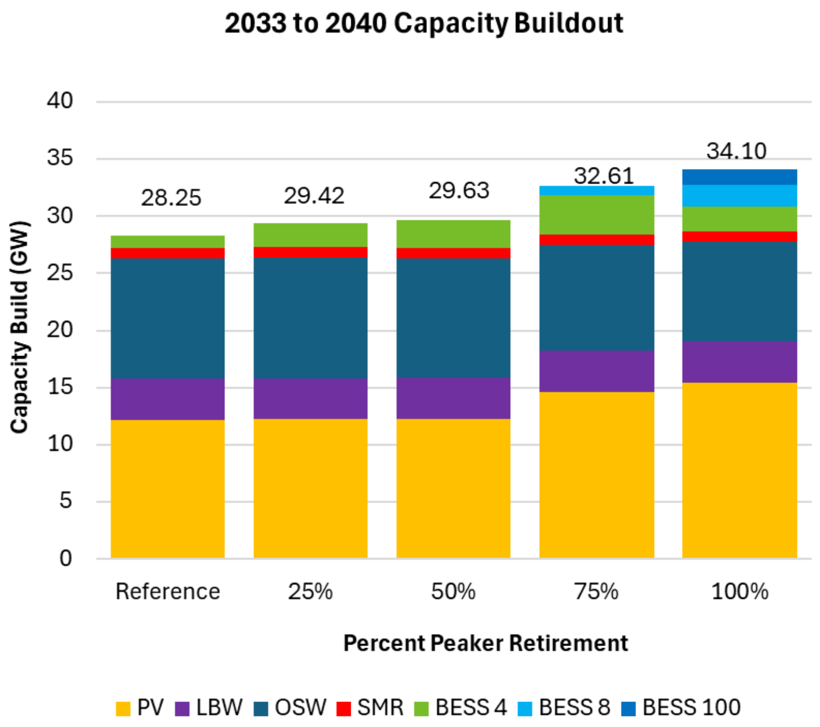
Peaker Retirement Assumptions

- Peaker retirement assumptions have not changed since the preliminary results
- Peaker units include simple-cycle natural gas units and all fossil units whose primary fuel is not natural gas
- Units are retired based on their in-service date, with the oldest units retired first

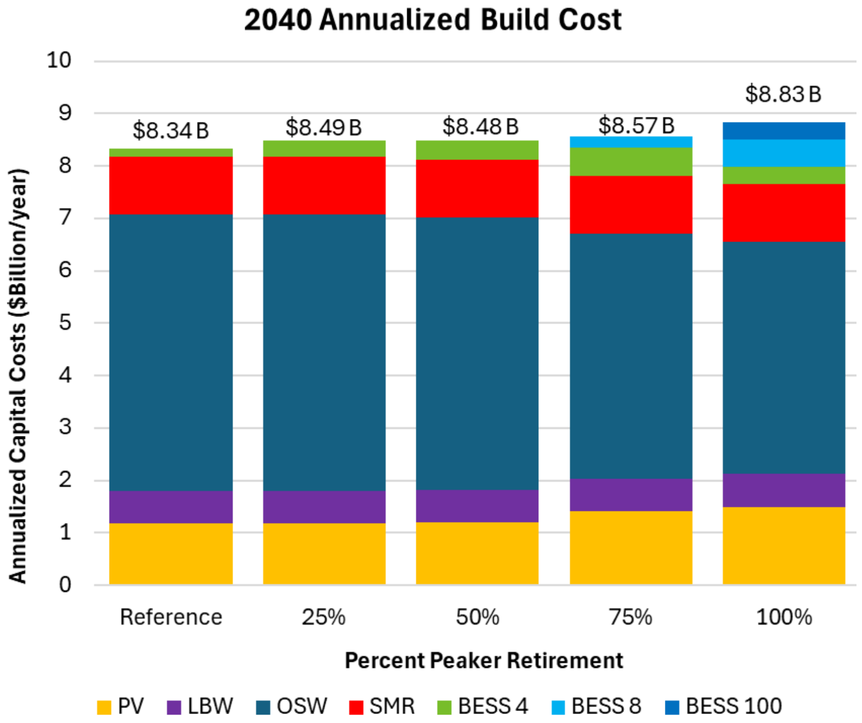
Percent of Peakers Retired	Available Peaker Generation
Reference	6,620 MW
25% Retired	5,119 MW
50% Retired	2,715 MW
75% Retired	1,596 MW
100% Retired	0 MW

Capacity Expansion Buildout

- **The impacts of peaker retirement are not evident until more than half of the peaker units are retired**
  - The buildout for the 25% and 50% Peaker Retirement scenarios are nearly identical to the Base case
  - Capacity expansion starts to ramp up in the 75% and 100% Peaker Retirement Scenarios with more buildout of batteries and PV
- **The most significant incremental change in buildout was going from 50% to 75% Peaker Retirement**
  - The 75% Peaker Retirement Scenario built 3 GW more than the 50% Peaker Retirement Scenario
  - The 100% Peaker Retirement Scenario only built 1.49 GW more than the 75% Peaker Retirement Scenario
- Each scenario built 900 MW of SMRs and 3,600 MW of land-based wind
- 100-hour batteries (1,362 MW) were only built in the 100% Peaker Retirement Scenario to serve as additional dispatchable resources in the absence of peakers



Capacity Expansion Metrics



- The 100% Peaker Retired Scenario had the largest buildout, therefore, it also had the highest build costs in 2040 out of all the scenarios
  - The main difference in build costs can be attributed to the additional $334M/year that was spent on building 100-hour batteries
- While the 50% Peaker Retired Scenario built 211 MW more capacity than the 25% Peaker Retired Scenario, the build costs were $6M/year less because the model built more PV and 4-hour batteries whereas the lower retirement scenario built more OSW, which is more expensive
  - Compared to the 25% Peakers Retired Scenario, the 50% Peakers Retired Scenario built additional 30 MW PV and 276 MW BESS 4, but 95 MW less OSW

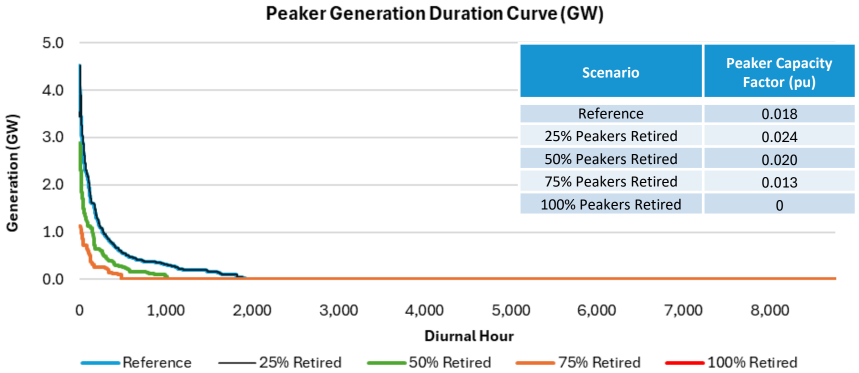
2040 Production Cost: Operational Metrics

Metric	Reference	25% Retired	50% Retired	75% Retired	100% Retired
Generation (TWh)	160	161	161	161	162
Non-Emitting Generation (TWh)	119	119	119	120	120
Emitting Generation (TWh)	21.3	20.4	20.2	19.4	19.4
Imports (TWh)	18.8	19.0	19.2	19.9	20.5
Carbon Emissions (million tons)	10.6	9.8	9.6	8.9	8.9
Hours with Emitting Generation	6,088	5,602	5,548	5,372	5,381
Curtailment (TWh)	12.8	11.9	11.6	9.8	7.9
Storage Generation (TWh)	7.2	8.5	8.7	11.1	12.0
Storage Load (TWh)	8.9	10.3	10.5	13.2	15.3

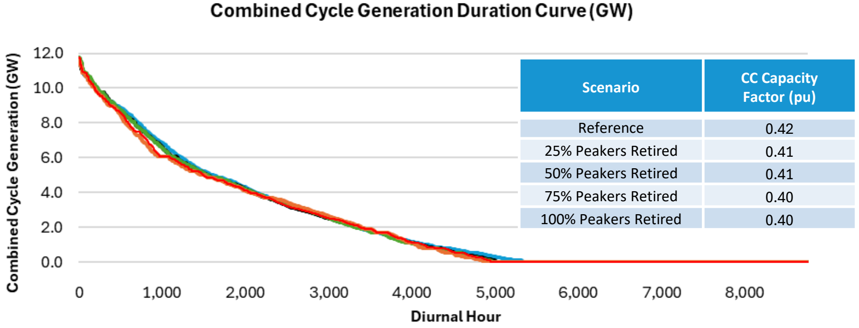
- Results are relatively the same between scenarios with incremental increases in battery operation and less curtailment as more peakers retire

2040 Thermal Operation

- As more peakers retire and more non-emitting resources are built to replace them, existing peakers are utilized less frequently until all peakers are retired
- Combined cycle generation showed little variation with changes in peaker retirement



Scenario	Peaker Capacity Factor (pu)
Reference	0.018
25% Peakers Retired	0.024
50% Peakers Retired	0.020
75% Peakers Retired	0.013
100% Peakers Retired	0



Scenario	CC Capacity Factor (pu)
Reference	0.42
25% Peakers Retired	0.41
50% Peakers Retired	0.41
75% Peakers Retired	0.40
100% Peakers Retired	0.40

STAKEHOLDER REQUESTED SCENARIO

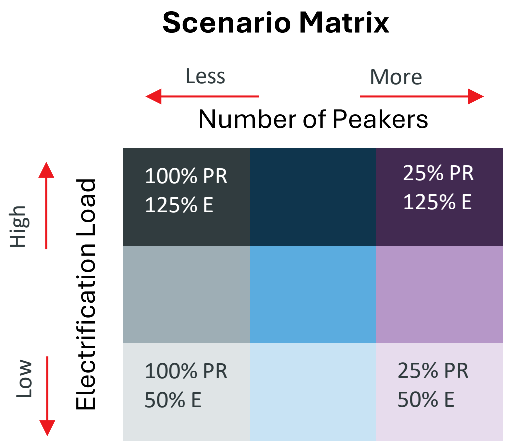
Final Results – Modified Electrification and Peaker Retirement

Modified Electrification and Peaker Retirement Takeaways

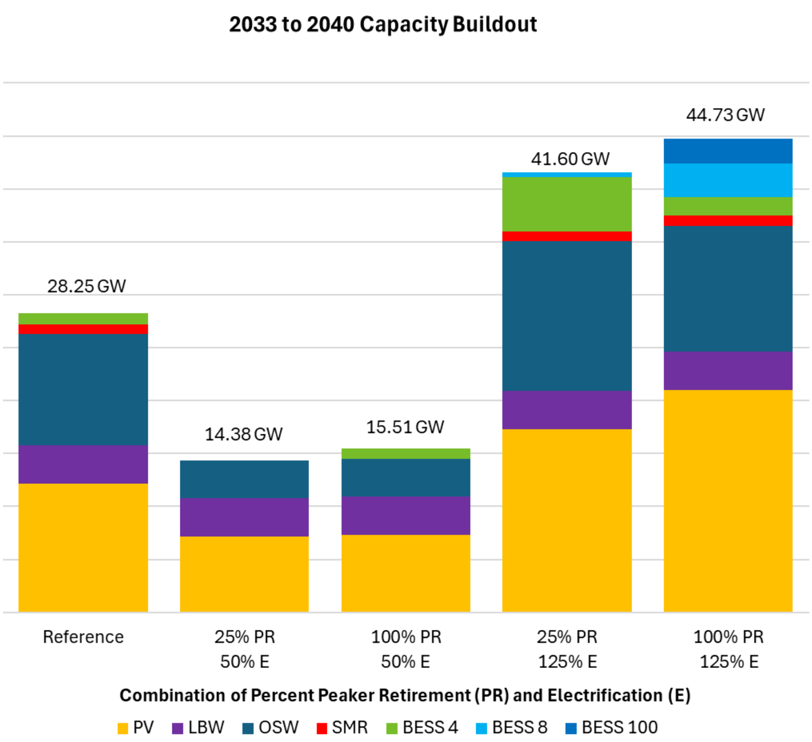
- **Electrification drives capacity expansion and combined cycle generation more than peaker retirement**
- Capacity buildout falls below the Reference buildout when electrification is kept to a minimum, regardless of the rate of peaker retirement
- The combination of 125% electrification and 100% peaker retired scenario yields the largest buildout of non-emitting resources

Electrification and Peaker Retirement Assumptions

- To understand which is the dominant factor driving capacity expansion and production cost metrics (electrification (*E*) or peaker retirement (*PR*)), the following "corner" scenarios were run that combine the high and low ends of each factor:
  - 25% Peaker Retire and 50% Electrification
  - 25% Peaker Retire and 125% Electrification
  - 100% Peaker Retire and 50% Electrification
  - 100% Peaker Retire and 125%Electrification

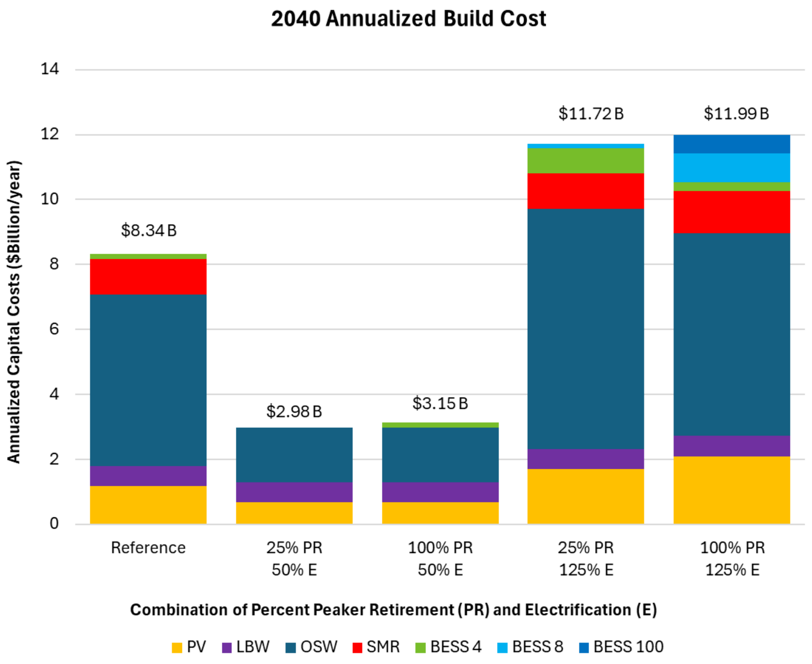


Capacity Expansion Buildout



- **Capacity expansion is mainly driven by electrification rather than peaker retirement**
- When electrification is kept to a minimum (50% E), the buildout is less than the Reference buildout regardless of whether there's more or less peakers retired
  - The buildouts are nearly identical despite the significant difference in peaker retirement
- At the highest electrification level (125% E), the buildout surpasses the Reference buildout even when only 25% of peakers are retired
- The combination of highest peaker retirement and electrification (100% PR and 125%E) resulted in the largest capacity buildout
  - This is the only scenario that built 100-hr batteries (2,325 MW)

Capacity Expansion Metrics



- The 2040 build costs reflect the same trend as the capacity buildout
- The build costs for the 50% electrification (50% E) scenarios with varying peaker retirement were nearly the same since they built similar types and amount of resources

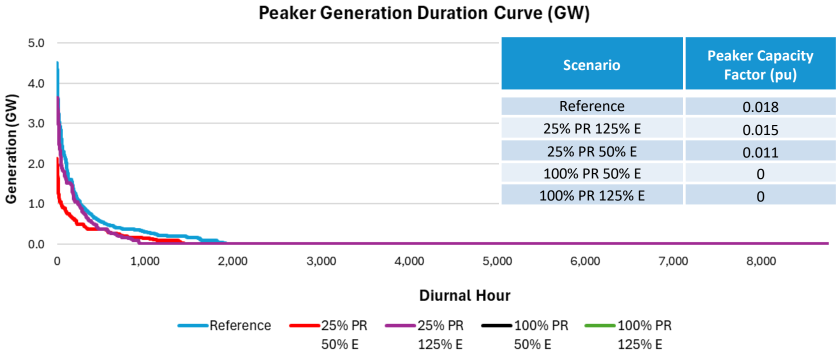
2040 Production Cost: Operational Metrics

Metric	Reference	25% PR 50% E	100% PR 50% E	25% PR 125% E	100% PR 125% E
Generation (TWh)	160	132	132	175	178
Non-Emitting Generation (TWh)	119	83	84	138	139
Emitting Generation (TWh)	21.3	25.0	23.9	18.1	17.8
Imports (TWh)	18.8	21.4	21.6	17.4	19.1
Carbon Emissions (million tons)	10.6	11.9	11.0	8.6	8.3
Hours with Emitting Generation	6,088	7,154	6,903	4,707	4,887
Curtailment (TWh)	12.8	6.1	5.4	16.7	11.2
Storage Generation (TWh)	7.2	4.5	5.9	12.6	15.5
Storage Load (TWh)	8.8	5.7	7.2	15.1	20.4

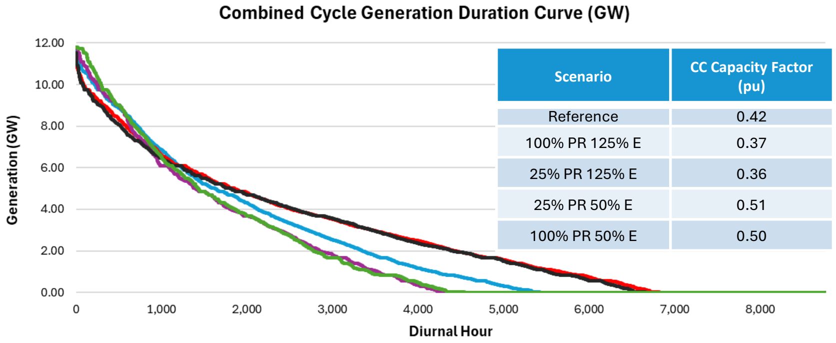
- The combination of the highest electrification and peaker retirement resulted in the lowest carbon emissions

2040 Thermal Operation

- When 25% of peakers are retired, the peaker utilization increases with higher electrification due to higher peak load
- Changes in combined cycle generation were driven by varying electrification levels
  - When electrification was kept constant the combined cycle generation did not change regardless of rate of peaker retirement
  - Combined cycle generation decreases with increasing electrification due to the addition of SMRs and batteries



Scenario	Peaker Capacity Factor (pu)
Reference	0.018
25% PR 125% E	0.015
25% PR 50% E	0.011
100% PR 50% E	0
100% PR 125% E	0



Scenario	CC Capacity Factor (pu)
Reference	0.42
100% PR 125% E	0.37
25% PR 125% E	0.36
25% PR 50% E	0.51
100% PR 50% E	0.50

NEXT STEPS

2024 Economic Studies Report

- The 2024 Economic Studies Report will be published in Q3
- The report will include the Policy, Stakeholder-Requested, and Benchmark Scenarios
- Due to timing constraints from 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, SENS results will be presented to the PAC in Q3 2025

Next Steps

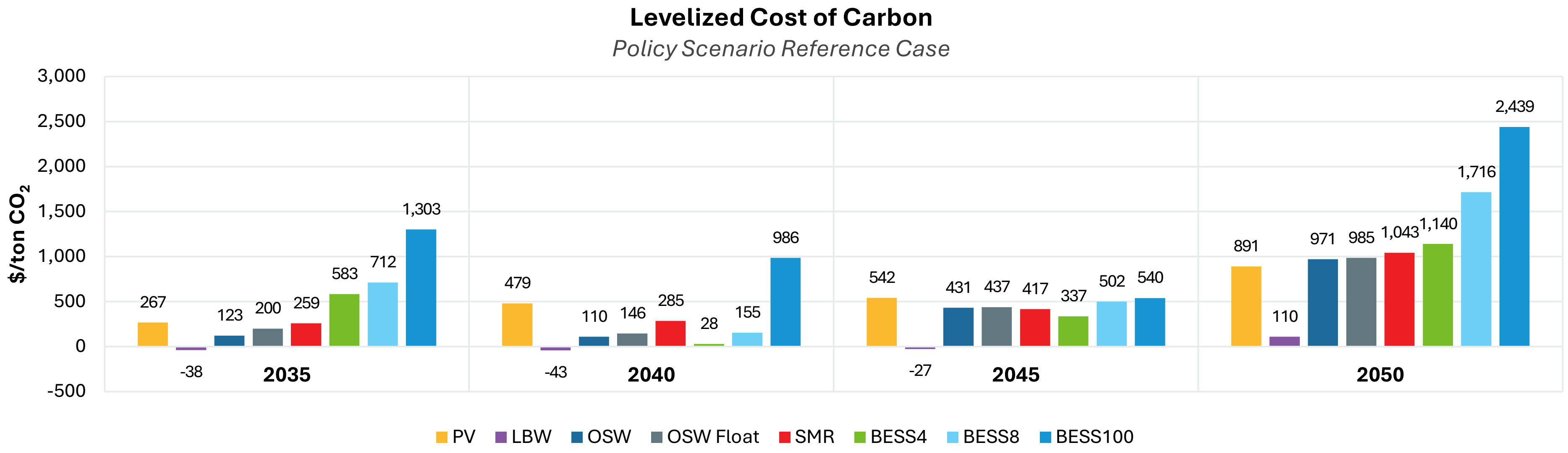
- Please send sensitivity requests for the Stakeholder-Requested Scenario or feedback to PACMatters@iso-ne.com
  - Sensitivities should be limited to a single “theme” or category of changes to allow for better understanding of the causal effect of the change to the results
- Additional results for the Policy Scenario will be presented at the July PAC
- Assumptions for the System Efficiency Needs Scenario will be presented at the July PAC
  - This date is dependent on FERC acceptance of the SENS Tariff revisions; a FERC order is expected before June 22, which is the requested effective date for the Tariff revisions

Questions

APPENDIX

Policy Scenario – Additional Results

Policy Scenario Reference LCOC



- As shown in previous results, LBW is consistently the most cost effective resource for reducing emissions
- Battery economics depend on the renewable buildout because they will not add any value to the system if there's not a lot of excess energy to be stored
- This analysis does not consider transmission costs, which would increase capital costs
- Levelized carbon costs are lower than marginal carbon cost because MCC considers all of the resources built in a year, while LCOC is looking at individual resource types

Bifacial Tracking PV Sensitivity: Build Costs

- Modeling new PV resources as single-axis tracking bifacial panels reduces total build costs by $3.7 billion, or 2.5%
- Although single-axis tracking bifacial PV is more expensive to build than fixed-tilt monofacial PV, the increased production from bifacial tracking panels allows the model to build less capacity of other resource types
  - The total PV capacity buildout decreases with bifacial tracking PV, but build costs increase

2033-2050 New Capacity Built by Resource Type (MW)

Type	Reference	Bifacial Tracking	Delta
PV	38,000	34,278	-3,722
LBW	3,600	3,600	0
OSW	17,848	18,648	+801
SMR	5,117	4,658	-459
Li-ion BESS	14,811	12,446	-2,364
Iron-air BESS	1,451	1,834	+384
Total	**80,826**	**75,465**	**-5,361**

2033-2050 Annualized Build Costs by Resource Type ($B)

	Reference	Bifacial Tracking	Delta
PV	28.71	30.61	+1.90
LBW	9.38	9.38	0.00
OSW	69.32	65.38	-3.94
SMR	27.15	24.98	-2.17
Li-ion BESS	14.42	14.93	+0.51
Iron-air BESS	0.75	0.72	-0.03
Total	**149.73**	**146.00**	**-3.73**

Accelerated Decarbonization Sensitivity: Build Costs

- The accelerated decarbonization scenario's build costs are higher than the Reference because the model has to build more expensive resources like SMRs and iron-air BESS earlier than the Reference to meet the accelerated carbon constraint
- Resource build costs are assumed to decrease over time as the technology matures, therefore, building resources before 2040 increases costs that would have been built later in the Reference Scenario when costs were lower

2033-2050 Annualized Build Costs by Resource Type ($B)

	Reference	Accelerated Decarbonization	Delta
PV	28.71	36.37	+7.66
LBW	9.38	9.38	0
OSW	69.32	111.86	+42.54
SMR	27.15	44.03	+16.88
Li-ion BESS	14.42	22.59	+8.17
Iron-air BESS	0.75	8.58	+7.83
Total	**149.73**	**232.80**	**+83.07**

Marginal Cost of Carbon Methodology

- The resource buildout from the capacity expansion model was input into the production cost model to simulate the 8,760 hourly operation of the system for each year from 2033-2050
- The capital costs (annualized build costs + fixed costs), production costs, and emissions were used to calculate the cost of reducing the next additional ton of carbon emission, or the marginal cost of carbon (\$/ton CO_2)
- The marginal cost of carbon (MCC) is calculated by comparing the emissions and net present value of the total system before any new resources have been added and after each year's buildout has been added