EXH. EKH-1T
DOCKET UE-210795
2022 PSE CEIP
WITNESS: ELAINE K. HART

BEFORE THE
WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

In the Matter of PUGET SOUND ENERGY, INC. 2021 Clean Energy Implementation Plan	**Docket UE-210795**

PREFILED RESPONSE TESTIMONY (NONCONFIDENTIAL) OF

ELAINE K. HART

ON BEHALF OF NW ENERGY COALITION AND FRONT AND CENTERED

October 10, 2022

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LIST OF EXHIBITS

INTRODUCTION

Q. Please state your name, title, and business address.

A. My name is Elaine K. Hart. I am a Founding Principal at Moment Energy Insights LLC. My business address is 5405 SW Shattuck Road, Portland, OR 97221.

Q. Please describe your background and experience.

A. I have ten years of professional experience in topics related to resource planning and clean energy policy implementation, including Integrated Resource Planning ("IRP"), decarbonization analysis, resource adequacy, renewable integration analysis, flexibility analysis, energy storage analysis, and optimization modeling. In my current role, I support intervenors, regulators, and electric cooperatives on topics related to resource planning, clean energy policy implementation, and resource adequacy.

Prior to founding Moment Energy Insights LLC in 2020, I was the Manager of the IRP team at Portland General Electric ("PGE"). In that role, I led the development of PGE's 2019 IRP and developed PGE's internal portfolio optimization and resource adequacy planning models. Prior to managing the IRP team, I was a Principal IRP Analyst and led internal energy storage modeling for the 2016 IRP and PGE's Energy Storage Potential Evaluation. I also supported the 2018 Renewable RFP and PGE's first Decarbonization Study.

Prior to PGE, I was a Managing Consultant at Energy and Environmental Economics, Inc., where I served as technical lead on projects related to clean energy policy, renewable integration, and grid flexibility, including:

- The "Western Interconnection Flexibility Assessment" on behalf of the Western Electricity Coordinating Council and the Western Interstate Energy

Board;

- A technical study on the "Feasibility and cost of potential 2030 GHG reduction goals" on behalf of the California Air Resources Board, California Energy Commission, California Public Utility Commission, and California Independent System Operator;
- A study of the impacts of adopting a 50% RPS in California on behalf of Pacific Gas and Electric, Southern California Edison, San Diego Gas & Electric, Los Angeles Department of Water and Power, and Sacramento Municipal Utility District; and
- Energy storage valuation analysis for a pumped storage developer in California.

I completed my Ph.D. in Civil and Environmental Engineering at Stanford University with a dissertation entitled "Optimization-based modeling methods for reliable low carbon electricity portfolios." I also hold an M.S. in Materials Science and Engineering from Stanford University and a B.S. in Chemistry from Harvey Mudd College. My qualifications are included as Exh. EKH-2.

Q. Have you provided testimony before the Washington Utilities and Transportation Commission before?

A. No, I have not.

Q. On whose behalf are you appearing in this proceeding?

A. I am testifying as a witness for the NW Energy Coalition ("NWEC") and Front and Centered.

Q. What is the scope of your testimony?

A. My testimony will focus on two issues with the modeling that Puget Sound Energy ("PSE") used to develop their 2021 Clean Energy Implementation Plan (CEIP). First, the methodology that PSE used to incorporate the social cost of greenhouse gases ("SCGHG") into portfolio optimization did not fully account for the value of adding clean energy resources to PSE's portfolio. Second, the values that PSE used to represent the effective load carrying capability ("ELCC") of energy storage in portfolio optimization were based on flawed analysis. For both topics, I will describe how PSE's portfolio optimization methodologies and assumptions undervalue clean energy resources, which could lead to suboptimal clean energy and energy storage acquisition targets, over-attribution of clean energy and energy storage acquisitions to the Clean Energy Transition Act ("CETA"), and overestimation of CETA incremental costs in PSE's 2021 CEIP.

Q. Please summarize the terms you recommend the Commission include as conditions of approval of PSE's CEIP to address these issues.

A. I recommend that PSE be required to re-optimize the CEIP Preferred Portfolio[1] and the No CETA Portfolio,[2] which is used to determine CETA incremental costs, as a condition for approval of the 2021 CEIP. In re-optimizing these portfolios, I recommend that PSE be required to directly apply the SCGHG to fossil fuel dispatch within the portfolio optimization model, rather than estimating the SCGHG associated with fossil fuel

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[1] This is also referred to as the "CEIP portfolio" in CEIP appendices and workpapers.

[2] This is also referred to as the "baseline portfolio," the "alternative lowest reasonable cost portfolio," and the "No CETA Bundle 11 Portfolio" in CEIP appendices and workpapers. This portfolio does not include a clean energy constraint, but must account for the SCGHG in portfolio design.

resources based on fixed cost adders, in order to account for the full value of avoiding GHG emissions with clean energy resources. The Commission should also require PSE to apply the SCGHG to fossil fuel dispatch in portfolio optimization in future CEIPs and IRPs.

I also recommend that PSE be required to incorporate their most recent energy storage ELCC values into these updated portfolio optimization runs to better account for the value that energy storage brings to their portfolio.

Based on these updated optimal portfolios, I recommend that PSE be required to recalculate acquisition targets for renewable resources, energy efficiency, demand response, and energy storage, and to recalculate CETA incremental costs.

ANALYSIS

SCGHG Modeling Methodology

Q. What is the Social Cost of Greenhouse Gas Emissions (SCGHG) and why is it important to include in utility planning, generally speaking?

A. The social cost of greenhouse gases reflects the cost of damages associated with incremental emissions of greenhouse gases. The cost is established and regularly updated by the Interagency Working Group on Social Cost of Greenhouse Gases, a consortium of fourteen Federal government agencies, including the U.S. Department of Energy and the U.S. Environmental Protection Agency. The Interagency Working Group describes the SCGHG as follows:

> The SC-GHG is the monetary value of the net harm to society associated with adding a small amount of that GHG to the atmosphere in a given year. In principle, it includes the value of all climate change impacts, including (but not

> limited to) changes in net agricultural productivity, human health effects, property damage from increased flood risk natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services.
>
> The SC-GHG, therefore, should reflect the societal value of reducing emissions of the gas in question by one metric ton. The marginal estimate of social costs will differ by the type of greenhouse gas (such as carbon dioxide, methane, and nitrous oxide) and by the year in which the emissions change occurs. The SC-GHGs are the theoretically appropriate values to use in conducting benefit-cost analyses of policies that affect GHG emissions.[3]

The SCGHG has been used by federal agencies in conducting cost-benefit analyses in rulemakings and other decisions since 2008.

Generally speaking, the purpose of including the SCGHG in utility planning is to ensure that the cost of climate, health, and societal impacts of GHG emissions associated with a utility's plan are reflected in their resource planning and acquisition decisions. Not incorporating the SCGHG in utility planning, by contrast, risks outcomes that are more costly from a societal perspective.

Q. How does CETA require utilities to include the SCGHG in utility planning, such as PSE's CEIP?

A. CETA requires Washington utilities to incorporate the SCGHG into resource planning documents and decisions. Specifically, RCW 19.280.030(3)(3)(a) states:

[3] https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf at 2.

> An electric utility shall consider the social cost of greenhouse gas emissions, as determined by the commission for investor-owned utilities pursuant to RCW 80.28.405 and the department for consumer-owned utilities, when developing integrated resource plans and clean energy action plans. An electric utility must incorporate the social cost of greenhouse gas emissions as a cost adder when:
>
> (i) Evaluating and selecting conservation policies, programs, and targets;
>
> (ii) Developing integrated resource plans and clean energy action plans; and
>
> (iii) Evaluating and selecting intermediate term and long-term resource options.

Commission rules further define the SCGHG as "the inflation-adjusted costs of greenhouse gas emissions resulting from the generation of electricity, as required by RCW 80.28.405, the updated calculation of which is published on the commission's website." WAC 480-100-605. In Docket U-190730, the Commission adopted specific dollar values for the SCGHG, which are published on the Commission's website.[4]

On December 28, 2020, the Commission issued General Order R-601 in Dockets UE-191023 and UE-190698 (consolidated), which adopted rules that implement RCW Chapter 19.405 and revisions to RCW Chapters 19.280 and 80.28. General Order R-601 addresses how the SCGHG should be included in an electric utility's Clean Energy Implementation Plan (CEIP). The Commission's order does not prescribe a specific methodology for incorporating the SCGHG into portfolio optimization, but states:

[4] *See* https://www.utc.wa.gov/regulated-industries/utilities/energy/conservation-and-renewable-energy-overview/clean-energy-transformation-act/social-cost-carbon.

> If a utility treats the SCGHG as a planning or fixed cost adder in its determination of the optimal portfolio, including retirements and new plant builds, we expect the utility to model at least one other scenario or sensitivity in which the SCGHG is reflected in dispatch.[5]

The order further notes: "Such modelling will help to inform how best to implement CETA's requirement to include the SCGHG emissions as a cost adder."[6]

Finally, the order clarifies that the "lowest reasonable cost" portfolio used to calculate CETA incremental costs should "include the SCGHG in the same manner required under Chapter 19.280 RCW."[7]

Q. Does PSE fully account for the SCGHG in the modeling supporting its final CEIP?

A. No, it does not.

Q. Please provide a high-level summary of the ways in which PSE's modeling does not fully account for the SCGHG.

A. PSE's portfolio optimization modeling does not account for the social cost of GHG emissions that can be avoided by dispatching fossil fuel resources less often or at lower levels as a result of introducing more clean energy into a portfolio. In this way, PSE's portfolio optimization methodology neglects a portion of the SCGHG benefits of clean energy resources.

Q. Please summarize how this failure to fully account for the SCGHG benefits of clean energy resources affected PSE's renewable energy targets and incremental costs in

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[5] General Order R-601 at 17.

[6] *Id*.

[7] *Id.* at 48.

the 2021 CEIP.

A. Because PSE's portfolio optimization approach underestimates the ability of clean energy resources to reduce fossil fuel resource dispatch, clean energy resources are undervalued by PSE's portfolio optimization model. As a result, PSE's portfolios, including the CEIP Preferred Portfolio and the baseline (or No CETA) portfolio, may have less clean energy than would be optimal considering total costs and total SCGHG. This has two potential consequences for PSE's clean energy plans. First, PSE's clean energy targets may be lower than they would be if they fully valued clean energy in designing portfolios. Second, PSE may be underestimating the amount of clean energy that would be acquired on the basis of the SCGHG without the CETA clean energy constraint in the No CETA Portfolio. This would over-attribute clean energy additions to CETA and would result in an overestimation of CETA incremental costs. Ultimately, over-attribution of clean energy acquisitions to CETA and overestimation of incremental costs could cause PSE to acquire clean energy resources more slowly than would otherwise be optimal.

Q. You stated that PSE's portfolios "may" have less clean energy than would be optimal and that PSE "may" be overestimating incremental costs. Could you summarize why you can't explain conclusively whether PSE's portfolios are suboptimal and whether PSE has overestimated incremental costs?

A. Yes. Portfolio optimization models are highly complex, with several interacting constraints, which can make it challenging to predict optimal outcomes. With information about relative costs and benefits, I can estimate directionally how a change in methodology or an input assumption might affect portfolio composition, but I cannot estimate the magnitude of the change or determine whether the change would be material.

To determine how a change in methodology or assumptions affects optimal portfolio composition, I would need to re-run PSE's portfolio optimization with different settings and inputs. I do not have a license for PSE's portfolio optimization model, so I am not able to conduct those tests. For this reason, I am recommending that the Commission direct PSE to re-run their models with the changes that I discuss below and update their acquisition targets and incremental cost calculations accordingly.

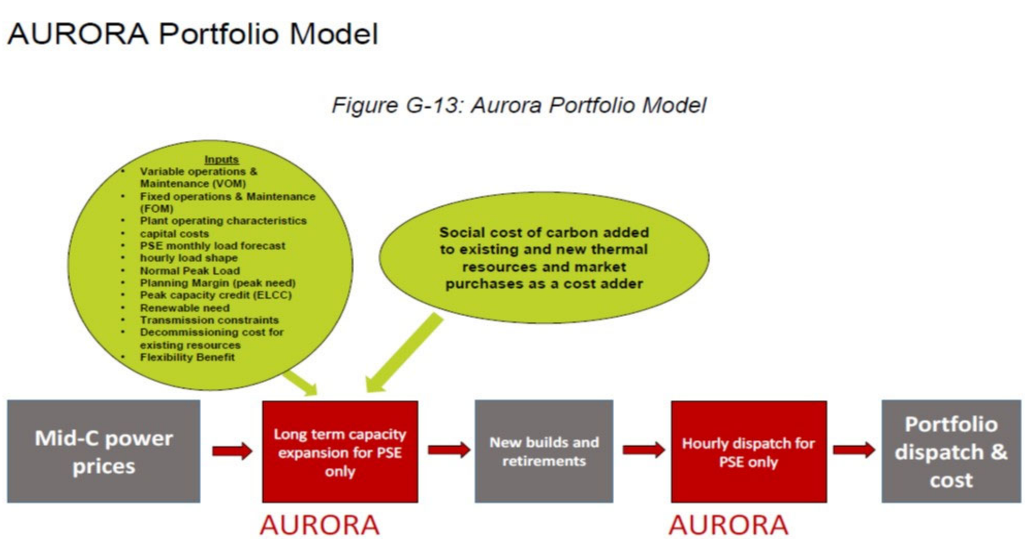
Q. Can you provide more detail on the ways the SCGHG is and is not incorporated into PSE's modeling?

A. Yes.

Q. How does PSE develop and evaluate portfolios in the IRP and CEIP?

A. PSE explains their methodology in Appendix G of the 2021 IRP. Figure G-13 from PSE's IRP (shown in Figure 1) shows the multi-step process that PSE uses to develop optimal portfolios and to determine how those portfolios perform with respect to resource dispatch, cost, and emissions.

Figure 1. PSE Portfolio Modeling Approach (Source: PSE's 2021 IRP, Appendix G)



As shown in Figure 1, PSE uses a long-term capacity expansion (LTCE) model in AURORA to develop portfolios for use in the IRP and CEIP. This model produces the optimal resource additions and retirements for each portfolio. PSE then uses a separate hourly dispatch model in AURORA to determine how each portfolio performs in terms of dispatch, cost, and emissions. Both the LTCE and hourly dispatch models represent resource dispatch decisions, but in different ways and for different purposes. The LTCE model represents resource dispatch decisions in order to account for key determinants of resource economics in resource build and retirement decisions, including fuel costs, variable costs, market value, and the SCGHG. AURORA makes some simplifications in the dispatch optimization within the LTCE model for computational efficiency. The hourly dispatch model simulates resource dispatch with more granularity in order to simulate how each resource would actually operate in a real system once it is built. The hourly dispatch model does not include the SCGHG.

Q. How does PSE's LTCE model account for the SCGHG?

A. PSE describes the LTCE model that they use to build optimal resource portfolios in Appendix G of PSE's 2021 IRP. As PSE explains, beginning on page G-31, the SCGHG is incorporated into the LTCE model by calculating a fixed cost adder for each existing and potential new fossil fuel resource, which estimates the amortized SCGHG associated with GHG emissions from the resource over its lifetime. To estimate the GHG emissions from the resource over its lifetime, PSE conducts a separate outboard dispatch simulation of the resource without the influence of the SCGHG and without the influence of the clean resources that might be selected in an optimal portfolio. The LTCE model sees these fixed SCGHG adders when it decides whether to build a new fossil fuel resource or to retire an existing fossil fuel resource. The LTCE model also incorporates the SCGHG as a cost adder applied to market purchases based on the unspecified emissions rate of 0.437 metric tonnes per MWh and the SCGHG in each year.

Q. Does PSE's approach account for the full value of the SCGHG when considering clean energy resources in portfolio optimization?

A. No, PSE's methodology does not account for the full value of the SCGHG when considering clean energy resources, including wind, solar, and energy efficiency, in portfolio optimization.

Adding clean energy resources to a portfolio avoids GHG emissions and provides value by reducing the total SCGHG for the portfolio in two ways. First, during hours when the utility would otherwise be buying energy from the market to help meet load, adding clean energy resources reduces market purchases and any associated emissions. PSE's methodology accounts for this component by penalizing market purchases in the portfolio optimization based on the unspecified emissions rate of 0.437 metric tonnes per MWh and the SCGHG in each year.

Second, during hours when the utility is relying solely on its portfolio of resources to meet load and not purchasing energy from the market, adding clean energy resources reduces the dispatch of fossil fuel resources in the portfolio to meet load. PSE's methodology does not fully account for this value. The outboard dispatch simulation that PSE uses to estimate the fixed SCGHG cost adders does not account for the potential impacts of additional clean energy on fossil fuel resource dispatch. If there is a significant amount of clean energy in the portfolio, fossil fuel resources may dispatch at lower levels than PSE's outboard dispatch simulation suggests because total generation in the LTCE model may not exceed PSE's load plus the zonal transmission limit for market sales (*see* Figure G-14 in PSE's 2019 IRP). In other words, by introducing clean energy, the system has less room remaining for fossil fuel resource dispatch and this provides value by reducing the total SCGHG. PSE's fixed SCGHG cost adders neglect this portfolio effect because they are conducted in an outboard dispatch simulation that cannot anticipate what resources will ultimately be selected by the LTCE model.

Within the LTCE model, the total estimated SCGHG associated with each fossil fuel resource is fixed and not tied to that resource's actual dispatch within the portfolio. As a result, the LTCE model does not recognize all of the GHG emissions reductions that could be achieved by introducing additional clean energy resources into the portfolio. PSE's methodology only accounts for the value of reducing fossil fuel resource emissions to the extent that the entire fossil fuel resource can be avoided by exclusion from the portfolio altogether. This presents a very high and unrealistic hurdle for the model to recognize the full SCGHG benefits of clean energy additions. In this way, PSE's approach artificially suppresses the influence of the SCGHG on optimal portfolio determination.

Q. How does PSE's failure to account for the full SCGHG benefits of clean energy resources affect their consideration in the LTCE model?

A. By neglecting the SCGHG benefits of avoiding fossil fuel dispatch with clean energy additions, the LTCE model underestimates the value of clean energy additions. This may result in portfolios that have less renewable energy or energy efficiency than the amounts that would achieve the lowest total cost, measured as the revenue requirement plus the total SCGHG.

Q. How much of the value of clean energy additions does PSE's portfolio optimization neglect?

A. It is not possible to determine precisely how much of the value of clean additions is neglected by PSE's LTCE model without re-running the model using different settings. However, PSE's analysis does provide some insight into the value of reducing fossil fuel dispatch by introducing clean energy into the portfolio. The clean energy additions in the CEIP Preferred Portfolio have a significant impact on the dispatch of existing gas resources over time, which leads to emissions savings that are not recognized by PSE's LTCE Model when it applies the SCGHG.

To understand how clean energy additions impact fossil fuel resource emissions at a high level, I compared the clean energy additions, existing gas resource dispatch, and GHG emissions from existing gas resources between the CEIP Preferred Portfolio and a portfolio with much less clean energy, the No CETA Bundle 11 Portfolio.[8] The results are shown in Figure 2 and the calculations can be found in Exhibit EKH-11.[9]

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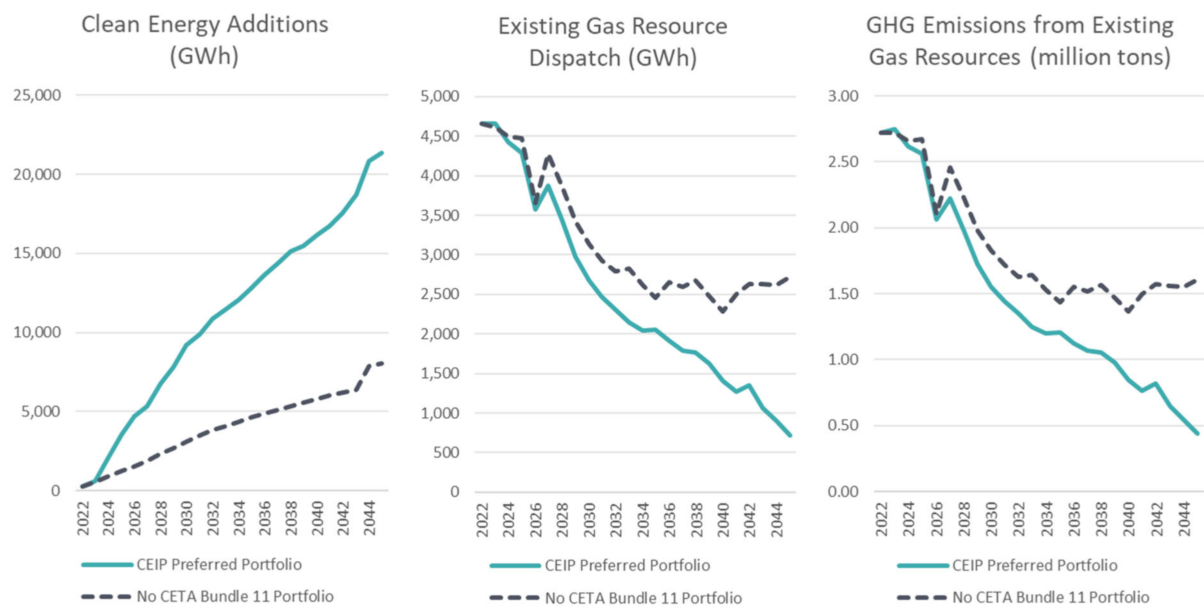
[8] This is the same "No CETA Portfolio" that PSE uses to calculate incremental costs.

[9] Note that these dispatch and emissions results are based on PSE's hourly dispatch model, which does not incorporate the SCGHG. These outputs simulate actual operations for each portfolio and do not reflect the dispatch simulated in PSE's LTCE model.

Figure 2. Impact of clean energy additions on PSE's existing gas dispatch and emissions



Compared to the portfolio with much less clean energy, I estimated the avoided emissions due only to reduced dispatch of existing gas resources in the CEIP Preferred Portfolio to be 9.7 million short tons between 2022 and 2045. These emissions reductions yielded a SCGHG savings of $423 million on a net present value basis in 2020$, or $4.8 per MWh of clean energy additions on a real levelized basis. In other words, I estimate that the LTCE model misses approximately $4.8/MWh of value associated with avoiding emissions by adding clean energy resources.

Q. How did under-valuing clean energy additions in the LTCE model impact resource selection in PSE's portfolios?

A. It is not possible to determine how PSE's approach specifically impacted resource selection without re-running the LTCE model with different settings. To conceptually illustrate how sensitive resource selection can be to the SCGHG methodology, however, I developed a highly simplified portfolio optimization model for a stylized system that broadly reflects the types of resource trade-offs that PSE faces. I used this stylized system to test the sensitivity of the optimal resource selection to the SCGHG methodology and found that the SCGHG methodology can dramatically affect the compositions of optimal portfolios.

To broadly reflect the types of resource trade-offs that PSE faces, the stylized system includes some existing gas resources, access to a wholesale energy market, and has the opportunity to procure a combination of renewable energy and natural gas peaking capacity. The system must meet load in each hour of an example day and must meet a simple planning reserve margin constraint at least cost. The system has no renewable energy requirement, but does have a SCGHG equal to $100 per metric tonne. In this way the system is set up to reflect a stylized "No CETA" or "lowest reasonable cost" portfolio. Additional information about the system, including all assumptions, calculations, and Excel Solver settings can be found in Exh. EKH-3.

Using this stylized system, I conducted two portfolio optimization runs to solve for the optimal amounts of additional renewable energy (priced at $50/MWh) and peaking natural gas capacity using two alternative approaches:

1. In the first approach ("Fixed SCGHG Adder"), which is based on PSE's SCGHG methodology in their LTCE model, I minimized the sum of all fixed costs, operational costs, SCGHG associated with market purchases, and fixed SCGHG per MW cost adders applied to the existing and any new gas capacity. Similar to PSE's approach, I calculated the fixed SCGHG per MW cost adders based on outboard dispatch simulations of the gas plants without accounting for the SCGHG or potential clean energy additions in the portfolio.

2. In the second approach ("SCGHG Applied to Dispatch"), I minimized the sum of all fixed costs, operational costs, and the total SCGHG associated with market purchases and natural gas plant dispatch. Using this approach, the SCGHG in the objective function depends on how the resources are dispatched so that clean energy additions that affect fossil fuel dispatch are given full credit for the value of avoiding GHG emissions.

I used all of the same input assumptions between the two portfolio optimizations – the only difference was the treatment of the SCGHG in the objective function. For each of the optimal portfolios, I then ran a separate dispatch simulation with no SCGHG to calculate portfolio dispatch, cost, emissions, and corresponding SCGHG to align with PSE's two-step portfolio modeling approach. Table 1 lists key results for the two optimized portfolios. Additional information is provided in Exh. EKH-3.

Table 1. Portfolio results using different SCGHG methodologies for a stylized system with a $50/MWh renewable resource option

Optimization Approach	Fixed SCGHG Adder	SCGHG Applied to Dispatch
Optimal Renewable Energy Addition	0 MW	776 MW
Optimal Natural Gas Peaking Capacity Addition	110 MW	0 MW
Total GHG Emissions	3,580 tonnes	778 tonnes
Total Fixed + Operational Costs	$261k	$374k
Total SCGHG	$358k	$78k
Total Fixed Costs + Operational Costs + SCGHG	$619k	$452k

This simplified example shows how sensitive the optimal portfolio can be to the SCGHG methodology. When the SCGHG was treated as a fixed cost adder, as it is in PSE's approach, no renewable energy was selected, 110 MW of peaking capacity was selected to meet the planning reserve margin, and there were 3,580 metric tonnes of GHG emissions over the course of the day. The portfolio cost, including the SCGHG, was $619k. In contrast, when the optimization model accounted for the full value of clean energy resources (using the SCGHG Applied to Dispatch approach), 776 MW of renewable energy was selected, no peaking capacity was needed to meet the planning reserve margin, and there were only 778 metric tonnes of GHG emissions over the course of the day. The portfolio cost, including the SCGHG, was $452k. In the case of the stylized system, applying the SCGHG to dispatch resulted in much more renewable energy additions, fewer natural gas additions, and lower total costs.

Similar to this simplified example, PSE's approach to incorporating the SCGHG into the LTCE model may have artificially suppressed clean energy additions, resulting in suboptimal portfolios in the CEIP. It is possible that incorporating more clean energy resources into these portfolios could have further reduced the total cost, measured as the sum of the net present value revenue requirement (NPVRR) and the SCGHG. Because optimization models can be so sensitive to assumptions and interacting constraints, the best way to credibly determine whether this is the case is to re-run the models, applying the SCGHG to dispatch in the LTCE model.

Q. How do the clean energy additions in the optimal portfolios in the CEIP affect CETA incremental costs?

A. PSE estimates incremental costs associated with generation additions by comparing annual costs between two portfolios: the CEIP Preferred Portfolio and the No CETA Portfolio. The No CETA Portfolio is intended to reflect the lowest reasonable cost portfolio, or what PSE would have done without the CETA minimum clean energy requirement. Both the CEIP Preferred Portfolio and the No CETA Portfolio are required to include the SCGHG.[10] Incremental costs are calculated by subtracting the annual costs of the No CETA Portfolio from the annual costs of the CEIP Preferred Portfolio. This calculation attributes the net cost of resource additions that arise in the CEIP Preferred Portfolio, but not in the No CETA Portfolio, to CETA. Accordingly, if the No CETA Portfolio has fewer clean energy additions, then more resource additions from the CEIP Preferred Portfolio will be attributed to CETA and will be reflected in incremental costs, resulting in higher incremental costs for the same resource actions. Therefore, if the portfolio optimization model has undervalued clean energy additions and resulted in suboptimal levels of clean energy in the No CETA Portfolio, incremental costs will be overestimated in the CEIP.

Q. Does PSE's No CETA Portfolio in the final CEIP represent the lowest reasonable cost portfolio for use in the CETA incremental cost calculation?

A. It is not possible to determine conclusively whether PSE has identified the lowest reasonable cost portfolio without re-running PSE's models using different settings. However, the stylized example described previously offers some insight. In the stylized system, the total cost, including the SCGHG, of the portfolio developed by applying the SCGHG to dispatch was $167k lower than the total cost of the portfolio developed by applying the SCGHG as a fixed cost adder. In this example, the portfolio developed by

[10] Note that the No CETA Portfolio is designed to specifically isolate incremental generation additions associated with the CETA clean energy constraint, so it incorporates the same energy efficiency and demand response resources as the CEIP Preferred Portfolio. PSE refers to this as the "No CETA Bundle 11 Portfolio."

applying SCGHG to dispatch was the lower reasonable cost portfolio. Similar to this simplified example, PSE's approach to incorporating the SCGHG into the LTCE model may have resulted in a suboptimal "lowest reasonable cost" portfolio for CETA incremental cost calculations. Because optimization models can be so sensitive to assumptions and interacting constraints, the best way to credibly determine whether this is the case is to re-run the models, applying the SCGHG to dispatch in the LTCE model.

Q. Does PSE have the ability to account for the full value of avoiding fossil fuel resource dispatch with clean energy resources within the LTCE model?

A. Yes. In the 2021 IRP, PSE tested Portfolio Sensitivity I, in which the SCGHG was applied directly to the simulated emissions from both market purchases and fossil fuel resources in the LTCE model. This allowed the LTCE model to account for the fact that additional clean energy that could displace dispatch of fossil fuel resources would avoid GHG emissions and reduce the total SCGHG.

Q. Did Portfolio Sensitivity I incorporate more clean energy additions than the Preferred Portfolio in PSE's 2021 IRP?

A. Renewable energy additions in Portfolio Sensitivity I were similar to those in the Preferred Portfolio. This finding indicates that the minimum renewable energy requirement applied to both the Preferred Portfolio and Portfolio Sensitivity I had a greater impact on renewable energy additions than the SCGHG methodology.

Q. If PSE found in the IRP that portfolio compositions were not sensitive to the SCGHG methodology, why do you believe that they could be sensitive to the SCGHG methodology in the CEIP?

A. PSE made significant updates to resource costs between the IRP and the CEIP, which could meaningfully impact the composition of optimal portfolios under different SCGHG methodologies.

Q. How do renewable resource costs affect the sensitivity of portfolio optimization models to the SCGHG methodology?

A. There is a strong relationship between renewable resource costs and the effects of the SCGHG on the composition of an optimized portfolio. For each renewable resource, there is a breakeven threshold price below which the resource becomes cost effective when considering the SCGHG. Above that price threshold, there will be no renewable resource additions in an optimized portfolio (barring minimum renewable energy requirements) regardless of the SCGHG methodology. I tested this sensitivity using the same stylized system described previously. The only difference in this test was that I increased the renewable cost from \$50/MWh to \$100/MWh. Table 2 lists key results from the two optimizations under this renewable cost assumption. Additional information is provided in Exh. EKH-3.

Table 2. Portfolio results using different SCGHG methodologies for a stylized system with a \$100/MWh renewable resource option

Optimization Approach	Fixed SCGHG Adder	SCGHG Applied to Dispatch
Optimal Renewable Energy Addition	0 MW	0 MW
Optimal Natural Gas Peaking Capacity Addition	110 MW	110 MW
Total GHG Emissions	3,580 mtCO2e	3,580 mtCO2e
Total Fixed + Operational Costs	\$261k	\$261k
Total SCGHG	\$358k	\$358k
Total Fixed Costs + Operational Costs + SCGHG	\$619k	\$619k

In this case, the $100/MWh renewable resource was not selected using either approach, indicating that the renewable resource was too costly for the SCGHG to impact whether it was selected, regardless of the methodological approach. This simplified example demonstrates how PSE's findings with respect to the SCGHG methodology in the IRP could have been affected by their resource cost assumptions. If PSE's renewable resource costs were sufficiently high, then I would expect the portfolio compositions in the Preferred Portfolio and Portfolio Sensitivity I to be relatively similar. This finding would not imply that estimating the SCGHG as a fixed cost adder adequately captured all of the SCGHG benefits of clean resources. It would only indicate that the SCGHG was not high enough to overcome the costs of renewable additions.

Q. Were the renewable resource cost assumptions in the 2021 IRP too high for the SCGHG methodology to significantly impact portfolio optimization results?

A. Yes, I believe so. I investigated this question by considering Washington Wind ("WA Wind"), the lowest cost renewable resource option in the 2021 IRP. Using information from the 2021 IRP, I estimated the breakeven cost threshold below which the SCGHG could materially impact resource selection for 2025 WA Wind by estimating the total value of 2025 WA Wind to the system, including energy value, capacity value, and avoided SCGHG value. For this calculation, I assumed that WA Wind avoided GHG emissions at the market emissions rate of 0.437 metric tonnes per MWh. My estimates are provided in Table 3 and calculations can be found in Exh. EKH-4.

Table 3. Estimation of breakeven cost threshold below which the SCGHG may impact optimal resource selection

2025 WA Wind Estimated Costs and Benefits based on PSE's 2021 IRP	(2020$/MWh)
Real-Levelized Cost of Energy (A)	$75.17/MWh
Energy Value (B)	$17.41/MWh
Capacity Value (C)	$4.84/MWh
Real Levelized Value without SCGHG (D = B+C) = Breakeven cost without the SCGHG	$22.26/MWh
Avoided SCGHG (E)	$42.94/MWh
Real Levelized Value with Avoided SCGHG (F = D + E) = Breakeven cost with the SCGHG	$65.20/MWh

Based on my estimates, I would expect that a 2025 WA Wind resource would be cost effective when accounting for the SCGHG at price points below about $65/MWh. At price points between about $22/MWh and $65/MWh, I would expect that including the SCGHG in portfolio optimization would materially impact the selection of WA Wind within an optimal portfolio.[11] At price points above about $65/MWh, I would not expect WA Wind to be selected by the LTCE model regardless of the SCGHG methodology. I calculated that a WA Wind resource added in 2025 in the 2021 IRP had a real levelized cost of energy ("rLCOE") of $75/MWh in 2020$ (*see* Exh. EKH-4), falling above the $65/MWh cost threshold. This analysis suggests that PSE's resource costs were too high in the 2021 IRP for the SCGHG methodology to significantly impact near-term renewable resource additions, which is largely consistent with PSE's findings.

Q. Were the renewable resource cost assumptions in the 2021 CEIP too high for the SCGHG methodology to significantly impact portfolio optimization results?

[11] Below about $22/MWh, the resource may be selected for economics without the SCGHG.

A. No, I don't believe so. PSE made significant changes to resource cost assumptions between the IRP analysis and CEIP analysis. Some of these updates corrected for errors in the 2021 IRP analysis and some of these updates were to align resource cost estimates with more recent capital cost trends. I estimated that the resource cost updates in the CEIP resulted in a rLCOE for 2025 WA Wind of about $48/MWh in 2020$ (*see* Exh. EKH-5). The updated 2025 WA Wind resource cost aligns more closely with recent wind cost trends and falls well below the estimated cost threshold at which the SCGHG may impact resource selection in portfolio optimization, $65/MWh. This means that the resource economics for 2025 WA Wind and potentially other clean resources may be fundamentally different between the IRP and the CEIP when taking the SCGHG into account. PSE's decision to estimate a fixed SCGHG cost adder using an outboard dispatch simulation may have much greater implications in the CEIP than it had in the IRP because resource costs in the CEIP are below the threshold at which the SCGHG may meaningfully affect resource selection. To understand the implications of PSE's SCGHG methodology for the CEIP, PSE would need to test the methodology applied in IRP Portfolio Sensitivity I with the same updated resource cost data that was used in the CEIP.

Q. **You mentioned that PSE did test a SCGHG methodology in IRP portfolio optimization that applied the SCGHG to dispatch ("IRP Portfolio Sensitivity I"). Did PSE test the SCGHG methodology applied in IRP Portfolio Sensitivity I in developing the CEIP Preferred Portfolio or No CETA Portfolio in the CEIP?**

A. No. *See* Exh. EKH-6.

Q. Has PSE been asked to test a portfolio optimization methodology that applies the SCGHG to dispatch in the CEIP?

A. Yes. NWEC requested that PSE test the SCGHG methodology applied in IRP Portfolio Sensitivity I with updated resource costs in the CEIP in their comments on the draft CEIP.

Q. How did PSE respond to NWEC's request to test the SCGHG methodology applied in IRP Portfolio Sensitivity I in the CEIP?

A. PSE included a section in Chapter 5 of the CEIP explaining why they believe that their approach is more appropriate than an approach that applies the SCGHG to dispatch in portfolio optimization. PSE used a simplified example in Chapter 5 to demonstrate that the total cost plus SCGHG of a gas plant that is dispatched with the SCGHG is lower than the total cost plus SCGHG of a gas plant that is dispatched without the influence of the SCGHG. PSE used this example to assert that applying the SCGHG as a dispatch cost in the LTCE model would "make fossil fuel plants appear more cost effective than appropriate, i.e., this methodology encourages utilities to acquire fossil fuel plants."[12] PSE goes on to claim that "such an artificial bias toward fossil fuel plants is clearly inconsistent with the need to reduce GHG emissions and contrary to the intent of CETA."[13]

Q. Does PSE's example demonstrate that applying the SCGHG to dispatch in the LTCE would create an "artificial bias toward fossil fuel plants"?

A. No. PSE's example compares a fossil fuel resource to itself under two different

[12] PSE's 2021 CEIP at 174.

[13] *Id*. at 175.

methodologies. This comparison provides no information about potential portfolio optimization results. Within a portfolio optimization, what matters in selecting resources is how attractive different options appear relative to alternatives using the same methodology. PSE's example does not provide any information regarding the attractiveness of a clean energy resource addition relative to fossil fuel resources or the attractiveness of a portfolio with many clean energy additions relative to a portfolio with fewer clean energy additions. It does not demonstrate that PSE's methodology would select more clean energy resources or lead to lower portfolio emissions. It does not address the complex resource economic questions that the LTCE model is designed to answer.

To demonstrate this, I conducted the same comparison that PSE included in Chapter 5 of the CEIP using the candidate gas resource from the stylized example described previously (*see* Exh. EKH-3 for these calculations). Similar to PSE's findings and consistent with general intuition, I calculated that the total cost, including fixed costs, operating costs, and SCGHG would be much lower for the candidate gas resource if the SCGHG was applied as a dispatch cost ($58k) than if it was not ($86k). By PSE's logic, this would imply that the gas resource would be more competitive in the portfolio optimization that applied the SCGHG to dispatch. And yet, the gas resource was not selected when the portfolio optimization applied the SCGHG to dispatch because the impact to the renewable resource economics was even greater. The total cost of the gas plant may have gone down by applying the SCGHG to dispatch, but its net cost relative to the renewable resource actually went up because the renewable resource brought so much more value to the portfolio when its full SCGHG benefits were accounted for. As a result, contrary to PSE's logic, the gas resource was not competitive and GHG emissions were significantly lower in the portfolio that was designed by applying the SCGHG to dispatch. PSE cannot discount this possibility based on their example. They must re-run their models to understand the implications of the SCGHG methodology on portfolio composition and GHG emissions.

Q. Why should PSE test a portfolio optimization methodology that applies the SCGHG to dispatch in the CEIP?

A. If PSE does not test a portfolio optimization methodology that applies the SCGHG to dispatch in the CEIP, the Commission cannot be confident that the No CETA (or baseline) portfolio in the CEIP represents the actual lowest reasonable cost portfolio accounting for the SCGHG. In addition, the Commission cannot be confident that the CEIP Preferred Portfolio incorporates the optimal amount of renewable energy additions.

Q. If PSE were to test the SCGHG methodology applied in IRP Portfolio Sensitivity I in the CEIP, would PSE have to re-optimize both the No CETA Portfolio and the Preferred Portfolio?

A. I recommend that PSE re-optimize both the No CETA Portfolio and the CEIP Preferred Portfolio. Re-optimizing both portfolios would provide the greatest certainty regarding the impact of the SCGHG methodology on the composition of these portfolios. At a minimum, however, to test the sensitivity of their approach to the SCGHG methodology with the updated assumptions in the CEIP, PSE should re-optimize the No CETA Portfolio applying the SCGHG to dispatch. This portfolio is not affected by the minimum clean energy requirements and will provide more information about how the SCGHG methodology affects resource selection. This test would also help to determine whether there is a lower reasonable cost portfolio than the portfolio PSE used to calculate incremental costs. If the re-optimized No CETA Portfolio yields a total portfolio cost (including the SCGHG) that is lower than the No CETA Portfolio in the CEIP, this would indicate that PSE's No CETA Portfolio in the CEIP was not the lowest reasonable cost portfolio. It would also indicate that applying the SCGHG to dispatch yields more optimal portfolios when considering the SCGHG and that this methodology should be adopted going forward.

Q. If applying the SCGHG to dispatch in the LTCE model does not materially change the composition of the Preferred Portfolio or the No CETA Portfolio, should PSE continue to rely on its current fixed SCGHG adder approach in future planning documents?

A. No. Portfolio optimization models can be highly sensitive to input assumptions and approximations. PSE's fixed SCGHG adder approach is an approximation that may reasonably estimate resource economics with the SCGHG under some circumstances and may dramatically underestimate the value of clean resources under others. The simplified example presented in this testimony illustrates this potential for extreme sensitivity to resource costs in particular, but other factors could also dramatically swing portfolio optimization results that leverage the fixed SCGHG adder approximation. Applying the SCGHG to fossil fuel dispatch in the LTCE model provides for a more accurate and transparent accounting of the SCGHG within portfolio optimization, while the fixed SCGHG adder approach neglects actual emissions reduction value provided by clean energy resources. Even if both approaches provided identical portfolios for the CEIP in this planning cycle, PSE should still adopt a methodology that applies the SCGHG to fossil fuel dispatch in the LTCE model to ensure that future planning cycles consider optimal portfolios that fully account for the SCGHG.

Q. How does the SCGHG affect resource dispatch in the LTCE model under PSE's current methodology and how would it affect resource dispatch if PSE were to apply the SCGHG to fossil fuel dispatch in the LTCE model?

A. As described in IRP Appendix G and shown in Figure 1, in PSE's current methodology, the SCGHG is applied to market purchases but not to fossil fuel dispatch in the LTCE model. As a result, fossil fuel resources see higher costs associated with market purchases than they would in reality, and they may dispatch more often than they would in a real system where market purchases are not penalized by the SCGHG. If PSE were to apply the SCGHG to fossil fuel dispatch in the LTCE model, PSE's fossil fuel resources would still see the higher costs associated with market purchases reflecting the SCGHG, but they would also be penalized according to the SCGHG for generating. In this approach, the SCGHG has a more symmetrical impact on fossil fuel resource dispatch – it both encourages dispatch by increasing the cost of market purchases and it discourages dispatch by increasing the cost of generating.

It is not possible to determine precisely how applying the SCGHG to dispatch would affect resource dispatch in the LTCE model without re-running the model using different settings. To gain some intuition, however, I examined the stylized example described previously (*see* Exh. EKH-3 for calculations). Recall that in this model, the first portfolio optimization approach applied the SCGHG as a fixed cost adder for fossil fuel resources and also applied the SCGHG to market purchases. In the second portfolio optimization approach, the SCGHG is applied to both market purchases and fossil fuel dispatch. Recall that each portfolio then underwent a second dispatch simulation to determine dispatch, costs, and emissions without the SCGHG. Each SCGHG approach was tested using two different resource cost assumptions: one with a $50/MWh renewable cost and once with a $100/MWh renewable cost. In Table 4, I've compared the natural gas dispatch results from the portfolio optimization step and the dispatch optimization step across the four portfolios investigated.

Table 4. Comparison of average natural gas capacity factors between portfolio optimizations and dispatch optimizations in the stylized system

Portfolio Run	Average Natural Gas Capacity Factor (Portfolio Optimization w/SCGHG)	Average Natural Gas Capacity Factor (Dispatch Optimization w/o SCGHG)
Fixed SCGHG Adder with $50/MWh renewables	75%	27%
SCGHG Applied to Dispatch with $50/MWh renewables	8%	8%
Fixed SCGHG Adder with $100/MWh renewables	75%	27%
SCGHG Applied to Dispatch with $100/MWh renewables	27%	27%

In the stylized example, the natural gas dispatch in the portfolio optimization was much higher when the SCGHG was applied as a fixed cost (and applied to market purchases) than it was when the same portfolio was tested in a dispatch simulation without the SCGHG (75% versus 27%). In contrast, when the SCGHG was applied to dispatch in the portfolio optimization, the portfolio optimization yielded the same natural gas capacity factors as the dispatch simulation without the SCGHG.

In short, applying the SCGHG only to market purchases and not to fossil fuel dispatch will tend to over-estimate fossil fuel resource dispatch in the LTCE model relative to actual operations. Applying the SCGHG symmetrically to both market purchases and fossil fuel resource dispatch will likely yield more realistic gas dispatch in the LTCE model.[14]

Q. If PSE does not consider the SCGHG in actual operations, would applying the SCGHG to dispatch in the LTCE model result in unreasonable or unimplementable dispatch assumptions in the CEIP?

A. No. As described previously, and shown in Figure 1, PSE uses the LTCE model to solve for the composition of each portfolio and then uses a separate dispatch simulation to determine how the resources in each portfolio might perform in actual operations. This final dispatch simulation does not incorporate the SCGHG into dispatch decisions, regardless of how the portfolio was developed. My recommendation is to apply the SCGHG to the dispatch in the LTCE model in order to fully account for the value of avoiding emissions with clean energy resources, not to apply the SCGHG to dispatch in the separate dispatch simulation that determines expected resource dispatch, costs, and emissions.

Q. What changes should the UTC require as conditions of approval of PSE's CEIP to ensure that PSE's decisions incorporate the full value of avoiding GHG emissions

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[14] The dispatch of coal plants might not follow this logic because coal plants have much larger emissions rates than the unspecified market purchase emissions rate. Applying the SCGHG to both coal dispatch and market purchases may severely suppress coal dispatch relative to economic dispatch. However, PSE's portfolios exclude coal beginning in 2026, so the relative importance of coal dispatch is unclear. This complexity is one reason that re-running the model is necessary.

with clean energy resources?

A. I recommend that PSE be required to re-optimize the CEIP Preferred Portfolio and the No CETA Portfolio, which is used to determine CETA incremental costs, as a condition for approval of the 2021 CEIP. In re-optimizing these portfolios, I recommend that PSE be required to directly apply the SCGHG to fossil fuel dispatch within the portfolio optimization model, rather than estimating the SCGHG associated with fossil fuel resources based on fixed cost adders, in order to account for the full value of avoiding GHG emissions with clean energy resources. Based on these updated optimal portfolios, I recommend that PSE be required to recalculate acquisition targets for renewable resources, energy efficiency, and demand response and to recalculate the associated incremental costs. Finally, the Commission should require PSE to apply the SCGHG to fossil fuel dispatch in the LTCE model in future CEIPs and IRPs.

Energy Storage ELCC

Q. What is effective load carrying capability ("ELCC") and what role does it play in portfolio optimization modeling?

A. The ELCC represents the contribution of a given resource to meeting a resource adequacy constraint.[15] Resource adequacy constraints are applied in portfolio optimization models to ensure that modeled portfolios can reliably meet load. ELCC values for a given resource are specific to each system and depend on the loads and existing resources in that system, as well assumptions regarding access to markets. In general, resources that generate or can be dispatched during periods of high load or high

[15] In PSE's 2021 IRP, this is also referred to as a resource's "peak capacity credit."

net load (load minus renewables) have higher ELCCs and contribute more to the portfolio than resources that are primarily available during periods with lower loads. In systems that primarily need energy, resources with short durations, like battery storage, will tend to have lower ELCCs than resources that can provide energy to the system over several hours. In contrast, in systems with shorter duration resource adequacy challenges, shorter duration solutions, like battery storage, may yield ELCCs on par with longer duration resources.

When a system has a resource adequacy need (a capacity shortage and/or an energy shortage), portfolio optimization models will generally select resources with higher ELCCs before resources with lower ELCCs, all else equal, in order to achieve resource adequacy at lowest cost. Other factors that influence which resources are selected include fixed costs, variable costs, fuel costs, the SCGHG, and wholesale market value.

Q. How does the ELCC of energy storage resources impact the CEIP?

A. The ELCC of an energy storage resource is one factor that affects whether the storage resource is selected in portfolio optimization. It therefore impacts the amount of energy storage included in the CEIP Preferred Portfolio and the No CETA Portfolio, which is used to determine incremental costs.

Q. How does PSE's modeling account for resource ELCCs?

A. In PSE's LTCE model, portfolios must meet all capacity needs and a specified planning reserve margin. Each resource or tranche of resources has an associated amount of capacity that it can contribute to meeting that constraint. The amount of capacity that a resource can provide is equal to the installed capacity multiplied by the resource's ELCC.

The LTCE model takes this information into account and seeks to meet the capacity and planning reserve margin constraint, along with all other constraints, at least cost.

Q. How do the energy storage ELCC values used to determine the portfolios in PSE's CEIP compare to the energy storage ELCC values used in planning by other utilities in the Pacific Northwest?

A. PSE used the energy storage ELCC values from the 2021 IRP in the CEIP. I compared the 4-hour energy storage ELCC values in PSE's 2021 IRP to 4-hour energy storage ELCC values in other recent resource plans from Northwest utilities. Results are shown in Table 5.

Table 5. 4-hour storage ELCC values from recent resource planning studies by NW utilities

Utility plan/source	MW (if provided)	4-hr storage ELCC
Northwestern Energy 2020 ELCC Study[16]	100	100%
PacifiCorp 2021 IRP[17] (winter value)		90%
PacifiCorp 2021 IRP[18] (summer value)		74%
Idaho Power 2021 IRP[19]		87.5%
Portland General Electric 2019 IRP Update[20]	100	84.0%
PSE 2021 IRP[21] (Lithium Ion Batteries)	100	24.8%
Avista 2021 Electric IRP[22]		15%

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[16] *See* https://www.northwesternenergy.com/docs/default-source/default-document-library/about-us/regulatory/2019-plan/appendix-1---elcc-study.pdf at 18.

[17] *See* https://www.pacificorp.com/content/dam/pcorp/documents/en/pacificorp/energy/integrated-resource-plan/2021-irp/Volume%20II%20-%209.15.2021%20Final.pdf at 220.

[18] *Id.*

[19] *See* https://docs.idahopower.com/pdfs/AboutUs/PlanningforFuture/irp/2021/2021_IRP_AppC_Technical%20Report_WEB.pdf at 99.

[20] *See* https://edocs.puc.state.or.us/efdocs/HAH/lc73hah13049.pdf at 63.

[21] Figure 7-19, PSE's 2021 IRP at 7-31.

[22] *See* https://www.myavista.com/-/media/myavista/content-documents/about-us/our-company/irp-documents/2021-electric-irp-w-cover-updated.pdf at 9-28.

PSE's ELCC value for 4-hour energy storage (24.8%) is among the lowest among utility plans that I reviewed. Most of the plans incorporated ELCC values for 4-hour energy storage of at least 70% and only Avista had a lower ELCC value for 4-hour energy storage than PSE.

Q. Has PSE investigated potential methodological reasons for the Company's relatively low ELCC values for energy storage?

A. Yes. PSE retained Energy and Environmental Economics, Inc. ("E3") to review their ELCC methodology and consider potential implications for the ELCC of energy storage in the context of the Company's Request for Proposals in 2021. E3's findings were presented at a public workshop (Exh. EKH-7) and were described in a public report (Exh. EKH-8). E3 identified several methodological updates that PSE could make to improve their ELCC analysis. In particular, the workshop presentation highlighted opportunities to update PSE's treatment of Mid-C market availability and generic battery storage characteristics and noted that these could have a high impact on ELCC (*see* Exh. EKH-7, slide 15).

Q. Has PSE updated their ELCC methodologies since filing the CEIP?

A. Yes. PSE presented updated ELCC analysis for the 2023 IRP at the August 24, 2022 Resource Adequacy Information Session. PSE's presentation (*see* Exh. EKH-9) notes several methodological updates to the Company's ELCC analysis, including five that were recommended in E3's ELCC methodology review (*see* slide 54 in Exh. EKH-9).

Q. Have PSE's ELCC methodological updates materially impacted the ELCC of energy storage?

A. Yes. Table 6, which presents information from slide 61 in Exh. EKH-9, shows how PSE's methodological updates for the 2023 IRP impacted the ELCC of energy storage resources, relative to the 2021 IRP.

Table 6. Energy storage ELCC values calculated for PSE's 2023 IRP, compared to the 2021 IRP. Source: PSE's Aug. 24, 2022 Resource Adequacy Information Session, slide 61 (included as Exh. EKH-9)

Resource	2021 IRP (annual)	2023 IRP (winter)	2023 IRP (summer)
Li-ion Battery (2-hour)	12%	84%	88%
Li-ion Battery (4-hour)	25%	96%	95%
Li-ion Battery (6-hour)	N/A	98%	98%
Pumped Storage (8-hour)	37%	99%	99%

The methodological updates for the 2023 IRP significantly increase the ELCCs of energy storage resources relative to those used in the 2021 IRP and 2021 CEIP. A 2-hour battery using the updated methodology provides about 7 times as much capacity to the portfolio as it would have in the CEIP and a 4-hour battery provides about 3 to 4 times as much capacity as it would have in the CEIP.

Q. How do PSE's updated ELCC values affect resource economics for energy storage?

A. PSE's updated ELCC values significantly impact the resource economics of energy storage relative to the analysis in PSE's IRP and CEIP. To investigate the resource economics of energy storage relative to other options for providing capacity, I used information from the 2021 IRP to estimate the net cost of providing 1 kW of reliable capacity from a 2-hour Li-Ion Battery, a 4-hour Li-Ion Battery, and gas peaking plant ("gas peaker" or "Frame CT"). I estimated the net cost of providing 1 kW of reliable capacity by dividing each resource's net cost (total fixed and operating cost plus the

SCGHG, minus its market value) by its ELCC. I compared the results when using the ELCC values from the 2021 IRP to those using the updated ELCC values.

In general, resources that can provide 1 kW of reliable capacity at a lower net cost are more cost effective for meeting resource adequacy needs than resources that provide 1 kW of reliable capacity at higher net costs. And I would expect that a resource with a lower net cost of providing reliable capacity would be selected in portfolio optimization before and in greater amounts than a resource with a higher net cost of providing reliable capacity. These values therefore provide a sense of whether these resources might be selected in portfolio optimization, relative to one another. The results are summarized in Table 7 and the calculations can be found in Exh. EKH-10.[23]

Table 7. Estimated net cost of reliable capacity from storage resources compared to a gas peaker in the 2021 IRP with different ELCC assumptions

Resource	2021 IRP (2020$/kW-yr)	2021 IRP cost and performance with 2023 IRP updated ELCCs (2020$/kW-yr)[24]
Li-ion Battery (2-hour)	$261	$38
Li-ion Battery (4-hour)	$412	$107
Gas Peaker (Frame CT)	$98	$101

My calculations indicate that with updated ELCC values, 2-hour Li-ion batteries would be more cost effective than gas peakers to meet resource adequacy needs, all else equal, and that 4-hour Li-ion batteries would be only slightly more costly than gas peakers, even with conservative cost and performance assumptions. Furthermore, because

[23] Note that the data provided by PSE in the 2021 IRP did not include dispatch results for a 4-hour Li-Ion Battery added in 2026, so I conservatively estimated the 4-hour Lithium Ion Battery net costs based on the cost and performance of the 2-hour Lithium Ion Battery. I assumed that the 4-hour battery would cost twice as much as a 2-hour battery and would provide the same market revenues as a 2-hour battery.

[24] These values represent the average of the summer and winter values.

gas peakers are added to PSE's portfolio in large increments (237 MW) and batteries are added in small increments (25 MW), I would expect 4-hour batteries to be selected before gas peakers for incremental capacity needs that are smaller than about 230 MW if PSE used the updated ELCCs.

In contrast, my calculations suggest that gas peakers appeared to be more cost effective than batteries in the near term in PSE's IRP and CEIP, which both used the ELCC values from the 2021 IRP. This is consistent with the relatively limited role of battery storage relative to gas plants in the near term in PSE's IRP and CEIP.

Q. How might PSE's updated ELCC values affect the CEIP?

A. Because the energy storage ELCC values from the 2021 IRP are so much lower than the updated ELCC values, the CEIP may underestimate the optimal amount of energy storage to acquire and overestimate the need for new fossil fuel resources. If PSE were to update the ELCC values in the LTCE model, I expect that CEIP Preferred Portfolio and the No CETA Portfolio would select more energy storage resources and fewer gas peakers to meet capacity needs. These changes could result in higher energy storage acquisition targets and lower incremental costs.

Q. What changes should the UTC require as conditions of approval of PSE's CEIP to ensure that PSE's decisions account for the capacity contributions of energy storage?

A. I recommend that PSE be required to incorporate their most recent energy storage ELCC values in re-optimizing the CEIP Preferred Portfolio and the No CETA Portfolio, which is used to calculate incremental costs, in order to better account for the value that energy storage brings to their portfolio. Based on these updated optimal portfolios, I recommend that PSE be required to recalculate acquisition targets for energy storage and to recalculate CETA incremental costs.

CONCLUSION

Q. Please summarize your recommendations.

A. I recommend that PSE be required to re-optimize the CEIP Preferred Portfolio and the No CETA Portfolio, which is used to determine CETA incremental costs, as a condition for approval of the 2021 CEIP. In re-optimizing these portfolios, I recommend that PSE be required to directly apply the SCGHG to fossil fuel dispatch within the portfolio optimization model, rather than estimating the SCGHG associated with fossil fuel resources based on fixed cost adders, in order to account for the full value of avoiding GHG emissions with clean energy resources. I also recommend that PSE be required to incorporate their most recent energy storage ELCC values into these updated portfolio optimization runs to better account for the value that energy storage brings to their portfolio. Based on these updated optimal portfolios, I recommend that PSE be required to recalculate acquisition targets for renewable resources, energy efficiency, demand response, and energy storage and to recalculate the associated incremental costs.

Q. Does this conclude your testimony?

A. Yes, it does.