ENERGY STRATEGIES

Analyzing the Cost of Small Modular Reactors and Alternative Power Portfolios

Prepared for

Healthy Environment Alliance of Utah

May 2019

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EXECUTIVE SUMMARY

Utah Associated Municipal Power Systems (UAMPS) members are considering the purchase of a portion of a 600 MW small modular reactor (SMR) power generation facility under development by NuScale Power at the Idaho National Laboratory near Idaho Falls, Idaho. The expected commercial operation date of the project is 2026. The Healthy Environment Alliance of Utah commissioned Energy Strategies, LLC (Energy Strategies) to conduct an independent, high-level assessment of the cost competitiveness of delivered power from the SMR plant relative to the costs of power from comparable alternative low- or non-carbon emitting resource portfolios that include wind, solar, and energy storage. The alternative portfolios were constructed in a manner such that they would provide the same energy and capacity value as the SMR resource being considered by UAMPS members.

The primary metric used to compare costs was the levelized cost of energy (LCOE). The LCOE of the SMR project was compared with the total LCOE of the low- or non-carbon emitting alternative portfolios, as well as a natural gas benchmark portfolio. The LCOE metric allows for a consistent comparison of different generation technologies as it accounts for each technology's lifetime, capital cost, operations and maintenance expenses, fuel expenditures (if any), and energy production. In addition to LCOE comparison, the study also presents the 20-year present value cost of each portfolio relative to the SMR project total cost.

Fundamental to the analysis are assumptions on the performance of resources used to develop the alternative portfolios. This analysis relied on publicly-available sources to derive all assumptions and, where possible, utilized sources that were both recent and relevant to the Intermountain West region where the SMRs are being developed. The majority of cost and performance assumptions were based on data from PacifiCorp's 2019 Integrated Resource Plan (IRP) development.

The study considers a number of sensitivities to assess the potential uncertainty of future cost assumptions and environmental policies. These sensitivities include:

- A low-end and high-end range for potential SMR costs, consistent with cost estimates presented by NuScale and UAMPS.
- Lower-bound cost forecasts for renewable energy and battery storage, accounting for deeper cost declines for these technologies.
- Carbon cost impacts on portfolios that contain resources with carbon-emitting technologies (natural gas) or “brown power” market purchases.

The assessment led to a number of findings regarding the relative costs of the SMR projects as well as recommendations for future analysis. The primary findings of the analysis include:

- On a levelized cost basis, the alternative resource portfolios, including those that are emissions-free, were approximately 40% ($24-$28/MWh) less costly than the SMR generation assumed in the Base Case of this study. This means that the SMRs will cost at least $35 million per year more than the alternative portfolios.
- On a present value basis, the alternative portfolios offer between $298 - $355 million in savings compared to the SMR Base Case portfolio. This estimate of present value savings is based on cost differentials starting in 2026 and continuing for 20 years of portfolio operation.
- After considering a $45/MWh low-end LCOE sensitivity for the SMR technology, the study finds that the alternative portfolios are still less expensive than SMRs. The average cost of the alternative portfolios is $40/MWh, which means that the alternative options are more than 10% less expensive than the lower-bound SMR cost estimate. Based on a $90/MWh high-end cost sensitivity for SMR resources, the SMR portfolio is more than twice as expensive as any of the alternative portfolios.
- Deeper capital cost declines for solar, wind, and battery energy storage resources as reported by NREL may reduce the costs of studied portfolios with these resources by 7 – 19%, which further increases the potential for these resources to be more cost-effective than the SMR project.
- After including a carbon allowance price based on the Energy Information Administration’s 2018 Annual Energy Outlook forecast, the SMR Base Case portfolio is slightly more expensive than the natural gas benchmark. Adding a carbon price to the alternative portfolios that include market purchases or gas capacity resources does not significantly change their cost.

1.0 INTRODUCTION

UAMPS is partnering with NuScale Power, Energy Northwest and the U.S. Department of Energy (DOE) to develop a SMR plant at DOE's Idaho National Laboratory using NuScale's new SMR technology. The plant, which will be the first of its kind, includes twelve 50 MW SMR units that combined would create a single 600 MW facility.[1] Thirty UAMPS members have approved Power Sales Contracts to participate in 185 MW of the project, which is referred to as the Carbon Free Power Project. The project is slated to begin construction in 2023 with commercial operation scheduled for 2026. The closest point of interconnection to transmission, PacifiCorp's Antelope substation, is approximately 3.5 miles away from the project site. In addition to the facilities connecting the project to the Antelope substations, transmission planning studies indicate there will likely be a need for additional 345-kV transmission lines beyond the Antelope substation.[2] These additional upgrades will enable the projects' output to flow onto PacifiCorp's transmission system and be delivered to UAMPS members.

At the request of the Healthy Environment Alliance of Utah, Energy Strategies conducted an independent analysis comparing the cost of UAMPS' 185 MW portion of the proposed SMR plant to alternative resource portfolios. Five portfolios were developed, consisting of different combinations of market purchases, natural gas-fired generation, and/or non-carbon emitting wind, solar, and energy storage technologies. A sixth portfolio consisting of a natural gas-fired combined-cycle combustion turbine (CCCT) was considered as a benchmark portfolio. Each alternative resource portfolio was designed to have equivalent energy and capacity values as

[1] Note that the UAMPS website and initial documentation describe the project as a 600 MW design (twelve units at 50 MW each); however, a presentation made by Chris Colbert, Chief Strategy Officer at NuScale, on April 18, 2019, at the Committee on Regional Electric Power Cooperation meeting, indicated that each SMR unit produces "up to 60 MW equivalent." To maintain consistency with posted UAMPS and PacifiCorp IRP assumptions, this study assumes a project size of 600 MW with each unit's nameplate capacity at 50 MW. It is unknown if the ultimate project size will have any impact on the total number of MW allocated to UAMPS. We do not believe this information materially impacts this analysis.

[2] These studies include those performed by Northern Tier Transmission Group, which identifies the Antelope Project as being needed for "Nuclear Resource Integration" in its 2018-19 draft Regional Transmission Plan published on December 28, 2018.

UAMPS' 185 MW SMR allocation. The study assumes that all portfolios begin providing energy and capacity at the beginning of 2026.

Two cost metrics were used to compare the cost of the portfolios: the LCOE in dollars per MWh and the 20-year present value of the portfolio cost, both reported in 2019 dollars.[3] The study included sensitivities considering how the LCOE of each resource portfolio might change based on potential future carbon regulations and different costs assumptions for SMR, wind, solar and battery energy storage system (BESS) technologies.

This study provides an independent, high-level investigation into the cost competitiveness of power from the SMR plant relative to the costs of power from alternative low- or non-carbon emitting resource portfolios likely to be available to UAMPS members in the 2026 timeframe. Energy Strategies does not take a position regarding UAMPS member's resource decisions nor does it advocate for or against any of the portfolios evaluated in this analysis. Rather, the findings are intended to be viewed as indicative of the relative economics of several resource portfolios that may be available to UAMPS members and to contribute to an informed conversation on the economics of SMR technology compared to other available resource options.

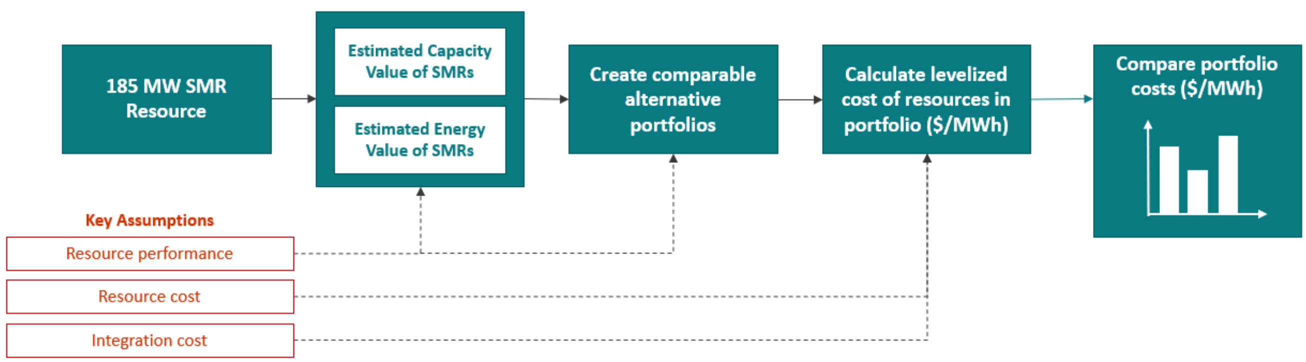
The following sections describe the assumptions and methods used to develop the portfolios and analyze their costs. The bulk of the report is focused on the portfolios, their costs, and sensitivities that may impact the total cost of the portfolios. While not a focus on this study, the report does include a high-level discussion of interconnection and transmission cost implications for the various portfolios. Finally, the report concludes with a summary of technical findings and areas to consider for additional analysis.

[3] Unless otherwise stated, all dollar values in this report are in 2019 dollars. An approximate 2% inflation rate was also assumed in this analysis.

2.0 ASSUMPTIONS AND ANALYTICAL METHOD

The study is based around a "Base Case" portfolio of SMR resources, five alternative portfolios with various low- or non-carbon emitting resources, as well as a natural gas benchmark portfolio. To develop the portfolios, the first step was to calculate the energy and capacity value of the Base Case SMR portfolio. Each alternative portfolio was created to have similar energy and capacity values as the SMR portfolio. This ensures that all portfolios provide the same energy and expected ability to serve system peak demand. Finally, the levelized and present value cost of each portfolio was calculated and compared. A summary of this study methodology is depicted in **Figure 1**.

Figure 1: SMR and Alternative Power Study Methodology



2.1 Resource Performance Assumptions

Performance assumptions, including energy and capacity values for the gas-fired, wind, solar, standalone BESS and hybrid (i.e., solar plus BESS and wind plus BESS), resources were derived primarily from PacifiCorp's 2019 IRP Supply Side Assumptions and are summarized in **Table 1**.[4] Capacity value (or "capacity credit") represents the percentage of a generators' capacity that

[4] See PacifiCorp IRP public presentation, dated November 1, 2018, "2019 Supply Side Table": http://www.pacificorp.com/content/dam/pacificorp/doc/Energy_Sources/Integrated_Resource_Plan/2019_IRP/Table_6.1-6.3-TRC_for_Supply-Side_Resource_Options_19_IRP_for_PDF.pdf

can be relied on meet system peak demands. The capacity factor, which represents energy output, is the ratio of annual energy expected to be produced by a facility as compared with the facility running at its maximum nameplate capability for the entire year.

The study focused on performance parameters reported for solar resources located near Milford, Utah, wind resources located in Wyoming, and market purchases made at Four Corners. BESS was assumed to be a lithium-ion four-hour capacity resource and the gas-fired resources were assumed to be a simple cycle combustion turbine (SCCT) in the alternative portfolio and a CCCT in the natural gas benchmark portfolio.

Table 1: Energy and Capacity Value Assumptions

Resource Type	Capacity Value	Capacity Factor	Data Source/Assumption
SMR	95%	92%	• Capacity value based on assumed summer de-rate and capacity factor based on "The Economics of Small Modular Reactors" by SMR Start (September 2017) • Capacity factor based on "Examination of Federal Financial Assistance in the Renewable Energy Market" prepared by Scully Capital and KutakRock for the DOE Office of Nuclear Energy (October 2018)
CCCT	100%	78%	PacifiCorp 2019 IRP Supply Side Resource Assumptions
Wind	21%	44%	PacifiCorp 2019 IRP Supply Side Resource Assumptions
Solar	54.4%	33%	PacifiCorp 2019 IRP Supply Side Resource Assumptions
Solar + Storage (4-hr)	65%	33%	PacifiCorp 2019 IRP Supply Side Resource Assumptions [5]
Wind + Storage (4-hr)	31%	44%	PacifiCorp 2019 IRP Supply Side Resource Assumptions [6]

[5] Assumed addition of storage results in 10% increase in capacity value
[6] *Id.*

Resource Type	Capacity Value	Capacity Factor	Data Source/Assumption
Storage (4-hr)	85%	0%[7]	Based on NREL Report: The Potential for Energy Storage to Provide Peaking Capacity in California under Increased Penetration of Solar Photovoltaics (March 2018)
SCCT	100%	0%[8]	Capacity value based on WECC *Pro Forma* Capital Cost Model
Market Purchases	100%	100%	Assumes firm capacity contract with 100% availability

The cost of those resources that we assume provide zero energy value (storage and SCCT) is captured in the portfolio LCOE analysis even though those resources are assumed to not produce any energy in the portfolio.

2.2 Additional Assumptions

Additional technical considerations important to the study method are summarized below:

- The 185 MW SMR project is a carbon-free, baseload generation asset that is being proposed to supply a portion of UAMPS members capacity and energy needs beginning in 2026 as a replacement for retiring coal-fired baseload plants currently in UAMPS portfolio. While the SMRs may be able to provide additional grid services, such as certain ancillary services and renewable integration, these operational issues are not considered in this analysis (although incremental integration costs are captured for each portfolio).
- Most data for the analysis was gathered from a single public source: PacifiCorp's 2019 IRP assumptions. The study also included a cost sensitivity to capture the potential for greater than expected declines in renewable energy costs, which are not fully reflected in PacifiCorp's IRP "base case" assumptions.
- LCOE values sourced from PacifiCorp's IRP are assumed to be real dollar values. We also assume that the SMR LCOE estimate is in real dollar terms.

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[7] No energy content assigned – value is entirely capacity driven

[8] *Id.*

- Interconnection costs for the SMR and alternative portfolios are not explicitly included in the analysis, but estimated cost impacts are addressed in **Section 4.0**. The SMR units will likely require the Antelope Transmission Project to interconnect and/or deliver power from the SMR project to UAMPS members. Alternative resources analyzed in this study may also require new transmission upgrades to interconnect, but the specifics of these upgrades would be dependent on the location of each new resource and are not known at this time.
- The study assumes that UAMPS members receive power from the SMR and alternative portfolios through Network Integration Transmission Service (NITS) on PacifiCorp's transmission system and, therefore, transmission service costs are not considered in the analysis since they are assumed to not vary across resource portfolios. However, any network upgrades required to deliver the resources via NITS would be spread across all users of the PacifiCorp system, including UAMPS members, so only very expensive transmission projects would have a material impact on the resource's overall economics. This analysis did not consider these potential costs and we do not provide any conclusions on this basis.

2.3 Portfolio Development

All portfolios analyzed in this study represent alternatives to the proposed Carbon Free Power Project and as such, were designed to match the energy and capacity values of UAMPS' 185 MW SMR plant. The capacity contribution and energy content of the resources in the alternative portfolios are detailed below.

Base Case Portfolio – SMR Resources Only

The UAMPS 185 MW SMR plant is the Base Case Portfolio in this analysis. Estimated capacity and energy value of a 185 MW SMR portfolio was developed using resource performance assumptions that have been publicly reported by NuScale and UAMPS. The study assumes a 92% capacity factor and a 95% capacity credit for the SMR facilities. This means that each portfolio was designed to include roughly 1,490,950 MWh and 176 MW of capacity value because this is the expected output and capacity value of the SMR facility.

Natural Gas Benchmark Portfolio

A natural gas portfolio was developed as a benchmark to compare the cost impact of SMRs verses portfolios based on renewables. The portfolio assumes the performance and cost parameters for a CCCT at 5,050 feet above sea level, consistent with PacifiCorp's 2019 IRP Supply Side Assumptions.[9] We assume a 215 MW portion of a larger CCCT with a capacity credit of 100% and a capacity factor of 78% for this generator that would be co-owned by UAMPS and another utility like PacifiCorp.[10]

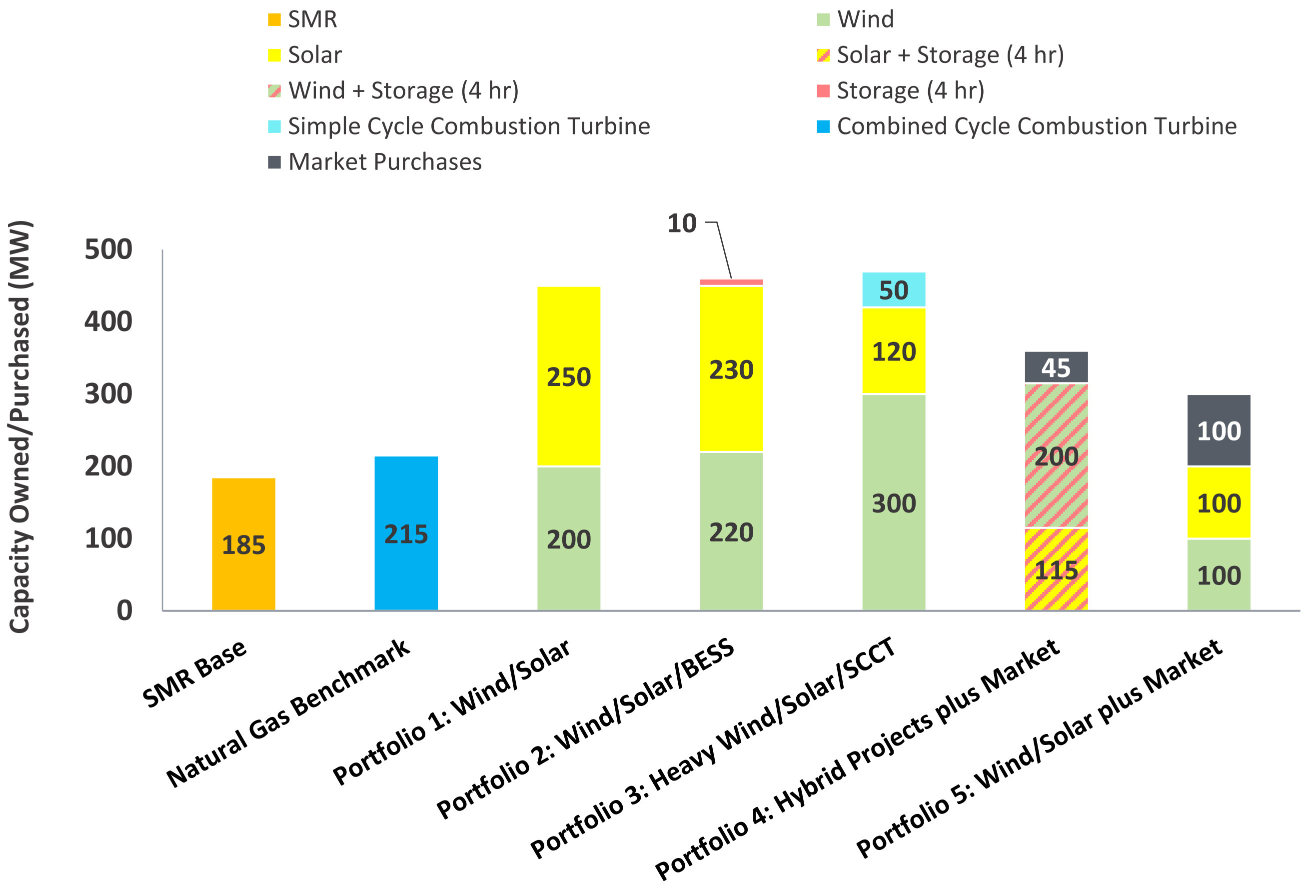
Alternative Portfolios

Five alternative portfolios were developed with total energy and capacity values comparable to that of the SMR Base Case portfolio. The portfolios contained varying levels of renewable and non-renewable resources, as well as capacity-only and energy and capacity resources, including: wind, solar, standalone BESS, and hybrid wind/solar plus BESS, market purchases, and natural gas-fired resources[11].

Figure 2 shows the type and capacity of resources that make up each portfolio in this study.

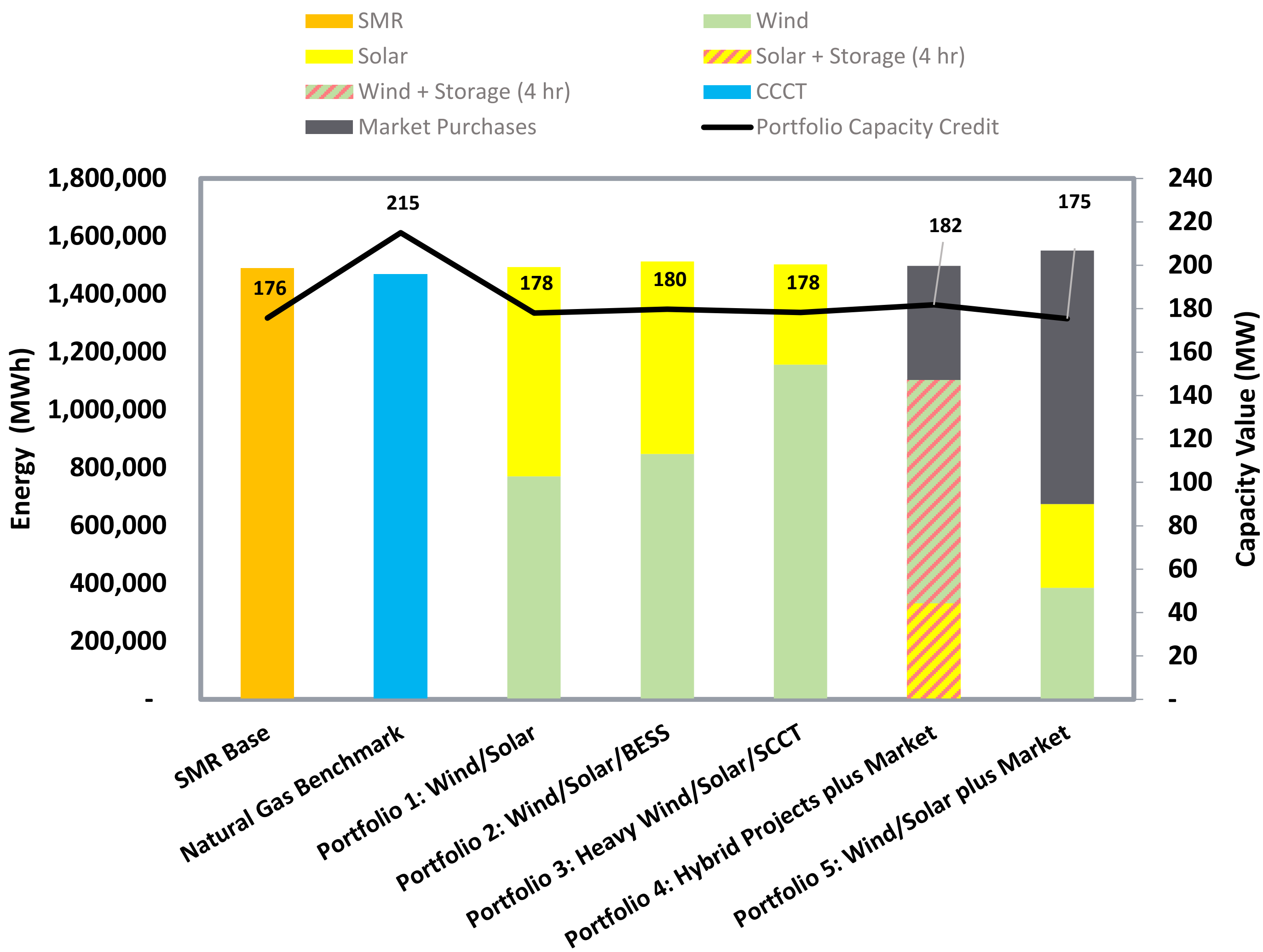
[9] Assumptions are consistent with the "Hunter Brownfield" dry-cooled CCCT 1x1 generator.
[10] PacifiCorp's 2019 IRP Supply Side table identifies a 344 MW CCCT resource at the Hunter brownfield site which forms the basis of our performance and cost assumptions.
[11] Alternative portfolio 3 considered a combination of wind, solar, and SCCT resources.

Figure 2: Portfolio Content by Nameplate Capacity (MW)



The comparable nature of each portfolio on an energy and capacity value basis and the resource composition of portfolios studied is shown in **Figure 3.** The diagram shows how the capacity value (black line) is held constant across the portfolios, while the energy content (bars) are all roughly equal to the energy content of the SMR Base Case portfolio.

Figure 3: Energy and Capacity Value of All Portfolios



Greenhouse Gas Considerations

Portfolios 1 and 2 are completely carbon-free, while alternative portfolio 3 includes SCCT as a capacity resource that would be likely result in minimal greenhouse gas (GHG) emissions (since the unit would not run frequently). Portfolios 4 and 5 include “brown” market power purchases that would create material GHG emissions associated with their energy supply.[12] We estimate

[12] While not considered in this analysis, GHG emissions associated with these portfolios could be offset through the procurement of unbundled renewable energy credits (RECs), emission offsets or other instruments to meet voluntary renewable goals.

the carbon (CO_2) emissions of these portfolios at roughly 170,000 and 375,000 metric tons per year, respectively. The natural gas benchmark portfolio assumes UAMPS members would be part owner of a larger CCCT. Because CCCTs are generally more economic and are often run at a high capacity factor, this study assumes that the CCCT in the natural gas benchmark portfolio is used as both a capacity and energy resource, and therefore, will emit material GHG emissions which we estimate to be slightly more than 500,000 metric tons of CO_2, annually. More detailed analysis of CO_2 emissions and carbon reduction policy should be a consideration for future analysis, but were not a focus in this study.

2.4 Study Considerations

This study takes a simplified approach to provide high-level information about the costs of SMR technology compared with other resource options. As such, there are technical issues not considered in this analysis that are ripe for future consideration, including:

- **Operational analysis** – This study did not evaluate the operational effects or tradeoffs of the different portfolios. Similarly, it did not consider how the portfolios would be integrated into UAMPS members' existing generation fleets.
- **Environmental goals** – This study does not assume that UAMPS members are seeking aggressive reductions in carbon emissions, nor are they seeking a high renewable penetration (such as 80-100% targets set by some municipalities). This is important because if UAMPS members were obligated to such goals and the SMR facilities were being built to achieve them, detailed operational and environmental analysis *of the entire UAMPS portfolio of resources* would be necessary to consider cost and environmental effectiveness of the various portfolios. Since this study is framed as a resource alternative analysis for only the SMR resource, versus a full portfolio analysis, it assumes that UAMPS members retain other contracts and generators to serve the balance of their load and to integrate and balance the portfolios in this analysis.
- **Least-cost solution** – The alternative portfolios were not optimized for least-cost. More work iterating and fine-tuning the portfolios could have resulted in lower cost options.
- **Levelized cost assumptions** – In performing this analysis, we considered developing original LCOE parameters for each resource option, including the SMRs, based on cost assumptions developed by Energy Strategies. However, while this would have improved

consistency among some of the underlying assumptions used by PacifiCorp and UAMPS/NuScale to develop the LCOEs, these benefits were outweighed by the desire to lean heavily on previously published public sources. We used LCOE values as provided by UAMPS, NuScale, PacifiCorp, Lazard and OTC Global adjusting only for capacity factors and inflation, where appropriate, but not for tax treatment or cost of capital.

- **Other grid services** – The study recognizes that the SMR resource may be able to provide additional grid services, such as certain ancillary services and renewable integration; however, these additional benefits are not considered in this analysis. It is also true that, once the resource is built and operational, the SMR facility will likely be more dependable than wind and solar generation as a capacity resource. While the study accounts for this, partially, through reduced capacity credits for wind and solar, it recognizes that as more variable generation is added to the system these capacity values may vary, which could require the addition of more energy storage or a more diverse set of resources than what was considered in this analysis.

3.0 PORTFOLIO COST ANALYSIS

The portfolio cost analysis compared the cost of the proposed 185 MW SMR plant to the costs of alternative resource portfolios and the natural gas benchmark. Two cost metrics were used for this comparison: the LCOE in dollars per MWh, and the 20-year present value of the difference in LCOEs for each resource portfolio. All resources have an assumed in-service date of 2026.

3.1 Levelized Resource Costs

Based on publicly-available materials, we assume a $65/MWh LCOE for the SMR (in 2018$).[13] Except for the BESS resource and market purchases, all other resource cost estimates are sourced from PacifiCorp's 2019 IRP assumptions. Costs assume a 10% investment tax credit

[13] UAMPS Board Presentation: Carbon Free Power Project; Governing Board Approval of Power Sales Contract, January 25, 2018.

(ITC) for solar resources, but no production tax credit value (PTC) for wind resources.[14] A summary of all levelized resource cost assumptions can be found in **Appendix A.**

The BESS levelized cost was derived from Lazard's Levelized Cost of Storage (LCOS) 4.0 report which assumes a $151/kW-year cost for a lithium battery resource in 2020.[15] While the Lazard estimate is about $57/kW-year lower than PacifiCorp's 2019 IRP estimate, this study conservatively assumes Lazard's 2020 installation cost estimate for the 2026 timeframe despite forecasted capital cost declines over that period. To address this, lower BESS resource costs were evaluated as a sensitivity to this study in **Section 3.3**.

Forward market prices are derived from Energy Strategies' long-term production cost modeling forecasts, combined with futures pricing published by OTC Global. Based on this data we assume $43/MWh as an average power price over the 20-year study period starting in 2026.

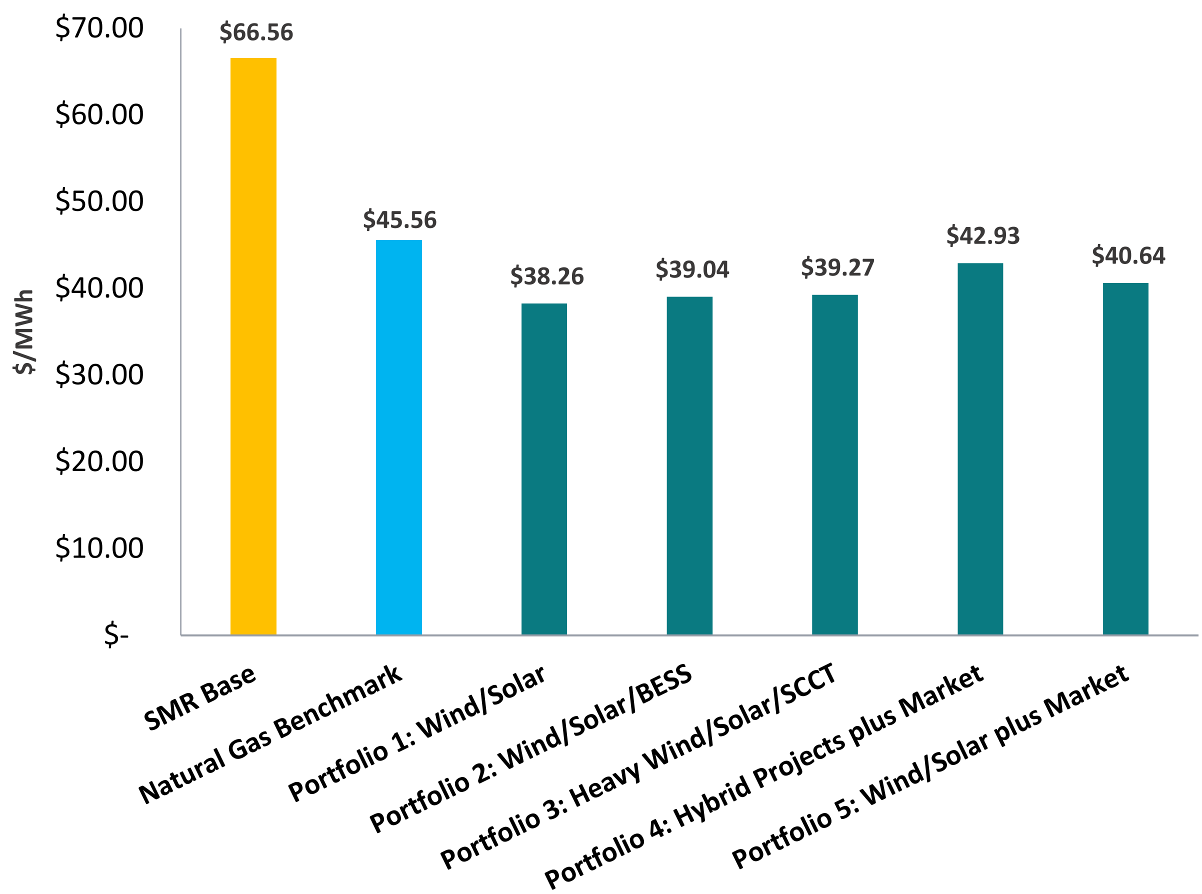
Integration costs are included in the portfolio cost analysis as a means to estimate the balancing area's incremental cost associated with incorporating the resource output into the overall resource mix on a sub-hourly basis. PacifiCorp's Open Access Transmission Tariff, Schedule 3 and 3a: "Regulation and Frequency Response," charges were used to estimate potential integration costs for SMR, wind and solar resources. Wind and solar resources were assumed to be on a "committed scheduling" construct and the SMR resource was assumed to be a non-variable resource. Energy storage and the SCCT were not assigned an integration cost. **Appendix B** contains further documentation on how these costs were derived. Wind and solar have integration costs of $1.69/MWh and $2.26/MWh, respectively, and the SMR integration cost is assumed to be $0.25/MWh. These values are were held constant in real terms throughout the study period (in other words, they are assumed to grow at the same rate as inflation).

[14] Additionally, no ITC value is assumed in this study for BESS, consistent with PacifiCorp's 2019 IRP assumptions.
[15] Lazard LCOS Analysis, Version 4.0, November 2018, available here: https://www.lazard.com/media/450774/lazards-levelized-cost-of-storage-version-40-vfinal.pdf

3.2 Portfolio Cost Analysis

The total portfolio costs on an LCOE basis, excluding the cost of interconnection or transmission, are summarized in **Figure 4**. The SMR Base Case portfolio cost is $67/MWh, while the alternative portfolios range from $38-$43/MWh. The analysis found that the SMR Base Case portfolio's levelized cost per megawatt-hour is $24-$28 higher than each alternative portfolio analyzed. The natural gas benchmark portfolio is $46/MWh, which is slightly higher than the alternative portfolios, but roughly 30% less expensive than the SMR portfolio.

Figure 4: Total Levelized Portfolio Cost ($/MWh)



The present value of each portfolio LCOE represents the total cost of that portfolio. Differences in this present value cost between portfolios represent estimated savings (or costs) between portfolio choices. The present value analysis was performed for 20 years, capturing total costs from 2026-2045. The differences in costs between the SMR Base Case and each portfolio were totaled and then discounted at a real discount rate of 4.91% (equivalent to a nominal discount rate of 6.91%, given this study's assumption of a 2% inflation rate) to calculate the present value of each portfolio. The values were brought back to present value terms (2019) for purposes of reporting costs and savings in this analysis.

The present value savings of the alternative portfolios and natural gas benchmark compared to the SMR Base Case portfolio are summarized in **Table 2**. This analysis conservatively estimates the savings represented by each portfolio over a 20-year span compared to a 185 MW SMR portfolio.[16] The present value analysis could have been extended for a longer period, capturing cost differences up to 40 years or more. However, using the 20-year period was conservative because the SMR LCOEs are "locked in" for 40 years (given that resources relatively longer asset life) while wind, solar, and energy storage resources would need to either be repowered or replaced after 20-30 years (given their relatively shorter asset life). Given that these technologies are declining in costs, not increasing, the LCOE value of the alternative portfolios in year 30 or year 40 would likely be lower than what is captured in year 20 of this analysis.

Table 2: Present Value Savings Relative to SMR Base Case Over 20 Years Starting in 2026 ($M)

Portfolio	Present Value of Savings Relative to SMR Base Case ($M)
Natural Gas Benchmark	$259
Portfolio 1: Wind/Solar	$355
Portfolio 2: Wind/Solar/BESS	$350
Portfolio 3: Heavy Wind/Solar/SCCT	$345
Portfolio 4: Hybrid Projects plus Market	$298
Portfolio 5: Wind/Solar plus Market	$338

The alternative portfolios indicate the greatest amount of potential savings, with alternative portfolio 1 (wind and solar resources only) offering the highest level of savings at $355 million

[16] Individual resources' useful lives vary between 15 and 40 years, however present value savings were calculated over a 20-year timeframe for simplicity.

on a present value basis compared to the SMR Base Case. These results indicate that, even though the alternative portfolios require the installation of additional MWs of resource capacity (185 MW of SMR vs. ~400 MW of wind/solar in Portfolio 1, for example), there are substantial cost savings that can be realized due to the lower per unit cost of wind and solar resources.

3.3 Sensitivities

To test uncertainty surrounding resource costs and future carbon policy, this study considered three sensitivities to explore alternative scenarios: (1) a low-end and high-end SMR cost; (2) lower resource costs for wind, solar and BESS; (3) consideration of a carbon pricing scheme that would impact the price of portfolios containing fossil-generation or brown-power market purchases.

SMR Cost Sensitivity

The NuScale SMR technology has not been demonstrated in a commercial application and there is uncertainty surrounding the actual cost of the future SMR project. An April 18, 2019, presentation by UAMPS and NuScale to the Committee on Regional Electric Power Cooperation stated that the levelized cost of energy for the SMR technology would be between $45-$65/MWh (2018$). PacifiCorp's 2019 IRP's Supply Side Resource Options table lists SMR costs at $94.62/MWh (2018$).[17]

This study assumed the LCOE of the SMR resource built by 2026 would be $66.56/MWh, which is the inflation-adjusted price of the $65/MWh in UAMPS and NuScale published materials. However, the analysis also compared the differences of the alternative portfolio LCOEs to the lower-bound of costs recently presented by UAMPS/NuScale ($45/MWh) and the high-end cost estimate reported in the PacifiCorp 2019 IRP ($94.62/MWh).

[17] The focus of this report is not to advocate for any particular cost assumption for the SMRs. The total cost of the SMR Carbon Free Power Project is inconclusive and will vary based on ultimate project design, completion date, off-taker arrangement, and transmission build-out required to interconnect the projects, among other factors.

The resulting costs for the SMR portfolios are summarized in **Figure 5**. The low-end SMR sensitivity results in an SMR portfolio with an inflation adjusted LCOE of $46/MWh, which is roughly 10% higher than the average cost of the alternative portfolios. The cost of the natural gas benchmark portfolio is on par with this low-end SMR sensitivity.

The high-end SMR sensitivity yields an SMR portfolio cost of $90/MWh which is more than twice the cost of the wind and solar alternative portfolio 1.[18] It is also roughly $45/MWh more expensive than the cost of the natural gas benchmark portfolio.

Figure 5: Levelized Portfolio Cost Sensitivity of SMRs with Low-End and High-End SMR Resource Costs ($/MWh)

Deeper Cost Reductions for Renewables and Energy Storage Sensitivity

While PacifiCorp's 2019 IRP resource cost projections do capture expected cost declines in renewable and energy storage prices, they are "mid" level cost assumptions and, given the extreme historic decreases in capital costs for these technologies, it is prudent to account for a

[18] The PacifiCorp IRP cost was adjusted slightly based on differences in capacity factor assumptions.

future where actual capital costs are lower than current forecasts. Therefore, this study includes a cost sensitivity for wind, solar and battery storage resources to account for potentially deeper cost declines relative to our Base Case cost assumptions. While hybrid wind/solar + BESS projects are also likely to see significant cost reductions in the coming decade, cost declines for these hybrid resources were not included in this sensitivity.

Figure 6 summarizes the impact of deeper cost declines in wind, solar and BESS resources on alternative portfolios 1, 2, 3, and 5, as they all contain these resources. **Table 3** compares these additional cost declines from the reduced resource cost sensitivity versus the base cost estimates which result in portfolio cost reductions ranging from 7% to 19% for those portfolios containing wind, solar or battery storage. The methodology used to determine the assumed resource cost declines is detailed below.

Figure 6: Levelized Portfolio Cost Sensitivity with Reduced Solar, Wind and Storage Costs ($/MWh)

Table 3: Base Resource Costs Compared to Deeper Cost Reductions Sensitivity for Wind, Solar and Battery Storage Resources ($/MWh)

	Base Cost of Portfolio ($/MWh)	Renewable Cost Sensitivity ($/MWh)	% Reduction in Portfolio Cost
SMR Base	$67	--	--
Natural Gas Benchmark	$46	--	--
Portfolio 1	$38	$32	17%
Portfolio 2	$39	$32	18%
Portfolio 3	$39	$32	19%
Portfolio 4	$43	--	--
Portfolio 5	$41	$38	7%

The cost reduction sensitivity assumptions for wind and solar were imputed based on capital expenditure (capex) ranges developed in the National Renewable Energy Lab (NREL) 2018 Annual Technology Baseline (ATB). To estimate a low-cost sensitivity for solar resources, NREL's 2018 ATB mid and low capex projections were compared for a new solar PV tracking resource build in 2026.[19] We calculated a LCOE for solar based on each capex value using the WECC 2017 *pro forma* capital cost model.[20] Based on the NREL ATB data, the low LCOE of a solar resource build in 2026 was 13% less than the mid cost estimate. This gave us a reasonable lower-bound value range, which we applied to the base cost estimate from PacifiCorp's IRP. The analysis results in an assumed lower-bound LCOE for solar of $34/MWh.

A lower-bound wind cost was derived using a similar method. However, since this study's base cost analysis used PacifiCorp's cost for a resource build in 2023, the analysis to derive a cost sensitivity value using NREL ATB data compared the NREL ATB mid cost for a 2023 wind resource against the low cost of a 2026 wind resource.[21] This comparison, which is properly calibrated for a new wind resource in 2026 (capturing 3 years of technology enhancement), results in a low cost sensitivity that is 24% less than our base cost values. Therefore, we assume a lower-bound LCOE for wind of $25.30/MWh.

[19] NREL ATB can be accessed at: http://www.nrel.gov/analysis/data_tech_baseline.html
[20] WECC *Pro Forma* Capital Cost Model can be access at: https://www.wecc.org/Pages/home.aspx
[21] The sensitivity used the "Group 4" resource assumptions for wind, which aligns with wind speeds in Wyoming.

The reduced cost of storage for this sensitivity relied on cost reductions between the 2020 base BESS cost from the Lazard 4.0 report compared to costs projected in a Joule report for a new BESS build in 2026.[22] The Joule report indicated a levelized cost of storage approximately $38/kW-year lower in 2026 than the Lazard 2020 projection, which adjusted for current dollars is $122/kW-year.

Carbon Price Sensitivity

This analysis did not assume a future price on carbon in the Base Case assessment. However, many load-serving entities, including PacifiCorp, consider a future carbon price in their resource planning processes as a way to capture risk associated with potential regulation. Accordingly, this study includes a sensitivity on a future carbon price utilizing the "$15 carbon allowance fee" forecast from the U.S. Energy Information Administration's Annual Energy Outlook (AEO) for 2018, which was surveyed as a medium carbon price sensitivity in PacifiCorp's 2019 IRP process.[23]

Figure 7 summarizes the impact of a carbon price on the natural gas benchmark portfolio and alternative portfolios 4 and 5.[24] The natural gas benchmark is comprised of a single CCCT, which was assumed to emit carbon emissions at a rate based on PacifiCorp's 2019 IRP assumptions.[25] Alternative portfolios 4 and 5 contain market purchases, for which an average carbon emissions rate was assigned based on rate the California Air Resources Board (CARB) applies to all WECC-wide unspecified power.[26]

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[22] See Joule Report dated January 2019:
https://www.sciencedirect.com/science/article/pii/S254243511830583X#appsec1

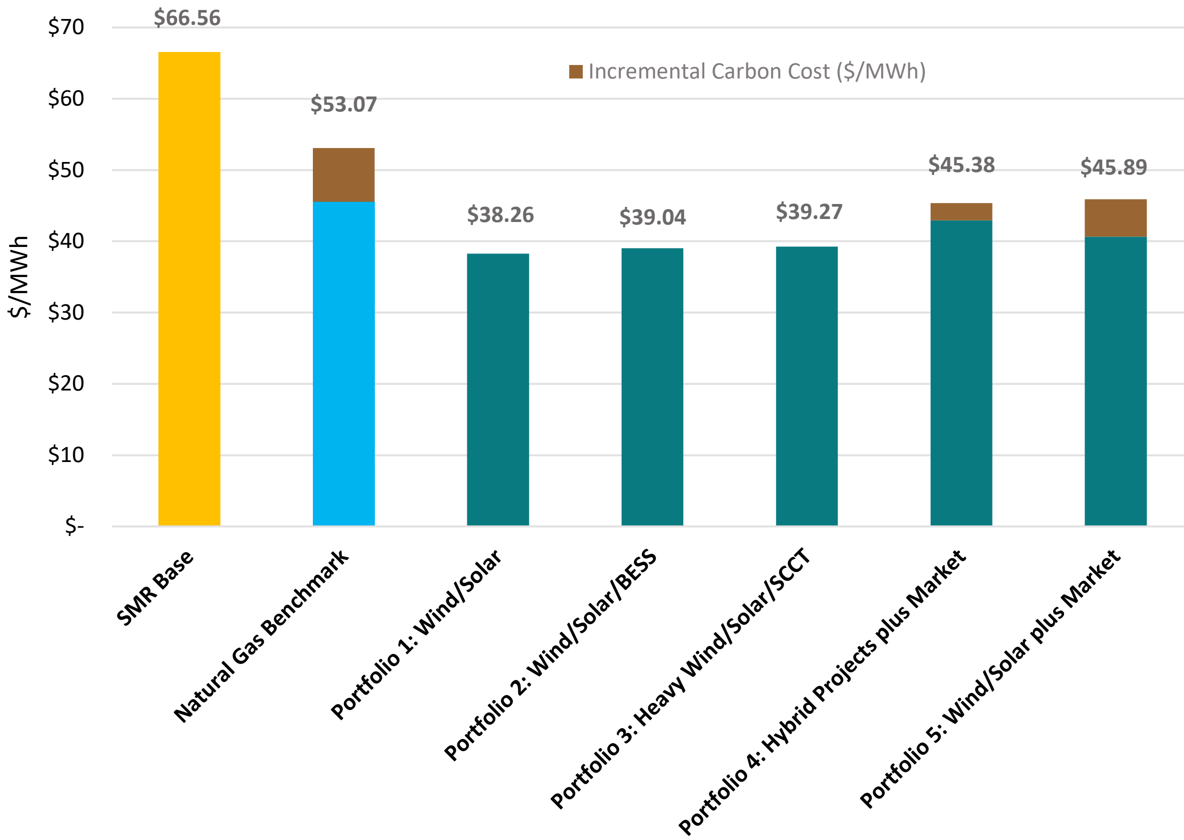
[23] See PacifiCorp 2019 IRP presentation dated September 27-28, 2018:
http://www.pacificorp.com/content/dam/pacificorp/doc/Energy_Sources/Integrated_Resource_Plan/2019_IRP/PacifiCorp_2019_IRP_September_27-28_2018_Public_Input_Meeting.pdf

[24] While alternative portfolio 3 contains a 50 MW SCCT resource, it is assumed as a capacity-driven resource that will contribute *de minimis* CO_2 emissions.

[25] PacifiCorp 2019 IRP Supply Side Assumptions for natural gas, CCCT Dry "G/H", DF, 1x1 is 117 lbs/MMBTU

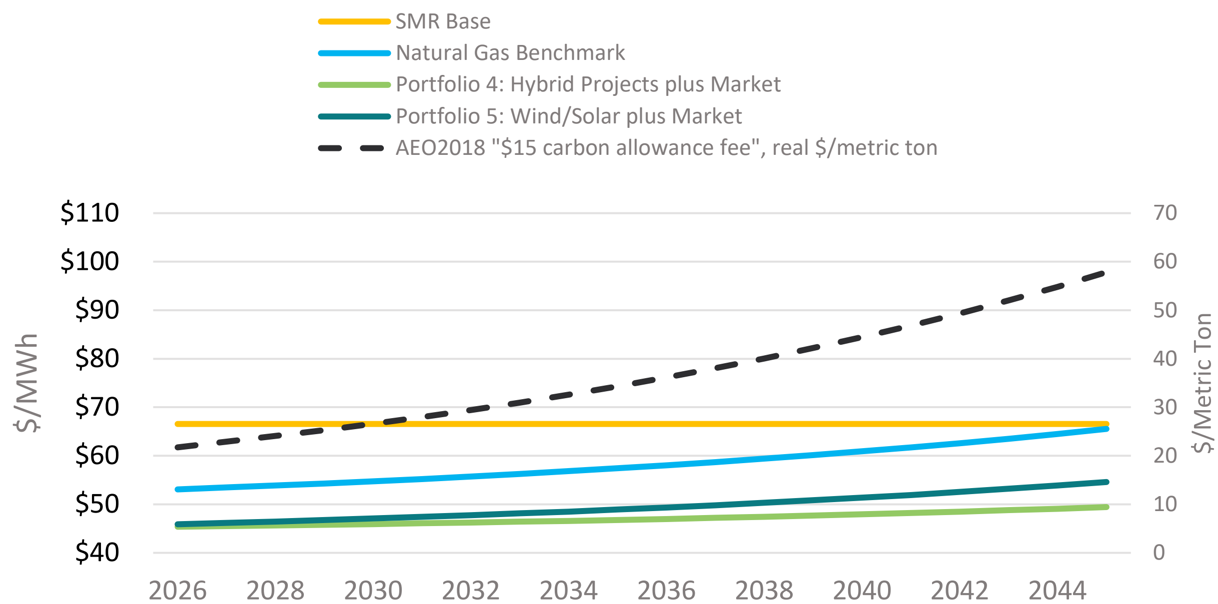
[26] CARB unspecified emissions factor is 0.427 Metric Tons/MWh,
https://efiling.energy.ca.gov/getdocument.aspx?tn=226392

Figure 7: Levelized Portfolio Cost Sensitivity with AEO 2018 "$15 Carbon Allowance Price" ($/MWh)



Over a 20-year time horizon, annual carbon cost impacts on each portfolio will increase at different rates depending on their respective carbon emissions rates. The incremental cost for the natural gas benchmark portfolio, portfolio 4, and portfolio 5 through 2045 is summarized in **Figure 8**. Relative to the SMR Base Case portfolio, the natural gas benchmark is projected to become more expensive shortly after 2045 (in real terms). However, even with the incremental carbon cost associated with market purchases in portfolios 4 and 5, these portfolios costs are still significantly lower than the SMR Base Case at the end of the 20-year time horizon that starts in 2026 on a levelized basis. Given that these portfolios have relatively low carbon intensity, including carbon costs using a medium price assumption does not significantly change the economic efficiency of these options compared with SMR resources.

Figure 8: Portfolio Cost for Carbon-Emitting Portfolios with a Carbon Price Compared to SMR Base ($/MWh) and Carbon Allowance Price ($/Metric Ton)



4.0 INTERCONNECTION AND TRANSMISSION COSTS

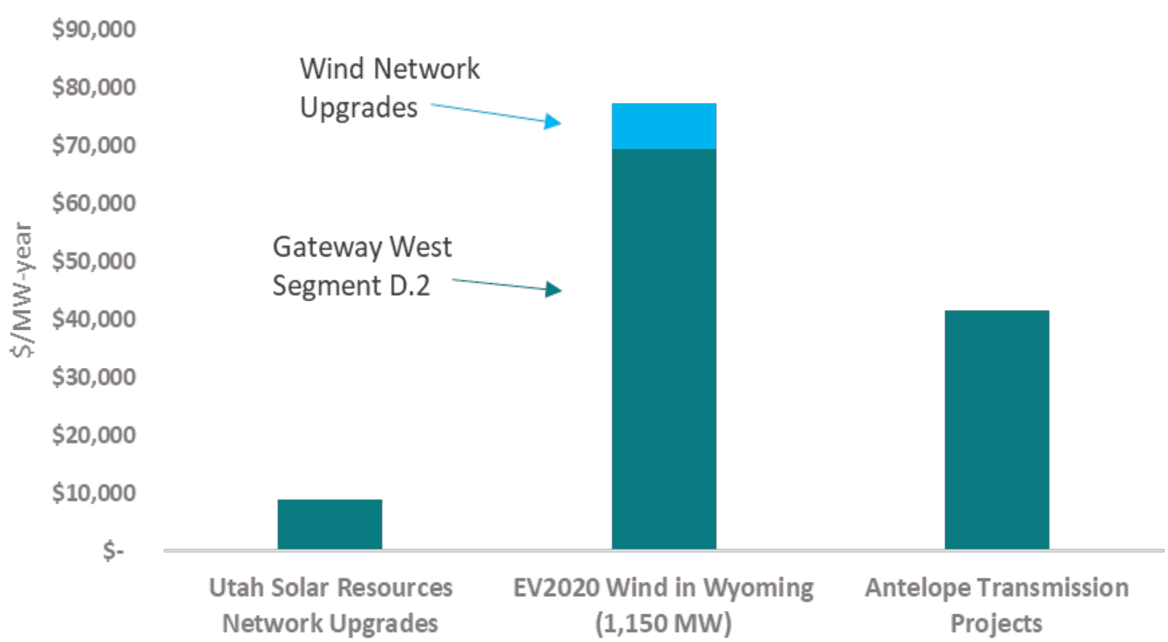
Interconnection costs were not considered in the cost analysis portion of the study. However, PacifiCorp's transmission customers, which include UAMPS, Rocky Mountain Power, and others, will ultimately pay the costs for network transmission upgrades required to connect or deliver new generation to the grid. Therefore, this study included an informational, high-level estimate of interconnection costs based on publicly-available data.

Figure 9 summarizes the broad comparison of levelized interconnection costs between the Antelope Transmission Projects, Utah solar, and Energy Vision 2020 (EV2020) Wyoming wind resources. The EV2020 projects are part of PacifiCorp's $3.1 billion investment plan for new wind and transmission in Wyoming.

Studies performed by PacifiCorp and Northern Tier Transmission Group indicate the 345-kV Antelope Transmission Projects are required for the 600 MW SMR interconnection. Because the Antelope Transmission Projects are beyond the point of interconnection of the SMR facility, they will likely be considered a Network Upgrade that all transmission customers will pay for. This study used the WECC *Pro Forma* Transmission Cash Flow model with capital cost input data compiled by Energy Strategies to determine an estimated levelized interconnection and transmission cost for the SMR project.[27] That analysis estimates the Antelope Project cost at $230 million, or $25 million per year for 40-years.

Recent solar projects in Utah have completed interconnection studies that indicate lower network upgrade costs compared to costs required to bring EV2020 wind projects online and costs potentially associated with the SMR interconnection.[28] Network upgrade costs identified in an interconnection study give an indication of the network transmission costs necessary to deliver the resource to load.

Figure 9: Levelized Costs to Interconnect SMR Project, Utah Solar and EV 2020 Wyoming Wind ($/MW-year)



[27] WECC *Pro Forma* Transmission Cash Flow model can be found at: https://www.wecc.org/Pages/home.aspx; This study assumed the Antelope Transmission Project includes 97 miles of 345- kV single circuit lines at $2.11 million per mile (excluding substation costs).

[28] EV2020 transmission costs based on public information from PacifiCorp testimony and estimated Gateway West, Segment D.2 costs of $739 million. Utah solar network upgrade costs based on Energy Strategies' PPA database and research/review of interconnection studies in PacifiCorp's interconnection queue.

5.0 KEY STUDY FINDINGS

The key findings of this study are:

1. **On a levelized cost basis, the alternative resource portfolios, including those that are carbon-free, were at approximately 40% ($24-28/MWh) less than the SMR Base Case portfolio**. Compared with SMR resource, this high-level assessment of resource options indicates that portfolios comprised of wind, solar and BESS (along with market purchases and a small SCCT) represent lower cost options for UAMPS' members meet energy and capacity needs while *incrementally* reducing total GHG emissions.

2. **On a present value basis, the alternative portfolios offer between $298 – $355 million in savings compared to the SMR Base Case portfolio**. The wind and solar only portfolio (alternative portfolio 1) offer the highest potential savings over the 20-year study period starting in 2026. The natural gas benchmark portfolio, without a future carbon price, offers a $259M savings compared to the SMR Base Case portfolio on a present value basis.

3. **Integration costs are not a significant factor in the cost analysis as they add roughly $2/MWh to the cost of the alternative portfolios**. The development of these cost assumptions was very conservative and including them in the cost analysis does not change the conclusion outlined above, which is that portfolios of wind and solar are lower cost compared to the SMR resource option.

4. **Cost sensitivity analyses reveal that the "Base Case" findings discussed above are robust:**
    - **Based on a $45/MWh low-end levelized cost sensitivity for SMR resources, the alternative portfolios are still roughly 10% cheaper than SMRs**. An all-natural gas portfolio is roughly the same price as the SMR assuming this lower-bound SMR cost.
    - **Based on a $90/MWh high-end levelized cost sensitivity for SMR resources, the SMR portfolio is more than twice as expensive as any of the alternative portfolios**, and approximately $45/MWh more costly than the all-natural gas portfolio.

5. **If renewable and storage resources experience deeper capital cost reductions, there may be additional "upside" cost savings associated with the alternative portfolios.** Deeper cost declines for future solar, wind, and BESS resources may further reduce the costs of portfolios with these resources by 7 – 19%. If these lower renewable and storage costs are achieved, the portfolios with these resources may cost less than half as much as the SMR portfolio.

6. **Accounting for a carbon price does not change any of the Base Case findings because (1) the alternative portfolios require no or low carbon-emissions and (2) the natural gas benchmark portfolio is much less costly to begin with, so it has "headroom" to absorb the incremental carbon cost through 2045.**

7. **Although this assessment was designed to be a high-level assessment of costs, additional analysis would help to shed light on several issues, including:**

    - **Portfolio cost-effectiveness in the context of achieving specific emissions reduction goals**. This study did not analyze UAMPS members' entire resource portfolio, nor did it focus on the cost of accomplishing certain clean energy goals, such as 80% or 100% renewables or achieving specific carbon reductions. The study considers the SMR units in isolation and assumes they will continue to be a part of a broader resource mix that includes non-renewable, dispatchable resources. While not considered in this study, other Energy Strategies analyses suggest that the total cost of serving UAMPS entire load with 80-100% wind, solar, energy storage, and balancing with market purchases/sales may cost more than a $65/MWh SMR resource.[29] The cost for a small entity to completely eliminate carbon is an area of ongoing research. This leads to the conclusion that, if UAMPS members adopt aggressive GHG reduction goals or are required to by legislation, and those reduction goals are aggressive (versus incremental or marginal), the analysis of SMR economics relative to other options should be studied under this specific policy context and the results of that analysis may indeed have different conclusions than the resource-to-resource comparison considered in this study.
    - **Accounting for the ancillary benefits offered by SMRs and other portfolios**. Integration benefits of SMRs have not been considered, nor were investment

[29] Wholesale Power Market Analysis for La Plata Electric Association performed by Energy Strategies (April 2019); available: https://www.lpea.com/sites/lpea/files/pdf/board_minutes/2019/EnergyStrategies_WholesaleEnergyMarkets.pdf

risk, among other potential costs and benefits across the portfolios. A more thorough analysis could include a line-by-line accounting of all portfolio costs and benefits.

- **Consideration of transmission upgrade costs required for various portfolios**. The Antelope Transmission Projects represent a significant upgrade, although its costs would eventually be borne by all of PacifiCorp's transmission customers. Regardless, any increase in UAMPS' member transmission rates could be incorporated in the economic analysis of the generation project (as could any transmission rate impact associated with other resources requiring substantial Network Upgrades).
- **Reliability impacts.** While we believe reasonable parameters were used to approximate the capacity credit for renewable resources, additional work could be performed to estimate more granular capacity credit assumptions.
- **Operational modeling.** It would be informative to evaluate the SMR resources and the alternative portfolios as a part of the UAMPS' generation mix through hourly production cost modeling or another analysis method that captures the variable nature of wind and solar generation.

6.0 APPENDICES

Appendix A: Levelized Resource Cost Assumptions, 2019$

Resource Type	Cost	Unit	Source	Notes
SMR	$66.30	$/MWh	UAMPS and NuScale materials	Cost after DOE support funding, cost of capital associated with municipality customers, and tax support including production tax credits (PTCs)
CCCT	$45.56	$/MWh	PacifiCorp 2019 IRP Supply Side Table	Energy and capacity resource
Wind	$33.28	$/MWh	PacifiCorp 2019 IRP Supply Side Table	No PTC
Solar	$39.50	$/MWh	PacifiCorp 2019 IRP Supply Side Table	10% ITC
Solar + Storage (4-hr)	$48.49	$/MWh	PacifiCorp 2019 IRP Supply Side Table	10% ITC for solar only
Wind + Storage (4-hr)	$37.95	$/MWh	PacifiCorp 2019 IRP Supply Side Table	No PTC/ITC
Storage (4-hr)	$160.24	$/kW-year	Lazard LCOS, Version 4.0	No ITC
SCCT	$82.00	$/kW-year	PacifiCorp 2019 IRP Supply Side Table	Capacity resource
Market Purchases	$42.77	$/MWh	Energy Strategies forecast/OTC Global	Used Four Corners as proxy market, 20-year price average

Appendix B: Resource Integration Cost Assumptions

Schedule 3/3a "Regulation and Frequency Response" charges from PacifiCorp's tariff were used to estimate potential integration costs for resources. The costs were developed based on the following assumptions:

- Escalated costs at 3% per year
- Assumed "committed scheduling" construct for all new resources, and assumed the SMR was a non-variable resource and all other non-dispatchable resources were variable resources
- Energy storage and combustion turbines were not assigned an integration cost

Calculated values were checked against integration costs in PacifiCorp's IRP for consistency. Integration costs in PacifiCorp's IRP are all less than $1/MWh, confirming the conservative nature of this estimate

Schedule 3/3a Costs (Committed Scheduling) ($/MW-year)				
		VER		Non-VER
2019	$	5,631	$	1,794
2020	$	5,744	$	1,830
2021	$	5,858	$	1,866
2022	$	5,976	$	1,904
2023	$	6,095	$	1,942
2024	$	6,217	$	1,981
2025	$	6,341	$	2,020
2026	**$**	**6,532**	**$**	**2,081**

Rates escalated in real-terms to anticipate future cost increases

Used to calculate $/MWh costs

Resource Type	Integration Cost ($/MWh)	
SMR	$	0.26
Wind	$	1.69
Solar	$	2.26
Solar + Storage (4-hr)	$	2.26
Wind + Storage (4-hr)	$	1.69
Storage (4-hr)	$	-
CCCT/SCCT	$	-
Market Purchases	$	-

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