Review of the Use of the System Optimizer Model in PacifiCorp's 2015 IRP

Including treatment of the Clean Power Plan and economic coal plant retirement

Prepared for Sierra Club, Western Clean Energy Campaign, Powder River Basin Resource Council, Utah Clean Energy, and Idaho Conservation League

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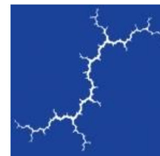

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EXECUTIVE SUMMARY

PacifiCorp utilized the System Optimizer model to conduct least-cost system planning in its 2015 IRP. Synapse reviewed this model, reviewed PacifiCorp's inputs and configuration choices, and conducted several sensitivity scenarios. The intent of these sensitivities was to allow the model to better optimize decisions in the face of planning constraints faced by PacifiCorp, and to demonstrate a more flexible and transparent approach. The Synapse runs considered endogenous retirements, a significant PacifiCorp omission, as well as alternative means of Clean Power Plan (CPP) compliance and renewable cost assumptions.

PacifiCorp chose to hard-code all power plant retirements into the System Optimizer model, based on an *a priori* determination of four Regional Haze compliant scenarios. While this approach ensured the model complied with Regional Haze, it severely limited the flexibility in finding a least-cost plan. The endogenous retirement sensitivity run by Synapse demonstrates clearly that the units chosen by PacifiCorp for retirement under the Preferred Portfolio are not necessarily the most economic units to retire under a more flexible approach. Hunter, Huntington, and Naughton all appeared potential candidates for retirement, but were not explored in PacifiCorp's IRP.

The Synapse team also implemented CPP compliance via a mass-based approach, a more transparent and easily optimized planning process than PacifiCorp's in-house 111(d) compliance tool. The PacifiCorp 111(d) tool required substantial manual manipulation by the IRP team at PacifiCorp, and ignored both the computational capability of the optimization tools built into System Optimizer, and largely discounted the value of using a capacity expansion tool in the first place. When Synapse adjusted the model to allow endogenous retirements, distinctly different trajectories and decisions were selected from PacifiCorp's Preferred Portfolio.

By forcing units to retire based on *a priori* assumptions, PacifiCorp's IRP development process violates basic principles of least-cost resource planning, and takes a major step backwards from progress made by PacifiCorp in its 2013 IRP. By effectively only modeling rate-based compliance with the CPP, PacifiCorp failed to seek a least-cost plan to meet customer requirements and emissions limits.

1. PacifiCorp's Implementation of Clean Power Plan and Coal Retirements in 2015 IRP

1.1 Clean Power Plan Implementation

PacifiCorp's 2015 IRP models a version of the Clean Power Plan (CPP) as proposed by EPA in 2014. Finalized in August 2015, the CPP is EPA's rule to meet CO_2 emissions limitations from existing sources after determining a Best System of Emissions Reductions (BSER). The proposed CPP, upon which the 2015 IRP is ostensibly based, allowed states to meet either mass-based emissions targets (measured in total tons of emissions), or rate-based emissions targets (measured pounds per megawatt-hour). In a rate-based compliance scenario, renewable energy and energy efficiency can "dilute" fossil emissions. PacifiCorp oriented its 2015 IRP around a single interpretation of the proposed CPP, using the dominant compliance mechanism—rate-based compliance for individual states—with the assumption that renewable energy and energy efficiency programs were fully fungible across states. This narrowness of focus left PacifiCorp in the position of structuring many of its assumptions and operational restrictions around this single expectation of the regulation, and does not comport with reasonable least-cost planning in the face of the uncertainty the Company faced at the time.

The proposed CPP set forth two basic routes for reducing state CO_2 emissions from existing sources: states could either meet the rate-based target using a combination of "building blocks"[1] or other programs, or meet an alternate mass-based target, measured in total tons of CO_2. EPA's proposal allowed states to choose the metric by which they measure compliance. The rate-based mechanism is a fairly unique measure of compliance, while the mass-based system is similar to the result of a cap-and-trade scheme, currently employed for national sulfur dioxide (SO_2) emissions under the Acid Rain Program, regionally for nitrogen oxides (NO_X) under a budget trading program, and for CO_2 in California and Regional Greenhouse Gas Initiative (RGGI) states. The rate-based approach, at least as used in EPA's target-setting in the proposed rule, assigned credit for renewable energy and energy efficiency programs implemented by entities in the state. The mass-based approach assigns credit for stack-based emissions reductions.

The rate-based compliance approach is, by all measures, far harder to model when optimizing for least-cost on a net present value basis. The mass-based approach is far simpler. Since at least the mid-1990s with the advent of SO_2 and NO_X trading programs, energy planners have understood that it was appropriate to model mass emissions caps using an opportunity cost for generators, regardless of whether emissions allowances were tradable. Every ton of emissions avoided by reducing generation eases compliance and thus has monetary value. In "hard cap" mass-emissions reduction modeling,

[1] EPA structured the proposed CPP around four fundamental "building blocks" that represented possible means for achieving the established emissions standard: (1) increasing existing coal plant efficiency, (2) displacing coal generation with existing natural gas, (3) increasing renewable energy acquisitions, and (4) implementing energy efficiency programs. Taken together, EPA estimated that these programs would reduce emissions by a certain amount in each state.

emissions have a shadow price—i.e., the cost of incrementally shifting production to lower emissions sources, on a per-ton basis. In a tradable credit program, the emissions have a direct monetary value, but the meaning is the same. In both cases, the cost of emissions is typically considered a variable cost—i.e., higher costs for high emissions resources should result in lower production.[2]

A rate-based trading mechanism is much more difficult to structure in capacity expansion models. Most off-the-shelf dispatch and capacity expansion models have not been structured to support this mechanism. Nonetheless, rate-based compliance is the mechanism that PacifiCorp has chosen to utilize in almost every one of the core cases in the 2015 IRP. PacifiCorp's System Optimizer model is not configured to determine a least-cost plan for rate-based compliance, but it is readily configured to determine a least-cost plan for mass-based compliance.

Out of the 15 "Core Cases" modeled by PacifiCorp, 12 assumed that PacifiCorp would comply on a rate basis. One assumed that PacifiCorp would not need to comply with the CPP at all, and just two assumed that PacifiCorp would comply on a mass basis. These two cases (C12 & C13) restricted the model from retiring coal units as a form of compliance, and thus cannot be representative of a possible least-cost plan to meet emissions targets.

To overcome the barrier that System Optimizer cannot search for a least-cost rate-based compliant plan, PacifiCorp fundamentally misused the model, manually choosing and excluding resources in order to meet targets in different states. PacifiCorp developed its separate in-house "111(d)" tool specifically to develop user-specified portfolios that meet rate-based compliance. This tool required the PacifiCorp IRP team to manually distribute and balance renewable energy and energy efficiency credits amongst states, check for unit operational violations, and choose buildout options manually, rather than allowing the model to choose least-cost options. By developing each individual portfolio manually, PacifiCorp undermined System Optimizer's ability to find least-cost plans. By choosing to model exclusively rate-based compliance, PacifiCorp hedged on one interpretation of EPA's proposed rule, and failed to evaluate if mass-based compliance with economic unit retirement could result in lower cost outcomes.

1.2 Final Clean Power Plan as Compared to Proposal

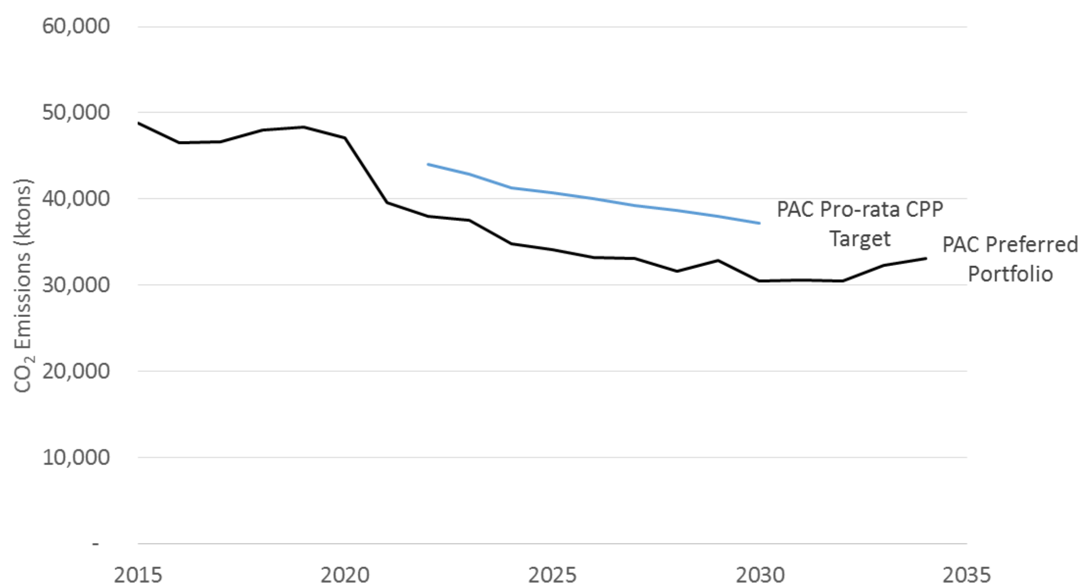
As regularly acknowledged by the PacifiCorp IRP team, during the development of the 2015 IRP, neither the Company nor stakeholders could know the final form of the CPP. As a result, PacifiCorp embarked on an ambitious and challenging plan to model the specifics of the rate-based proposed rule based on state-average emission rates. While this option remains as a compliance pathway in the final rule, the final rule eliminates the eligibility of the vast majority of renewable energy PacifiCorp uses to meet its compliance limitations in the IRP. The final rule also provides additional compliance pathways, including

[2] This mechanism is described in fair detail in a paper from Resources for the Future from 2008: Burtraw, D and D. Evans. 2008. Tradable Rights to Emit Air Pollution. Resources for the Future Discussion Paper. RFF DP 08-08

unit-specific emissions rates, alternative rates based on a weighted average state emission rate, and mass-based targets with and without new source complements (i.e., new fossil units).

While the PacifiCorp Preferred Portfolio appears to be compliant with the final mass-based goals, based on PacifiCorp's pro-rata share of emissions in Arizona, Colorado, Montana, Oregon, Utah, Washington, and Wyoming, (shown in 1.3 Why Mass-Based Compliance and Economic Coal Retirement Matters), it is by no means clear that the plan represents a least-cost pathway towards compliance.

Figure 1: PacifiCorp system-wide CO_2 emissions compared to mass-based target



1.3 Why Mass-Based Compliance and Economic Coal Retirement Matters

PacifiCorp's coal fleet has faced, and continues to face, a variety of new environmental regulations that impose costs and operating restrictions. Since 2008, PacifiCorp has engaged in significant capital and operating expenditures to comply with Regional Haze obligations and the Mercury and Air Toxics Standards (MATS) rule. Going forward, PacifiCorp's coal units will likely see costs for additional Regional Haze obligations, and may see impacts of National Ambient Air Quality Standards (NAAQS), as well as a coal combustion residual (CCR) rule, and CO_2 emissions costs from the Clean Power Plan.

This raises the question of whether PacifiCorp specifically avoided reviewing mass-based compliance and economic unit retirement not because it was too difficult to accomplish or because the model couldn't handle the inputs, but because this modeling would result in numerous coal unit retirements that are not strategically advantageous to PacifiCorp.

Why do economic coal unit retirements matter? Coal comprises about 50 percent of PacifiCorp's owned capacity, and nearly 70 percent of its generation. Even eliminating any new gas builds and taking into

account expected near-term retirements, PacifiCorp has excess energy resources through at least 2024.[3] While the existing fleet remains, the system has very little headroom for new low-emissions, low-cost resources. Unless energy efficiency, renewable energy, and other low emissions resources have the opportunity to compete in a level playing field against PacifiCorp's existing fleet, we cannot know how much of a benefit ratepayers would find in a cleaner fleet.

In a 2011 Wyoming rate case,[4] Powder River Basin Resource Council argued that PacifiCorp had failed to appropriately evaluate if the retirement of Naughton 1 & 2 would be less expensive than installing expensive environmental retrofits at those units. As a result of the settlement emerging from that proceeding, PacifiCorp agreed to evaluate future environmental capital expenditures in litigated dockets. Shortly thereafter, PacifiCorp filed a Certificate for Public Convenience and Necessity (CPCN) for retrofits at Naughton 3. During that proceeding, intervenors discovered errors in PacifiCorp's analyses, and upon revising the model, PacifiCorp discovered that Naughton 3 could not be considered economically beneficial. In mid-2012, PacifiCorp withdrew its application, effectively proving that economic coal retirements mattered in decision-making.

In its 2011 IRP (March 2011), PacifiCorp effectively ignored impending environmental regulations for the purposes of the IRP, assuming that existing coal units would continue operations unabated. This IRP conducted a "proof-of-concept modeling of coal unit replacements,"[5] but disclosed little about the study or its specific results. The study was not used to inform the action plan or concurrent capital expenditures.

Around 2011, Ventyx (now ABB), the model vendor for System Optimizer, upgraded the ability of the capacity expansion model to allow for "endogenous" coal retirements. In other words, the model became capable of choosing if existing thermal units should be operated, retired, or changed (i.e., converted to natural gas), independent of user choice. This capacity had not been used by PacifiCorp in the 2011 IRP, but under regulatory pressure, PacifiCorp expanded the study in the 2011 IRP Update (March 2012) to review investments at Naughton, Jim Bridger, Hunter, Craig, and Hayden.[6] In this study, PacifiCorp reviewed the economics of retiring or retrofitting individual units. In addition, PacifiCorp began testing the model's ability to endogenously retire coal units.

PacifiCorp's IRP methodology peaked in 2013, when PacifiCorp significantly improved its transparency and logic.[7] In that IRP, low gas prices and high CO_2 prices led to the retirement of the vast majority of

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[3] Results from 2015 IRP, Core Case CO5a-3Q. 2015.

[4] 20000-384-ER-10

[5] Termed the "coal plant utilization study." 2011 IRP, p180

[6] 2011 IRP Update, p67.

[7] In the 2013 IRP, PacifiCorp expanded the endogenous retirement capability of System Optimizer. Each unit was allowed to continue operation, or retire or convert to natural gas. The same endogenous retirement capacity was then used by PacifiCorp to examine investments in individual coal units for the purposes of Certificates of Public Convenience and Necessity in Wyoming and Pre-Approvals in Utah.

PacifiCorp's fleet.[8] Stakeholders suggested that, following this IRP, various sensitivities should be evaluated to assess the economic robustness of the fleet. The IRP had raised questions about units that had not previously been considered economically vulnerable.

The 2015 IRP provided an opportunity to refine PacifiCorp's IRP methodology, and start an informed conversation about ratepayer costs and benefits towards transitioning to a cleaner fleet. PacifiCorp found an opportunity in the Clean Power Plan to circumnavigate this conversation and to decide, without explanation, which units they felt should be retired and over what timeframe. PacifiCorp completely eliminated the endogenous retirement capacity of System Optimizer in all but one core case (C14a). In the remainder of the IRP, PacifiCorp instead chooses a "Regional Haze Scenario" in which some units are retrofit and others are converted or retired early. In every case, PacifiCorp simply programs in the retirement schedule, denying the opportunity for the model to choose an optimal path under environmental constraints. This complete turnaround is a shortfall in the 2015 IRP, and represents a significant step backwards by the utility in finding a least-cost plan to meet environmental compliance requirements.

Allowing the model to choose to retire units optimally results in a lower cost plan than when retirements are guessed by planners. PacifiCorp confirms this outcome for the case in which a CO_2 cost is also imposed: "When allowing endogenous coal unit retirements beyond those assumed for Regional Haze scenarios (core case C14a), costs are lower than the C14 portfolios developed with specific timing for assumed coal unit retirements."[9] In the 2015 IRP, PacifiCorp removed the opportunity for ratepayers to evaluate one of the most important elements of their fleet and the singular, key decision of the IRP.

2. OVERVIEW OF SYNAPSE'S ANALYSIS

The Synapse team acquired System Optimizer to explore the impact of correcting the modeling deficiencies in PacifiCorp's IRP. We used the model to begin the process of constructing an optimized long-range resource plan, complete with economic coal unit retirements, mass-based CPP compliance,

[8] From the 2013 IRP, p161: "Building upon modeling techniques developed in the 2011 IRP and 2011 IRP Update, environmental investments required to achieve compliance with known and prospective regulations at existing coal resources have been integrated into the portfolio modeling process for the 2013 IRP. Potential alternatives to environmental investments associated with known and prospective compliance obligations are considered in the development of all resource portfolios. Integrating potential environmental investment decisions into the portfolio development process allows each portfolio to reflect potential early retirement and resource replacement and/or natural gas conversion as alternatives to incremental environmental investment projects on a unit-by-unit basis. This advancement in analytical approach marks a significant evolution of the IRP process as it requires consideration of potential resource contraction while simultaneously analyzing alternative resource expansion plans."

[9] 2015 IRP, p210.

and with lower criteria emissions than the PacifiCorp plan. The assessment built upon the Company's 2015 IRP System Optimizer database with four incremental changes to the model:

- **Mass-Based CPP Approach** via implementation of an annual CO_2 price in $/ton;
- **Endogenous Coal Unit Retirements** by relaxing of constraints imposed by PacifiCorp on the model to prevent units from being retired;
- **Incorporation of Avoidable O&M** where major capital expenditures in the two years prior to retirement were assumed to be avoidable, and deducted from "decommissioning" costs; and
- **Lower Renewable Energy Costs** based on recent cost estimates, in order to test the sensitivity of new build options to costs.

We discuss these incremental changes in further detail below.

2.1 Mass-Based CPP Approach via Carbon Pricing

PacifiCorp's System Optimizer model is not configured to determine a least-cost plan for CPP rate-based compliance. As described above, a mass-based approach would be much simpler to model and fit into the existing construction of the System Optimizer framework without requiring so many opaque steps. A straightforward way to model a mass-based target is via a CO_2 price. The Synapse team used the Synapse Low CO_2 Price forecast—representative of a Clean Power Plan compliance structure that is relatively lenient—to incorporate the CPP compliance requirement in PacifiCorp's long-range resource planning.[10]

Figure 2 shows the Synapse Low CO_2 Price applied: from $16.7/ton in 2020[11] to approximately $41.4/ton in 2035 (nominal dollars). This is in comparison to the default Core 14a case price of $22/ton in 2020 rising to $76/ton by 2034. CO_2 prices in $/ton were modeled as a direct emissions cost at the unit-level, and translated into an equivalent $/MWh adder for market level transactions, including spot purchases and sales, and front office transactions (FOTs).[12]

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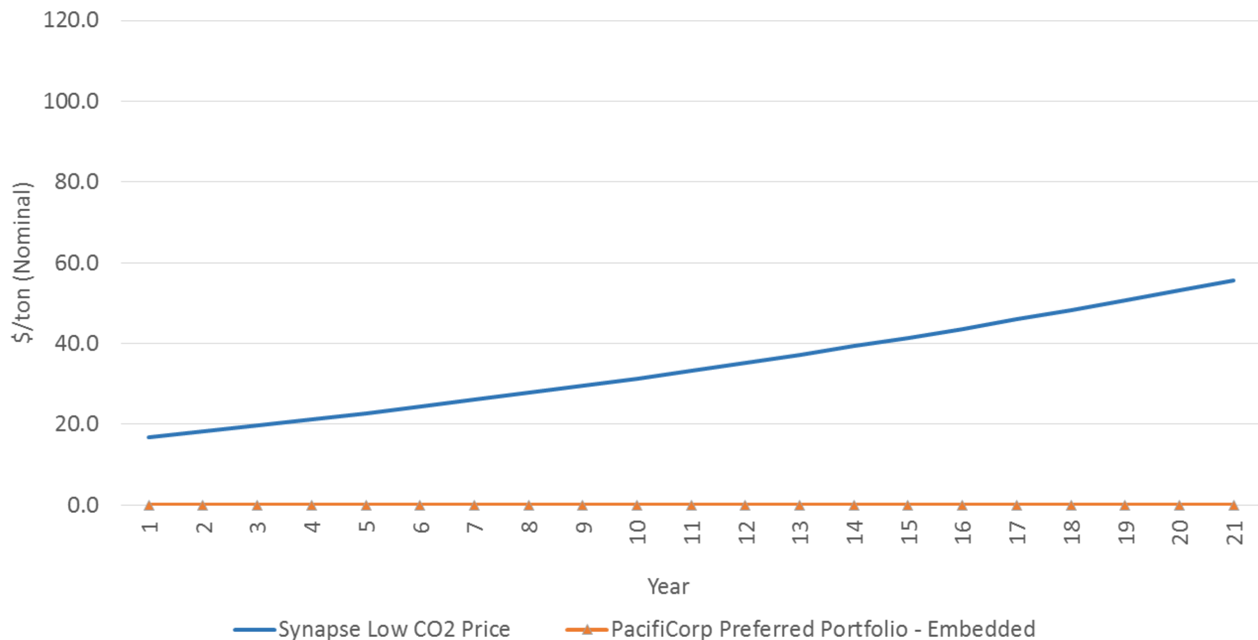
[10] Luckow, P., E. A. Stanton, S. Fields, B. Biewald, S. Jackson, J. Fisher, R. Wilson. 2015. *2015 Carbon Dioxide Price Forecast*. Synapse Energy Economics.

[11] Modeling was performed prior to the release of the final Clean Power Plan rule, which moves compliance requirements to 2022.

[12] We assumed an incremental electricity price ($/MWh) adder to PacifiCorp's Preferred Portfolio market price, based on an implied tons CO_2/MWh from Core Case 14a (a case that *included* a carbon price) and Synapse's Low CO_2 price in $/tons CO_2.

Figure 2. Synapse CO_2 Low Price forecast



2.2 Endogenous Coal Unit Retirement

As noted above, in the 2015 IRP, PacifiCorp also completely eliminated the endogenous retirement capacity of System Optimizer in all but one core case (C14a), in which it allowed five coal units to be endogenously retired.[13] The Synapse team built upon this case, and the straightforward mass-based CPP compliance implementation described above, to enable the model to choose investments and retirements at all plants in 2020 and beyond.

Results for generation capacity and coal unit retirements, summarized below in

Figure 3, show that System Optimizer chooses a drastically different coal unit retirement schedule when allowed to choose retirements based on costs. The effect of allowing System Optimizer to find a least-cost resource plan by *choosing* which units to retire and build rather than *telling* it which units to retire and build, under a straightforward mass-based CPP compliance pathway, retires units earlier—beginning in 2020 with Hayden 1 & 2 and Craig 1, and followed by the retirement of Hunter 1, Naughton 2 and Cholla 4 in 2021, and Hunter 2 in 2022.

This is important because Hunter and Naughton are not identified in any of PacifiCorp's Regional Haze scenarios as potential near-term retirements, yet they are clearly marginal units in this analysis. Hayden,

[13] C14a only allowed Hunter 1 & 3, Bridger 3 & 4, and Wyodak to be retired endogenously.

Craig, and Cholla are all the subject of recent PacifiCorp assessments and are similarly removed from consideration in the Core Cases of the 2015 IRP.

Figure 3. Generation capacity by year: PacifiCorp Preferred Portfolio (top) and Alternative IRP with 1) endogenous retirements and 2) mass-based CPP compliance (low CO_2 price)

Source: Synapse analysis.

2.3 Adjustment to Decommissioning Costs to Capture Avoidable O&M

Sound least-cost utility resource planning should appropriately avoid major capital expenditures immediately before a retirement. The decommissioning costs PacifiCorp included in its 2015 IRP include both the costs to actually retire and dismantle the plant, as well as recovery of any stranded costs incurred during the analysis period. For example, incurring a capital expense in one year entails a de-facto hurdle to retire the next year, because the model assumes that stranded capital investments are moved into a regulatory asset and recovered in full. Aside from the open question of if PacifiCorp can or should assume that stranded costs are recoverable for retiring units (or should be considered a forward-going cost), the assumption makes little sense in context of logical forward planning. In the years leading up to a unit's phase-out, it would not be reasonable to incur many major capital expenditures. Why invest in life extension measures for a unit that has only a few years of life remaining?

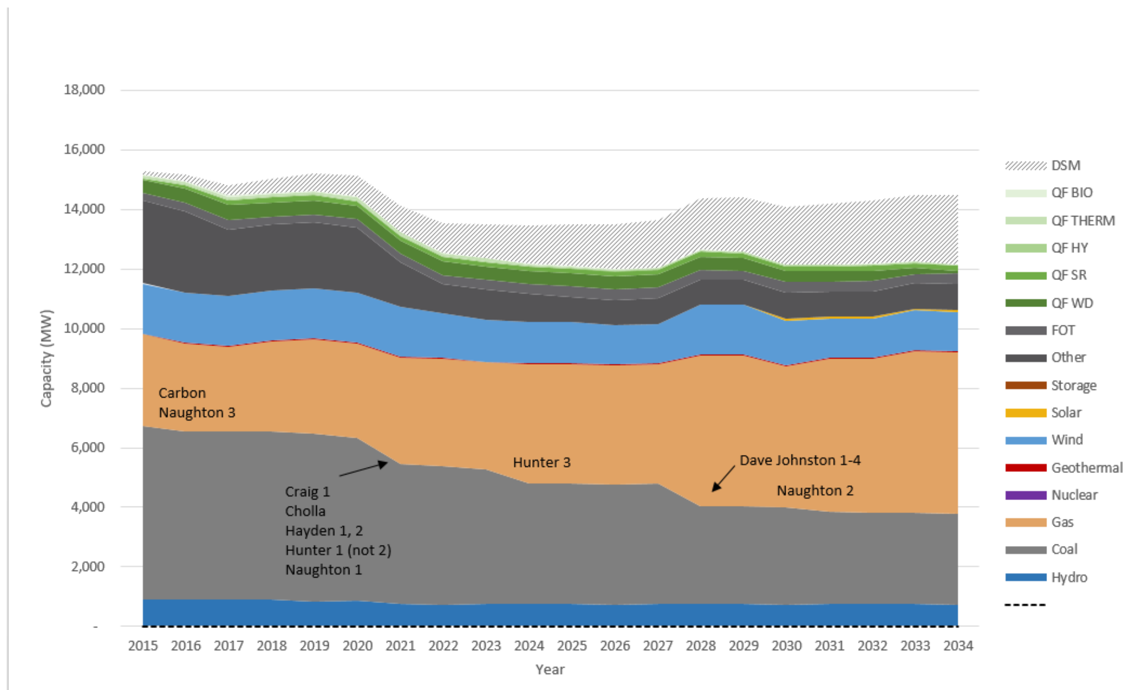
To account for this reality, the Synapse team added a third cost term to the total decommissioning cost of a unit: avoidable fixed O&M and run rate capital. We assume that in the two years prior to a unit going offline, retirement is known and major capital expenditures can be avoided. Ongoing fixed O&M expenses are still incurred (although major outages are avoided), as are known and potential future requirements for SCRs on most units (Synapse's endogenous retirement case assumes Reference Regional Haze assumptions of the IRP).[14]

By adjusting the decommissioning costs in this manner, we continue to assume that PacifiCorp recovers stranded investments in existing units when they retire, but allow unit retirements to be primarily driven by their economics. These units can now be used to contribute towards compliance requirements, if it is least-cost to do so, in a way that is more consistent with the System Optimizer framework than PacifiCorp's in-house tool. We assume the Dave Johnston units 1-4 retire at the end of their book life in this case, as well, to establish consistency with realistic expectations about this plant's operational usefulness in the existing portfolio at 2027. Other units that reach the end of their economic life after 2027 are not forced into retirement.

As shown in Figure 4, below, this adjustment advances the retirement of Hunter 2 by one year, to 2021.

[14] Due to time and expense limitations, Synapse made the simplifying assumption that capital expenditures two years prior to retirement could be avoided, but not expenses in earlier years. A more advanced version of this might include evaluating the merits of specific capital expenditures relative to the timing of the retirement decision.

Figure 4. Generation capacity by year: Alternative IRP with 1) endogenous retirements, 2) mass-based CPP compliance (low CO_2 price), and 3) adjusted decommissioning costs



2.4 Lower Renewable Energy Costs

The capital costs for renewable energy, specifically wind and solar, in PacifiCorp's System Optimizer model are not indicative of commonly held costs for these technologies. PacifiCorp includes a range for new wind builds at $2135-$2188/kW and new solar builds at $2546-$2829/kW (see Table 1). In addition, there is no new wind added to PacifiCorp's system in its 2015 IRP, and very little solar (7 MW in Oregon in 2016). The combination of these two facts calls into question whether new renewable energy is being excluded from the Company's IRP due to its high costs. To test this hypothesis, Synapse modeled alternative capital costs for both new wind and solar technologies, as recommended by Utah Clean Energy (UCE).

Table 1. Alternative wind and solar resource capital

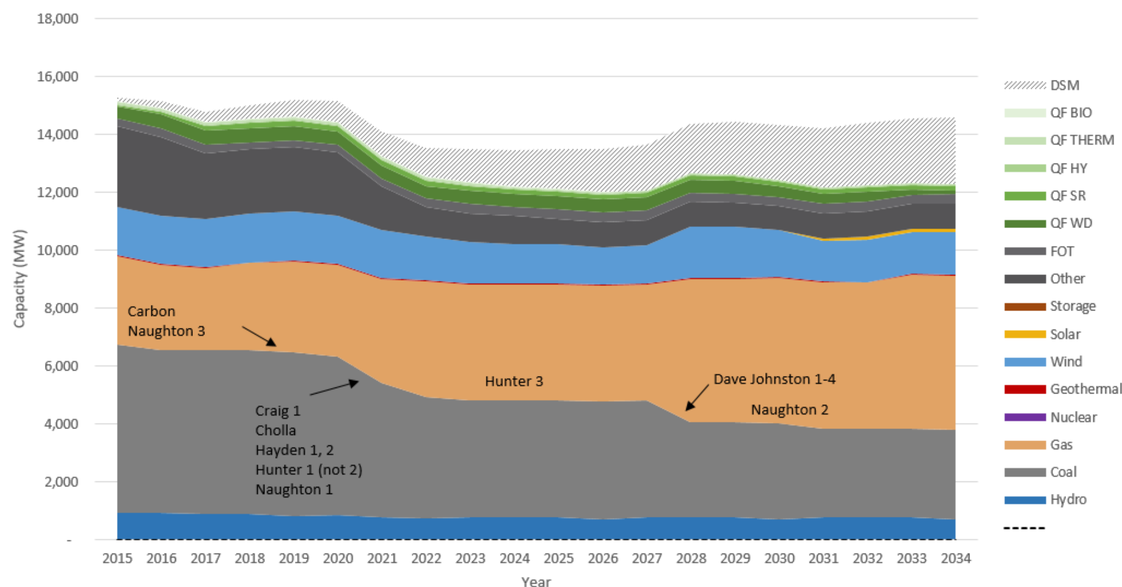
PacifiCorp's (PAC) Resource Assumptions (IRP Table 6.1)	Capacity	PAC's Capital Cost	UCE Recommended Capital Cost [1,2]
Wind			
2.0 MW turbine 29% CF WA/OR	100 MW	$2,135/kW	$1,747/kW
2.0 MW turbine 31% CF UT/ID	100 MW	$2,188/kW	$1,800/kW
2.0 MW turbine 43% CF WY	100 MW	$2,156/kW	$1,768/kW
Solar			
PV Poly-Si Fixed Tilt 26.5% CF	50.4 MW	$2,546/kW	$1,717/kW
PV Poly-Si Single Tracking 31.6% CF	50.4 MW	$2,702.kW	$1,873/kW
PV Poly-Si Fixed Tilt 25.4% CF	50.4 MW	$2,659/kW	$1,830/kW
PV Poly-Si Single Tracking 29.2% CF	50.4 MW	$2,829/kW	$2,000/kW

[1] *Wind values are based on US DOE Wind Vision Report, Chapter 2, pages 12-13, available at: http://www.energy.gov/sites/prod/files/wv_chapter2_wind_power_in_the_united_states.pdf.*
[2] *Solar values are based on IHS Outlook for US Solar PV Capital Costs and Prices, 2014–2030 / October 2014.*

To test the impact of the updated renewable energy costs, Synapse applied the costs provided by UCE as incrementally lower $/kW costs to a modified version of the case described above, with endogenous retirements, mass-based CPP compliance through a low CO_2 price, improved decommissioning costs, and assumed phase-out of the Dave Johnston plant in 2028. Applying the improved renewable energy costs to the previous case with a forced retirement of the Dave Johnston units (1-4) in 2028 was important: new wind farm opportunities are possible and economic at the Dave Johnston brownfield site. The case Synapse models continues to select no new renewable energy until either Dave Johnston retirement is forced or new transmission is added.

Overall, improved renewable energy costs do not untangle the layers of constraints PacifiCorp has included in its application of System Optimizer for its IRP. Even highly economic wind and solar fails to replace even new gas and existing coal (see Figure 5), suggesting that there are additional constraints beyond those identified here. Results show that under the current underlying structure of PacifiCorp's System Optimizer model, Wyoming is represented as highly transmission constrained between all nodes, and from Wyoming to Utah and Idaho. It is unclear if this constraint alone limits new renewable additions.

Figure 5. Generation capacity by year: Alternative IRP with 1) endogenous retirements, 2) mass-based CPP compliance (low CO_2 price), 3) adjusted decommissioning costs, 4) improved wind and solar capital cost assumptions, and 5) forced Dave Johnston 1-4 retirement in 2028



3. Constraints in the System Optimizer Model

System Optimizer is a highly complex modeling structure that allows extensive flexibility, yet also allows layers of constraints to dictate outcomes. PacifiCorp's use of the System Optimizer model layers in multiple overlapping constraints, some of which are not readily apparent. The model generally allows users to modify the model through scenarios, which have a different meaning in the System Optimizer framework than in common IRP parlance. Scenarios in the System Optimizer model are specific tweaks that cover any form of change in the model, from costs to transmission options, buildout constraints, or operational constraints.

To create an IRP scenario (i.e., 5a-3Q, the Preferred Portfolio), PacifiCorp layered nearly 20 scenarios covering transmission changes, market price changes, Regional Haze scenarios, CPP compliance options, system updates, and various other constraints in the system. These scenarios may (and often do) overlap and negate each other, making it difficult to track at any given time the series of constraints that may either prevent or require specific units to be built or retire. For example, PacifiCorp applies a number of "technology groups" to various scenarios, which individually limit cumulative and annual wind and solar buildout. These are overlaid with other scenarios that also limit or eliminate completely buildout options. Scenarios that eliminate or limit transmission are layered with scenarios that change when units are retired, and scenarios that impart (or remove) emissions costs. Ultimately, modifying PacifiCorp's System Optimizer model requires significant knowledge of the model, a detailed mapping of

the scenarios and their meaning, and significant time. It is feasible, or likely, that in our short engagement, we did not find all of the relevant constraints that prevented the System Optimizer model from creating a reasonable buildout.

4. SUMMARY RESULTS

We summarize total costs and emissions for each of the cases explored by Synapse, and compare them to the Company's Preferred Portfolio. In the tables below, the cases are identified as:

A) Endogenous Retirements + Low CO_2 Price (Mass-based CPP Compliance) (**Section 2.2**),

B) Endogenous Retirements + Low CO_2 Price (Mass-based CPP Compliance) + Improved Decommissioning Costs + DJ 1-4 Retires 2028 (**Section 2.3**), and

C) Endogenous Retirements + Low CO_2 Price (Mass-based CPP Compliance) + Improved Decommissioning Costs + DJ 1-4 Retires 2028 + Utah Clean Energy Recommended Renewable Costs (**Section 2.3**).

These cases correspond to the sub-sections in Chapter 2, as noted. All of the cases considered reduced emissions below the PacifiCorp Preferred Portfolio. While CO_2 emissions in the Preferred Portfolio itself are likely compliant with the final Clean Power Plan targets, it is likely that over-compliance will generate credits that could be sold to other parties, within the states in which PacifiCorp operates or beyond. Therefore, the correct CO_2 price is one that correctly represents regional compliance, and not necessarily the one that produces the exact mass reductions required by PacifiCorp alone.

The Synapse team used the Reference Case Regional Haze scenario, a conservative emissions scenario designed to reach compliance with possible Regional Haze requirements, assuming that EPA federal plans are rigorous (i.e., assuming that PacifiCorp does not prevail in litigation loosening the requirements). The resulting state-by-state NOx and SO_2 emissions are well below the Preferred Portfolio, and serve to demonstrate that the Synapse scenarios are also likely to be compliant with Regional Haze requirements.[15]

[15] PacifiCorp did not implement changes in NOx and SO_2 emissions rates associated with the various Regional Haze Scenarios, and thus the SO model does not track NOx and SO_2 emissions correctly. Thus, to generate state-by-state NOx and SO_2 emissions, we mapped unit-specific heat input SO results to unit-specific NOx and SO2 emissions rates from PacifiCorp-provided workpapers.

Table 2. Summary of emissions in PacifiCorp Preferred Portfolio and Synapse cases (2015-2034)

Emissions	PAC Preferred	Case A	Case B	Case C
Total CO_2 (Mt)	878	865	832	826
Total NOx (Kt)	551	552	515	514
Total SO_2 (Kt)	546	500	491	486

In reporting costs, we have included the PVRR both with and without the costs of CO_2 allowance purchases. The logic in doing so is that CO_2 pricing could be simply an internal dispatch adder that PacifiCorp uses to adjust dispatch, without actually incurring costs to consumers. Similarly, CO_2 revenues could be returned directly back to customers in rebates, or used (as in RGGI) to offset energy efficiency or renewable energy programs, thus effectively remaining "inside" the system. Either way, we see these largely as transfer payments that would not be reflected in the overall system costs.

A large part of the differences in costs between the Synapse scenarios and the PacifiCorp Preferred Portfolio is the assumption of Reference Case Regional Haze assumptions. This case is a conservative case with regards to compliance, and installs SCR's on five more units than assumed under Regional Haze 3, the assumptions used in the Preferred Portfolio. Overall, the Reference Case has over $730 million (NPV) of capital costs that are not incurred in Regional Haze Scenario 1, but accomplishes significantly deeper reductions.

Table 3. Summary of costs in PacifiCorp Preferred Portfolio and Synapse cases

Costs (M$ NPV)	PAC Preferred	Case A	Case B	Case C
PVRR (2015-2034)	$28,095	$36,233	$36,363	$36,323
PVRR (CO_2 cost excluded)	$28,095	$28,137	$28,678	$28,720
Difference from PAC Pref.		$42	$541	$583

5. Discussion and Conclusions

The Synapse System Optimizer analysis considered a number of improvements to allow the model to better optimize decisions in the face of planning constraints faced by PacifiCorp. Our runs considered endogenous retirements, a major PacifiCorp omission, as well as alternative means of CPP compliance and sensitivity to renewable cost assumptions.

The endogenous retirement sensitivity demonstrated clearly that the units chosen by PacifiCorp for retirement under the Preferred Portfolio are not necessarily the most economic units to retire under a more flexible approach. Hunter, Huntington, and Naughton all appeared potential candidates for retirement, but were not explored in the PacifiCorp's IRP.

Implementing Clean Power Plan compliance via a mass-based approach proved to be a more transparent and easily optimized planning process than PacifiCorp's in-house compliance tool. When coupled with endogenous retirements, this resulted in distinctly different retirement trajectories than PacifiCorp's Preferred Portfolio. While both the Preferred and Alternative Plans appear to be compliant with the final rule, allowing more flexibility allows a broader array of planning decisions and uses the model as it was designed for: to find least-cost planning solutions.

By forcing units to retire based on *a priori* assumptions, PacifiCorp's IRP development process violates basic principles of least cost resource planning, and represents a major step backwards from the significant progress made by PacifiCorp in its 2013 IRP.