Review of Tennessee Valley Authority's Draft 2025 Integrated Resource Plan

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1. INTRODUCTION

Sierra Club engaged Synapse Energy Economics (Synapse) to review Tennessee Valley Authority's (TVA) draft 2025 Integrated Resource Plan (IRP). TVA originally planned to release the IRP in March 2024, but anticipating the finalization of federal climate regulations later that spring, TVA delayed the release until September 2024. In the intervening months, TVA updated its modeling to incorporate the final regulations in one scenario. The current IRP builds on TVA's prior IRP, which it finalized in 2019.[1] The following report outlines Synapse's assessment of the Company's draft IRP based on information that the Company made publicly available.

1.1. Background on TVA

TVA is a federally owned electric utility and is the largest provider of public power in the United States. The Company produces electricity for 153 local power companies which together serve around 10 million people in Tennessee and six surrounding states.[2] TVA has a mission of "providing affordable and reliable energy, being a responsible steward of the environment, and supporting economic development."[3] The Company also has a goal to reduce its carbon dioxide emissions 70 percent from 2005 levels by 2030 and 80 percent by 2035, with an ultimate goal of reaching net-zero emissions by 2050.[4] The Company's mission, therefore, goes beyond just providing power, but also being a good steward of the health and environment of the communities it serves.

1.2. TVA's IRP

TVA's IRP serves the same purpose as resource planning processes performed by regulated utilities; but as a federally owned public entity, the procedures governing TVA's IRP are unique. Investor-owned utilities typically create IRPs under rules set by their state regulatory commissions. There is great variation across states in how stakeholders are engaged, whether IRP processes are formally litigated, and whether IRPs are ultimately approved or acknowledged by a commission. But generally, stakeholders are engaged throughout the modeling and IRP development process and provide feedback (through comments or a litigated process). Then the commission ultimately reviews the IRP and makes a judgment about whether a utility's plan is in the public interest or needs revisions.

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[1] Tennessee Valley Authority (TVA). "2019 Integrated Resource Plan." Available at: https://www.tva.com/environment/integrated-resource-plan/2019-integrated-resource-plan.

[2] TVA Integrated Resource Plan 2025, Draft Resource Plan at ES-2.

[3] Id.

[4] TVA. "2021 Carbon Report." Available at: https://www.tva.com/environment/environmental-stewardship/sustainability/carbon-report.

In contrast, TVA's IRP proceeds similarly to other federal agency decisions: through notice and comment rulemaking. TVA issues its draft IRP as well as an environmental impact statement, which initiates a period of public review and comment. After the comment period, the presidentially appointed Board of Directors[5] revises and adopts (or rejects) the IRP.[6] Although there are "open houses," there is no public hearing and no finding that the IRP serves the public needs, and TVA largely limits stakeholder participation during the IRP process to only the stakeholders that it approves to join the IRP Working Group.[7]

Given the limited transparency surrounding TVA's IRP, one key point of leverage for stakeholders is the public comment period following the issuance of the draft IRP. To inform the design of the final IRP, this report describes (1) our concerns with TVA's modeling assumptions and scenario framework in its draft IRP, and (2) our recommendations for development of a preferred portfolio and short-term action plan.

2. FINDINGS AND RECOMMENDATIONS

Synapse's review resulted in the primary findings below.

Strategies and Scenarios Findings

Finding 1. TVA presented a range of economic, energy, and policy futures through its scenario framework but presented a very limited view of future resource cost assumptions.

Finding 2. TVA did not test a strategy that promotes both carbon-free supply and demand-side resources simultaneously.

Finding 3. TVA did not select a preferred portfolio in its draft IRP. A preferred portfolio is important for the utility to communicate its plan to stakeholders and the public, and to commit to a short-term action plan.

Model Inputs Findings

Finding 4. TVA modeled a high load growth scenario, but did not specifically evaluate or discuss the potential impact of data center load growth.

Finding 5. TVA's Aging Coal Fleet Evaluation predated the U.S. Environmental Protection Agency's (EPA) 111 greenhouse gas (GHG) emissions rule and found that it was most economic for TVA to retire all its coal by the early 2030s.

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[5] TVA. 2024. "Board of Directors." Available at: https://www.tva.com/about-tva/our-leadership/board-of-directors.

[6] 84 Fed. Reg. 48987 (September 17, 2019).

[7] TVA. 2024. "Engagement in the 2025 IRP." Available at: https://www.tva.com/environment/integrated-resource-plan/working-groups.

Finding 6. TVA can move up the retirement of Shawnee to avoid installing co-firing and other environmental equipment necessary for compliance with the final 111 rule, or other likely future carbon regulations.

Finding 7. TVA did not model a full range of battery energy storage (BESS) technologies, and specifically did not model long-duration battery energy storage (LDES) resources.

Finding 8. TVA modeled a number of advanced resource options but did not reflect the full cost and potential risks of reliance on these resource options in its modeling.

Finding 9. TVA did not capture the costs, risks, or uncertainty associated with advanced technologies including carbon capture and sequestration (CCS) and small modular nuclear reactors (SMR).

Finding 10. TVA relied on slightly higher than average costs for new wind and solar resources, and lower than average costs for new gas resources. This biased the model results in favor of new gas resources.

Finding 11. The cost promoters that TVA used for its resource strategies bring new renewable costs in line with the advanced trajectories, yet TVA only presented the results of its analysis with the promotors removed.

Finding 12. TVA used static and binding renewable build limits in some scenarios.

Final Results Findings

Finding 13. TVA's Scenario 6C, which relies on carbon-free commercial-ready-results in $23 billion lower social impacts than Portfolio 6A as measured by the social cost of carbon (SCC) between 2024–2050.

Finding 14. TVA's Scenario 6C results in between $3.1 and $5.0 billion in lower health impacts than the reference portfolio (6A). This is the same range as the total present value of the revenue requirement (PVRR) delta between the two scenarios, which is a total of $4 billion.

We therefore provide the recommendations below to TVA.

Scenario and Strategies

Recommendation 1. TVA should model a more representative range of scenarios that feature the National Renewable Energy Laboratory (NREL) Annual Technology Baseline's (ATB) Advanced resource technology costs. At a minimum, there should be a moderate economic growth and moderate load growth case that features this cost projection.

Recommendation 2. TVA should develop its long-term resource plan with a more holistic view of resource options—both supply- and demand-side.

Recommendation 3. TVA should present the net present value (NPV) results of the portfolios both before and after the "promotion" adders are incorporated in post-processing.

Recommendation 4. In its final IRP, TVA should clearly identify a Preferred Portfolio and should develop a short-term action plan based on the resource additions in its Preferred Portfolio.

Model Inputs

Recommendation 5. TVA should evaluate how demand from data centers can impact its system in the future and what impact it can have on future load and demand.

Recommendation 6. TVA should lock in the retirement dates for its existing coal assets and not consider extending them to meet future load growth.

Recommendation 7. TVA should plan to retire the Shawnee coal plant before January 1, 2032, to avoid investments to enable gas co-firing that the final 111 rule would otherwise require.

Recommendation 8. TVA should model a larger range of BESS resources, including a long-duration resource of 50- or 100-hours.

Recommendation 9. TVA should model and understand the large range of the potential costs and risks associated with reliance on advanced technologies in its IRP.

Recommendation 10. TVA should incorporate into Strategy B quantification of the potential costs and risks of relying on advanced technologies such as CCS and SMRs.

Recommendation 11. TVA should model NREL's advanced cost trajectories in a wider range of scenarios. At the very least, TVA should model Scenario 6, which is 111-compliant, with NREL ATB's Advanced cost decline trajectories.

Recommendation 12. TVA should model a sensitivity that removes the solar build cap beyond 2030 and the BESS build limit later in the study period. TVA should also model sensitivities with build limits that relax over time.

Recommendation 13. TVA should justify its new gas resource costs and model scenarios with higher costs that are more in line with industry standard projections for combined cycle units and combustion turbines.

Final Results

Recommendation 14. TVA should pursue Strategy C, the Carbon-Free Commercial-Ready strategy, as the basis for its preferred portfolio.

Recommendation 15. TVA should focus its near-term investment on commercially deployed technologies like solar PV and BESS.

Recommendation 16. TVA should include consideration of the societal and health impacts of each portfolio in its evaluation metrics and quantify the difference between portfolios.

Recommendation 17. TVA should quantify the social cost of GHG emissions associated with each of its portfolios and take these costs into account on its scorecard.

3. TVA RELIES ON A TWO-PART MODELING FRAMEWORK COMPRISED OF SIX WORLD-VIEW SCENARIOS AND FIVE RESOURCE STRATEGIES

In its draft IRP, TVA uses a two-part framework to organize its modeling. TVA relies on six scenarios to represent different views of the world and the future, and five strategies to organize potential resource options that can be used to meet electricity demand in each potential future. While the scenarios represent different versions of external conditions that TVA does not control, the strategies represent different approaches to resource procurement that TVA could choose to adopt going forward. The result of running a strategy through a scenario is a portfolio. Running the five strategies in each of the six scenarios results in 30 possible resource portfolios that the Company compares across metrics including cost, reliability, and carbon emissions.

In this section, we summarize our findings from reviewing TVA's scenario and sensitivity framework and provide recommendations for TVA to implement in the future. Overall, we find that the framework allowed TVA to test a reasonable range of scenarios, but we are concerned that TVA ultimately chose no preferred portfolio and therefore didn't commit to short-term actions, and that despite testing a relatively comprehensive range of economic and energy demand futures, TVA tested only a narrow view of future new resource cost assumptions.

3.1. TVA's six scenarios feature a variety of future economic, energy, and policy futures, but only one scenario features alternative resource technology cost decline assumptions

TVA models six scenarios that capture a variety of economic, energy, and policy future outlooks by testing a range of likely values for key input variables (Table 1). TVA does a relatively good job capturing multiple distinct views of the world with its scenarios. However, we are concerned that the scenarios rely on a limited view of new resource cost assumptions.

Table 1. Scenarios with Key Uncertainties that TVA modeled

Key Uncertainties	1: Ref w/o GHG rule	2: Growth	3: Stagnant	4: Regulation	5: Reg + Growth	6: Ref with GHG rule
Economic Outlook	Moderate	High	Very Low	Low	High	Low
Electricity Demand	Moderate	High	Very low	Low	Very High	Low
Natural Gas Prices	Moderate	Very High	Very Low	Moderate	Low	High
Market Power Prices	Moderate	Very High	Very Low	Very High	High	High
Carbon Dioxide Regulations	No	No	No	Very High	High	Moderately High
Behind-the-Meter Generation and Storage	Moderate	Moderately High	Moderately High	Low	Very High	High
EV Adoption	Moderate	High	Low	High	Very High	Low
Electrification	Moderate	Moderate	Moderate	High	Very High	Moderate
National Energy Efficiency Adoption	Moderate	Moderate	Low	High	Moderate	High
Resource Technology Costs	Moderate	Moderate	Moderate	Moderate	Advanced	Moderate
GHG Rule	No	No	No	Draft	Draft	Final

Notes: Key Uncertainties presented as defined in Draft IRP at B-2. The table in the IRP draft excludes Scenario 1 but refers to the Key Uncertainties in other scenarios relative to Scenario 1. For the purposes of this version of the table, we used "Moderate" levels for Scenario 1. Where a level in another scenario was listed as "Same," we interpreted that as "same as Scenario 1," and listed the level as "Moderate" in our table. We added Resource Technology Costs and GHG Rule rows to our version of the table based on details found in the Draft IRP scenario descriptions.

TVA designs its scenarios to evaluate multiple levels for many variables (i.e., low, moderate, high). For example, the economic forecast is shown at the following levels: Very Low (Scenario 3), Low (Scenarios 4 and 6), Moderate (Scenario 1), High (Scenarios 2 and 5). Similarly, behind-the-meter generation and storage additions are shown at the following levels: Low (Scenario 4), Moderate (Scenario 1), Moderately High (Scenarios 2 and 3), High (Scenario 6), and Very High (Scenario 5).

Each variable level was tested in a range of scenarios. For example, three scenarios do not feature GHG regulation, and three do. Similarly, four scenarios feature moderate electrification, and two feature high or very high electrification. Overall, we find that TVA designed its scenarios to capture a relatively representative and balanced view of most variables that it evaluated. However, resource technology costs are a noteworthy exception to this trend.

TVA presents five scenarios with moderate resource technology costs using the NREL ATB Moderate forecast, and only one scenario—Scenario 5 with the proposed regulations and high growth assumptions –with advanced resource technology costs. Moderate cost declines represent reference or status quo assumptions, while advanced resource technology cost declines will promote higher adoption of commercial-ready technologies. TVA has not justified why it would expect to see advanced resource technology costs in a scenario with high growth and proposed GHG regulations (Scenario 5), but not in a scenario with just high growth assumptions (Scenario 2), or alternatively in a scenario with just the finalized GHG regulations (Scenario 6). While the company's moderate cost decline projections were relatively in line with industry (albeit a little high, as we will discuss in Section 4.4 below), TVA's limited evaluation of alternative cost decline projections is concerning. By limiting the advanced cost declines to only one scenario, TVA failed to fully analyze the impact that more rapid future cost declines could have on its optimal build plan.

TVA can model a variety of resource cost options across multiple scenarios just as it did for many other variables. Specifically, TVA can incorporate advanced resource technology costs into a scenario with a moderate economic outlook and moderate load forecast to provide a more balanced mix of scenarios.

It is important that TVA tests a range of resource cost assumptions, because these assumptions affect how each portfolio scores on TVA's cost and risk scorecard. TVA scores its portfolios on a variety of metrics, grouped into the categories of Low Cost, Risk Informed, Environmentally Responsible, and Diverse, Reliable, and Flexible. In the draft IRP:

- Strategy A (Reference) is the lowest-cost strategy overall but receives lower marks on Environmental Responsibility and Risk Informed
- Strategy C (Commercial-ready low carbon) is the second-lowest-cost strategy overall, achieves the fastest near-term reductions in carbon dioxide intensity, and reduces regulatory and financial risk

In addition to affecting the resource builds in each portfolio, resource costs will affect the PVRR associated with each portfolio. Strategy C relies on commercial-ready carbon-free technologies—and it ranks just behind Strategy A (TVA's reference planning approach) as the least-expensive strategy, while scoring higher than all other strategies in every other metric category. Advanced cost decline trajectories could make Strategy C even less expensive than Strategy A, but TVA will not be able to quantify this impact unless it models a scenario with a moderate economic outlook and advanced cost declines. Including this scenario would enable TVA to better understand the circumstances under which the different strategies score better across its scorecard metrics.

Of the scenarios that TVA did model, Scenario 6 best represents regulatory conditions that TVA will likely face going forward. Over the IRP planning horizon, TVA will likely face at least moderate levels of carbon regulation, and Scenario 6 is the only one that incorporates the final 111 rule. In this report, we therefore focus on results from Scenario 6.

Recommendation

TVA should model a more representative range of scenarios that feature NREL ATB's Advanced resource technology costs. At a minimum, there should be a moderate economic growth and moderate load growth case that features this cost projection.

3.2. TVA's five strategies evaluate different potential resource pathways for the future but are hard to interpret

TVA designs five different resource strategies that can be optimized to meet demand across the six scenarios (Table 2). In each strategy, TVA emphasizes a different subset of technologies. All technology options are available in all strategies, but TVA applies cost adjustments (described below) to favor or "promote" a different subset of technologies in each strategy. While this framework does a reasonable job creating distinct resource portfolios, it does not fully capture an integrated approach that combines consideration of supply- and demand-side resources together. In addition, TVA chose not to provide modeling results inclusive of the cost promoters, limiting the interpretability of the results.

Table 2. Strategies that TVA modeled

Strategy Name	Description	Resources Emphasized
A: Baseline Utility Planning	Least-cost planning	Base cost for all resource types
B: Carbon-free Innovation Focus	Increased deployment of emerging carbon-free technologies	High promotion of nuclear and CCS; Moderate promotion of renewables and battery storage
C: Carbon-free Commercial Ready Focus	Increased deployment of wind, solar, and storage	High promotion of renewables and battery storage
D: Distributed and Demand-side Focus	Increased deployment of distributed generation and demand-side resources	High promotion of distributed and demand-side resources
E: Resiliency Focus	Increased deployment of small dispatchable resources and battery storage	High promotion of battery storage, aeroderivative combustion turbines, and reciprocating engines; moderate promotion of LDES and Nuclear

Source: Draft IRP at C-1 to C-3.

TVA "promoted" resources in the EnCompass model through a combination of decreasing the cost that the model saw for the given resource type and specifying minimum build requirements.[8] It applied a moderate and a high promotion.

- "Moderate" promotion of solar and wind resources means that TVA reduced the cost of these resources by 15 percent.

[8] TVA Integrated Resource Plan 2025, Draft Resource Plan at C-4.

- "High" promotion means that TVA reduced the cost by 25 percent, added a minimum annual capacity addition, and increased the solar build limit.

TVA then removed the cost reductions when calculating scorecard metrics in order to assess portfolio costs.[9]

The use of "promotions" is an interesting modeling approach, but it results in levels of resource deployment that are not aligned with economics (although this is true any time you hard-code resources or limit resource deployment). TVA could mitigate this concern if it reported results with promotions included (in addition to the results it currently provides with the promotions added back in). The modeling results with promotions included would provide critical information on what the portfolio PVRR would be if resource costs fell to the level needed to economically achieve that level of deployment. However, TVA does not currently report results with the promotions included. These results would be particularly valuable because, as we discuss below, many of the promotors put resource costs in the range of NREL's Advanced technology cost trajectories, meaning that portfolio costs including the promotions could be used as a proxy for the results of a scenario that used advanced resource cost trajectories.

Overall, TVA's strategies are an interesting way to organize different resource options but ultimately result in slightly artificial and unrealistic portfolios that are concentrated in specific resource options. TVA does not have portfolios that explore more representative "all of the above" or holistic views of the future (except for the baseline strategy). This is important because each resource option can provide a different set of services to the grid and will be economic for different reasons and on different timescales. And many of the resource options tested distinctly—for example, high DER adoption—can be deployed in tandem with any of the other resource strategies tested.

Recommendation

TVA should design a resource strategy that promotes both commercial-ready renewables (Strategy C) and demand-side resources (Strategy D).

TVA should present the NPVRR results of the portfolios both before and after the "promotion" adders are incorporated in post-processing.

3.3. TVA does not choose a preferred portfolio or design a short-term action plan as part of its draft IRP

For IRPs to be effective, they must tie concretely to near-term utility actions. Concerningly, TVA did not select a Preferred Portfolio or establish a short-term action plan as part of the draft 2025 IRP. TVA did

[9] Id. at C-3.

note that the final IRP will include a "recommended strategic portfolio direction through 2035" and will "discuss implementation plans."[10]

For the IRP to drive TVA's near-term planning, it is important that TVA selects a Preferred Portfolio that performs well over a range of the most likely future scenarios and balances least-cost optimization with other priorities such as environmental performance and risk. TVA should also design a short-term action plan based on the resources that appear in its Preferred Portfolio. Key uncertainties for TVA include future load growth, future environmental regulation, and future technological development. TVA should select a strategy that performs well across different load growth levels, that is adaptable to future GHG regulations, and that minimizes ratepayers' exposure to risk of technology under-performance or cost-overruns.

Recommendation

In its final IRP, TVA should clearly identify a Preferred Portfolio and should develop a short-term action plan based on the resource additions in its Preferred Portfolio. Based on the modeling results, such a Preferred Portfolio would draw heavily on the Strategy C portfolios.

4. KEY MODELING INPUTS AND ASSUMPTIONS INTRODUCE BIAS INTO TVA'S CONSIDERATION OF DIFFERENT RESOURCE STRATEGIES

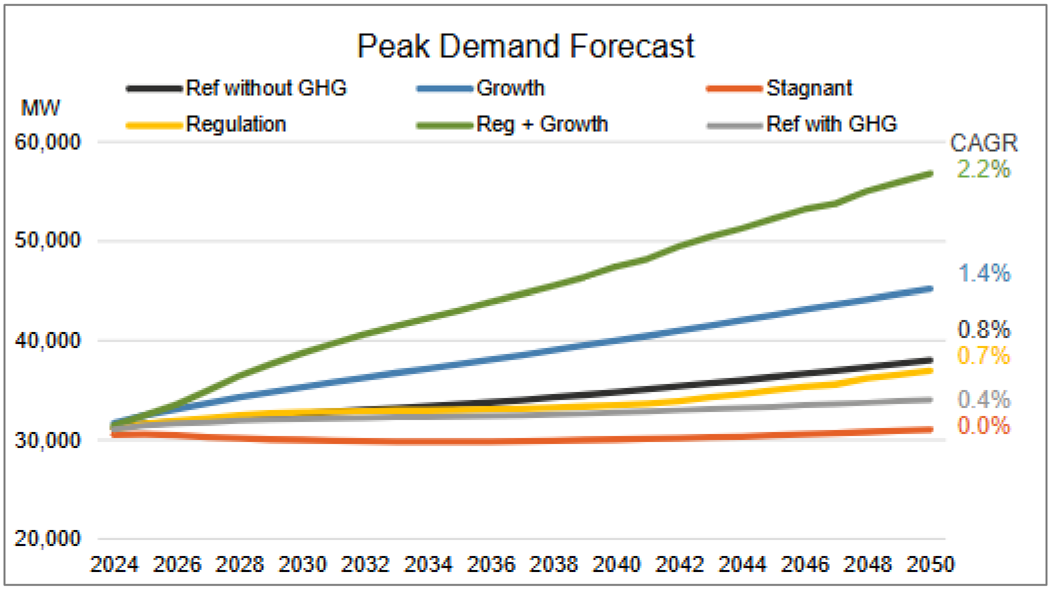
We carefully reviewed TVA's inputs assumptions for load and resources (new and existing) and found several items that warrant further attention. On load, TVA evaluated a reasonable range of economic assumptions but critically did not consider a future with increased data center load. For existing resources, while TVA does model its coal fleet retiring by the early 2030s, the timing of Shawnee's retirement would still necessitate investment to comply with the final 111 rule. Additionally, there is nothing locking in the retirement dates of TVA's other coal plants if it faces unexpected data center load in the future. For new resources, TVA relied on assumptions that systematically favored new gas resources over renewables, including using lower-than-average costs for new gas resources but moderate costs for new renewable resources, and constraining renewable builds with static annual build limits.

[10] Id. at 5-1.

4.1. TVA does not research or evaluate the potential for data center load growth in its service territory

TVA designed its scenarios to encompass a range of different assumptions around economic growth and the regulatory environment. This resulted in six distinct peak demand and energy forecasts—ranging from a stagnant forecast to one with demand nearly doubling by 2050 (Figure 1).

Figure 1. TVA's load growth forecasts for each scenario



Source: Draft IRP at B-7.

However, the Company makes no mention anywhere in its IRP of data center load. While TVA should not be actively building new resources and planning a short-term action plan around uncertain load, it should be proactive in understanding how it may be impacted by this industry trend in the future. TVA's highest load growth scenario does capture some manner of high load, but it was not designed to capture any particular assumptions around data center load growth. And looking at other locations with data center load growth expected—such as Virginia—we see growth rates as high as 4 and 6 percent, far above the 2 percent compound annual growth rate that TVA modeled in its highest load growth forecast.

Recommendation

TVA should evaluate how demand from data centers can impact its system in the future and what impact it can have on future load and demand.

4.2. TVA's analysis consistently shows that retirement of all its coal plants by the early 2030s is the lowest-cost option, and TVA can take steps to maintain its retirement plans

In its IRP modeling, TVA hard-codes coal plant retirement dates rather than evaluating economic retirement dates (Table 3).[11] In addition to the plants shown in Table 3, TVA also has a long-term power purchase agreement with another coal-fired plant that expires in 2032.

The retirement dates for TVA's remaining coal units are based on an "Aging Coal Fleet Evaluation" that TVA completed in 2021.[12] The study pre-dates the 111 rule and shows that near-term retirement and replacement of TVA's coal units is in the best interest of ratepayers based on the performance and economics of the units alone. One factor that played a role in determining planned end-of-life dates for TVA's four remaining coal plants is the Effluent Limitations Guidelines (ELG) Rule.[13] This rule establishes stringent wastewater discharge standards at coal plants. TVA did not provide any details on how it modeled the ELG Rule in the current IRP.

The fleet evaluation recommended that the last of TVA's coal plants, Shawnee, retire by year-end 2033, noting that TVA's "coal fleet performance is challenged, driving cost and system reliability pressure," and that the plants "are operating well beyond their original book life and are among the oldest still in operation in the nation." [14]

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[11] Id. at E-11.

[12] TVA. 2021. "Aging Coal Fleet Evaluation." Available at: https://tva-azr-eastus-cdn-ep-tvawcm-prd.azureedge.net/cdn-tvawcma/docs/default-source/environment/aging-coal-fleet-evaluation2eeb5bd7-1983-4d03-ac5b-c105e2686d07.pdf?sfvrsn=3425c191_5.

[13] TVA Integrated Resource Plan 2025, Draft Resource Plan at ES-4.

[14] Id.

Table 3. TVA's remaining coal units

Coal Plant	State	Summer Capacity (MW)	Number of Units	Online Year	Retirement Year: 2021 Fleet Evaluation	Retirement Year: Draft IRP
Cumberland	TN	2,470	2	1973	2026, 2028	2026, 2028
Kingston	TN	1,398	9	1954–1955	2026 (3 units), 2027 (6 units)	2027
Gallatin	TN	976	4	1956–1959	2031	2031
Shawnee	KY	1,206	9	1953–1955	2033	2033

Source: EIA Form 860, 2023 data; Draft IRP at E-11; TVA. 2021. "Aging Coal Fleet Evaluation." Available at: https://tva-azr-eastus-cdn-ep-tvawcm-prd.azureedge.net/cdn-tvawcma/docs/default-source/environment/aging-coal-fleet-evaluation2eeb5bd7-1983-4d03-ac5b-c105e2686d07.pdf.

TVA can take steps to maintain its planned coal plant retirement dates even if it sees future data center load growth

Given the poor economic performance and low availability of the coal units, it is important for TVA to plan proactively to ensure it has enough replacement resources online to allow for timely retirement of the units, even if load growth is higher than expected. Utilities around the country are seeing sudden increases in load from data centers and manufacturing, which has led to delays in coal unit retirement. For example, the Omaha Public Power District in Nebraska recently pushed back the retirement date of its two remaining coal-fired units at the North Omaha power plant, in part because of data-center-fueled load growth in the area.[15]

It is in the best interest of TVA ratepayers to follow through on the planned retirement dates to minimize the costs and risk to ratepayers of delays in coal unit retirement. As TVA wrote in its fleet evaluation study, "substantial performance and cost risk is carried by operating a coal fleet reaching the end of its useful life."[16] TVA also faces coal supply risks, noting that the "long-term financial health of the coal mining industry could influence the ability to procure coal and/or the price of coal."[17]

Recognizing the benefits to ratepayers of retiring the units on schedule, TVA can incorporate load growth from any new large customers that materialize in its service area as an input to its resource planning. Specifically, it can optimize how it meets the new load with resource additions, rather than treating load growth from new customers as a static input that it must accept regardless of whether it has the resources available to serve the load. For example, if delaying the addition of a certain load by a year or more gives TVA time to more economically procure replacement resources and avoid delaying a coal plant retirement, then TVA can delay extension of service to that load until it has the resources available to serve it.

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[15] Halper, E. 2024. "A utility promised to stop burning coal. Then Google and Meta came to town." *Washington Post.* October 12. Available at: https://www.washingtonpost.com/business/2024/10/08/google-meta-omaha-data-centers/.

[16] TVA Aging Coal Fleet Evaluation, May 2021 at 8.

[17] Id.

TVA can move up the retirement of Shawnee to avoid installing co-firing equipment at the plant to comply with the 111 rule

Because the Aging Coal Fleet Evaluation study pre-dates the 111 rule and TVA didn't evaluate the economics of retirement in its IRP, it currently models retiring Shawnee by the end of 2033. Under the final 111 rule, units can avoid needing to install any equipment to comply if they retire by January 1, 2032. If units operate after this date but commit to retiring prior to year-end 2039, they must co-fire with at least 40 percent gas starting on January 1, 2030.

Retiring Shawnee in 2033 means that TVA will need to install equipment to enable gas co-firing at the Shawnee units. TVA could avoid needing to make this capital investment if it moves the retirement of Shawnee forward by one year and retires the unit by January 1, 2032. This means TVA could save from early retirement and avoiding the cost of installing co-firing and other required environmental compliance equipment.

Recommendation

TVA should lock in the retirement dates for its existing coal assets and not consider extending them to meet future load growth.

TVA should plan to retire the Shawnee coal plant before January 1, 2032, to avoid investments in co-firing and other environmental compliance equipment that the final 111 rule, or other future carbon regulations, requires.

4.3. TVA models BESS and advanced resource options with unsupported cost and deployment assumptions

As discussed above, TVA made all technology options available for selection by the model in all strategies, but "promoted" certain technologies in each strategy.

TVA designed Strategy B – Carbon-Free Innovation, to promote advanced resource options, including SMRs and CCS. In Strategy C, TVA promoted commercial-ready technologies including solar, wind, and BESS (including LDES).

For battery storage more broadly, TVA modeled a limited set of technologies. Specifically, TVA modeled 4-hour BESS and 10-hour advanced chemistry battery technology but not LDES options such as 50- or 100-hour storage. This is concerning because different durations of storage provide different values to the system, and modeling a limited range of resources or limited resource value can produce a sub-optimal resource mix. For example, a 2-hour BESS system provides narrow peak services but is less expensive than a 4-hour BESS system, and therefore can more economically meet a specific peak need. A 50- or 100-hour BESS system also provides different value than a 10-hour system, but TVA did not capture that dynamic in its modeling. While LDES is still in the commercial phase of development, it is no more nascent than other technologies that the Company has modeled such as CCS and SMRs. Additionally, a number of utilities, including Southwestern Service Company of New Mexico (in its 2023

IRP), are modeling scenarios that rely on LDES. And over half a dozen states have LDES pilot projects in the works, including Georgia, Virginia, New York, Colorado, and Minnesota.

For SMRs, which are not yet commercially deployed at scale, TVA relied on costs estimates informed by TVA's experience with exploring small modular reactors at the Clinch River Nuclear site.[18] Our major concern with SMRs is that TVA's scorecard doesn't adequately capture the risk that SMRs will not become available or will be more costly than TVA currently projects. Scenario 5 with high load growth and proposed GHG regulations includes the most SMRs—between 9 and 12.5 GW by 2050—and SMRs are built in all portfolios regardless of strategy. Otherwise, SMRs show up only in B and E portfolios, with the model building between 1,140 MW and 3,715 MW of SMRs by 2050.[19]

For CCS, TVA only modeled the technology on combined cycle gas plants, not on coal plants (as all coal is to be retired by the early 2030s). CCS is not deployed at scale yet, so the level of uncertainty around the cost is much greater than for existing non-emitting technologies such as solar PV and BESS. The model selects combined cycle + CCS between now and 2050 in 15 portfolios—specifically, in all portfolios with Strategy B, all Scenario 4 and 5 portfolios, and in Portfolio 3A. Even more concerning is that in four of those portfolios, TVA builds over 1 GW of combined cycle + CCS in 2033—less than 10 years away. Existing tax credits available for CCS are generation-based and therefore incent high resource utilization. This means that TVA would have to operate its gas plants at high levels, and therefore secure a high firm gas supply, to ensure the technology is economic. This exposes ratepayers to risk not just from construction of the CCS but from gas prices with continued reliance on high levels of natural gas generation. Because CCS imposes an energy penalty—running the CCS equipment consumes some of the electricity generated by the unit—combined cycle units with CCS must burn more fuel to generate the same amount of output electricity as a combined cycle unit without CCS. This energy penalty further increases customer exposure to fuel price volatility in portfolios that rely heavily on combined cycle with CCS.

Finally, CCS can have negative air quality impacts in some circumstances. While sulfur dioxide and particulate matter in a generator's exhaust stream must be strictly controlled for post-combustion CCS equipment to function correctly, increased fuel burning due to the CCS energy penalty can increase emissions of other air pollutants such as nitrogen oxide.[20] CCS can also result in increased emissions of ammonia, which can result in formation of secondary particulate matter, depending on factors such as location and weather.[21]

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[18] TVA Integrated Resource Plan 2025, Draft Resource Plan at 3-17.

[19] Draft IRP data files, "incremental-capacity-tables-9-30-2024.xlsx.".

[20] van Harmelen, T, van Horssen, A, Jozwicka, M, Pulles, T Odeh, N, and Adams, M. 2011. *Air pollution impacts from carbon capture and storage (CCS).* European Environment Agency Technical Report. Available at: https://www.osti.gov/etdeweb/servlets/purl/1031195.

[21] Waxman, A, Huber-Rodriguez, HR, and Olmstead, S. 2024. *What are the likely air pollution impacts of carbon capture and storage?* Available at: https://dx.doi.org/10.2139/ssrn.4590320.

Recommendation

TVA should model a larger range of BESS resources, including a long-duration resource of 50- or 100-hours.

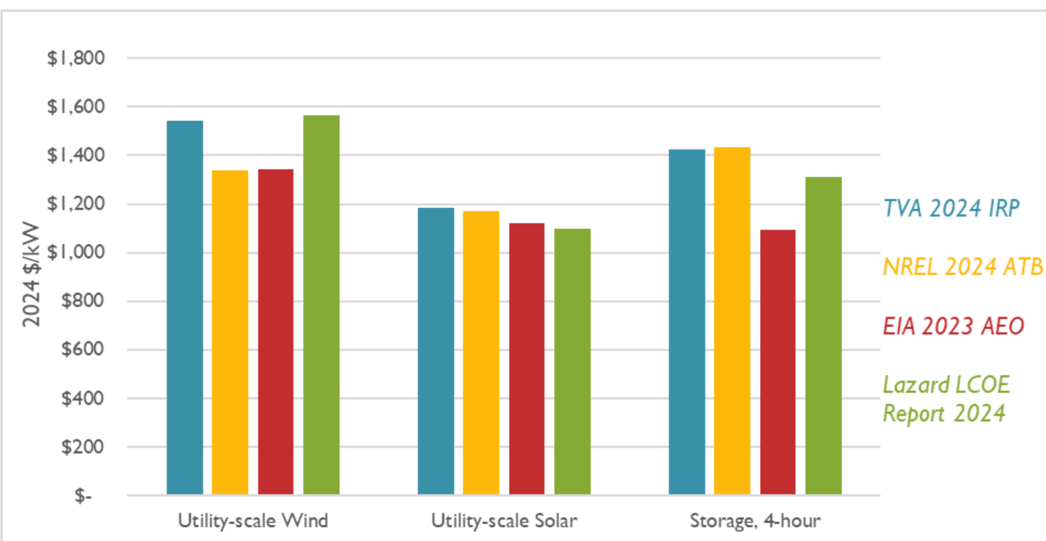
TVA should model and understand the large range of the potential costs and risks associated with reliance on advanced technologies in its IRP.

4.4. TVA relies on slightly high cost assumptions for new renewables, and lower-than-average costs for new gas resources

For utility-scale technologies, TVA modeled NREL 2023 ATB's Moderate resource cost trajectories for all scenarios except for Scenario 5—where it modeled NREL ATB's Advanced case. As discussed in Section 3.1 above, TVA's evaluation of alternative resource cost assumptions was limited relative to its evaluation of alterative projections of many other variables—including load, commodity prices, and regulations.

Based on our review of TVA's cost assumptions we find that its *current* renewable costs are generally in line with other industry sources (Figure 2), albeit at the high end of such sources. However, there are some small deviations that get larger over time. We also find that TVA's cost assumptions for new gas resources are below industry standard projections. This is concerning because it means that TVA's modeling is potentially understating the cost of new gas resources, and therefore favoring new gas resources over alternative options.

Figure 2. 2024 $/kW Overnight capital costs of solar, wind, and BESS for TVA compared to other industry sources



TVA's cost assumptions for new wind and solar resources slightly overstate the likely cost of building new renewable energy resources

In the near term (2029), TVA's resource cost assumptions for solar are comparable to NREL's ATB Moderate scenario projections, and slightly higher than NREL's Advanced scenario projections (Table 4 and Table 5). However, TVA's resource cost assumptions for MISO wind[22] are 15 percent higher than NREL's Moderate scenario projections in the near term.[23] The differences between TVA's and NREL's Moderate scenario projections grow over the study time period from 2030–2050. During that time, TVA's costs on average are 12 percent and 20 percent higher than NREL's Moderate scenario projections for solar and wind, respectively. By 2050, TVA's solar costs are 17 percent higher than NREL Moderate scenario projections and 32 percent higher than NREL's Advanced scenario projection. Similarly, TVA's wind costs projections are 25 percent higher than NREL's Moderate scenario projections and 39 percent higher than NREL's Advanced scenario projections. TVA states that its renewable energy cost estimates reflect recent cost proposals for solar and wind projects which are then blended into NREL's Moderate case costs. Using industry-standard cost estimates such as NREL's ATB Moderate scenario resource cost assumptions is generally good practice in IRPs, so departing from that benchmark by 20 percent for wind is noteworthy.

Conversely, TVA uses storage costs (for 4-hour duration storage) that are slightly below NREL's Moderate scenario projections. On average from 2030 to 2050, TVA's storage costs are 1 percent less than NREL's Moderate scenario projections.

Table 4. Comparison between TVA, NREL Moderate and Advanced new resource cost assumptions ($2024/kW)

Resource	2029			2050		
	TVA	NREL Moderate	NREL Advanced	TVA Base	NREL Moderate	NREL Advanced
Solar	1,186	1,169	1,087	695	595	524
Wind	1,542	1,338	1,280	1,260	1,012	907
Storage	1,423	1,436	1,096	947	956	675
Combustion turbine	733	1,115	1,115	760	919	919

[22] MISO wind is primarily from wind farms in the Midwest.

[23] Unless otherwise mentioned, we refer to TVA's MISO wind cost curve when we mention TVA's wind costs. TVA's other wind cost curves are substantially higher cost.

Table 5. Percent difference between TVA, NREL Moderate and Advanced new resource cost assumptions (TVA cost is X% > than NREL)

Resource	2029		2050	
	TVA vs NREL Moderate	TVA vs NREL Advanced	TVA vs NREL Moderate	TVA vs NREL Advanced
Solar	1%	9%	17%	32%
Wind	15%	20%	25%	39%
Storage	-1%	30%	-1%	40%
Combustion turbine	-34%	-34%	-17%	-17%

Below we show TVA's cost trajectories for solar PV (Figure 3), wind (Figure 4), and short-duration storage (Figure 5) compared to NREL's ATB Conservative, Moderate, and Advanced cases over 2024–50.

Figure 3. Solar cost trajectories for TVA compared to NREL ATB

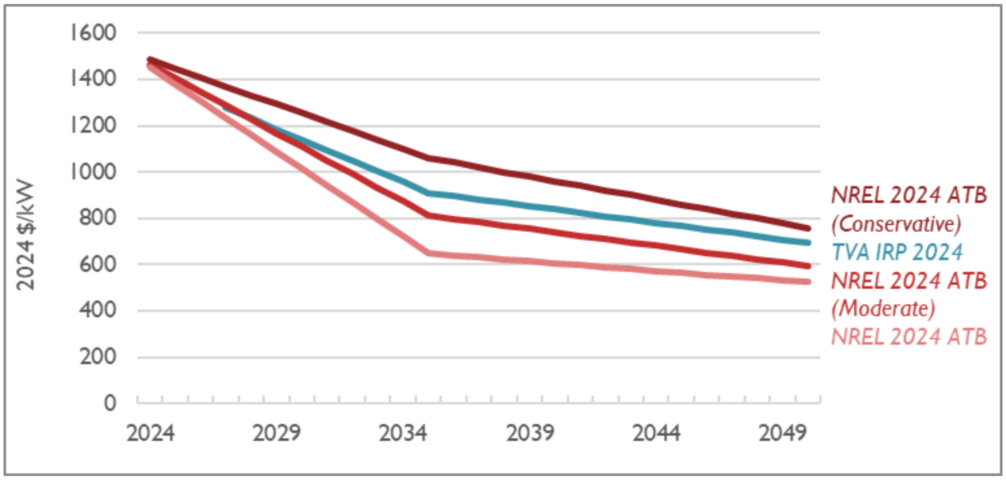


Figure 4. Wind cost trajectories for TVA compared to NREL ATB

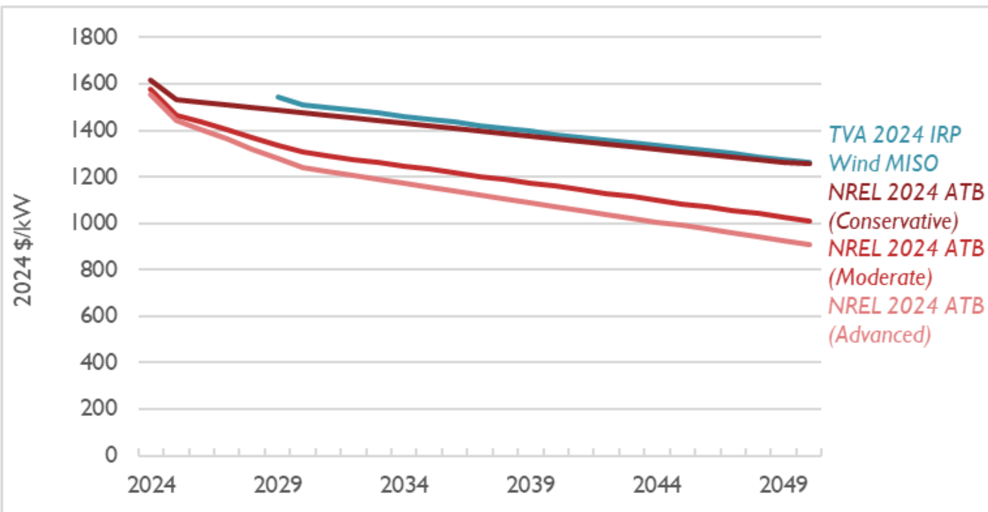
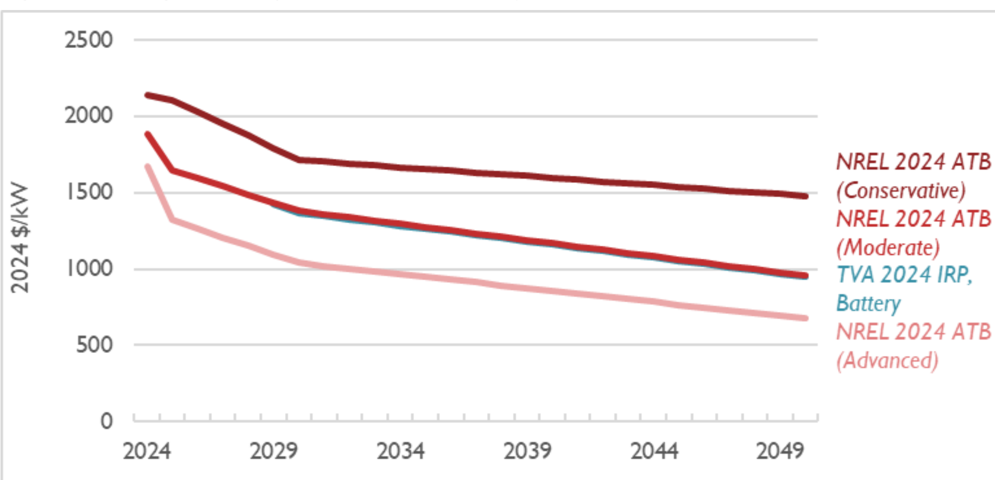


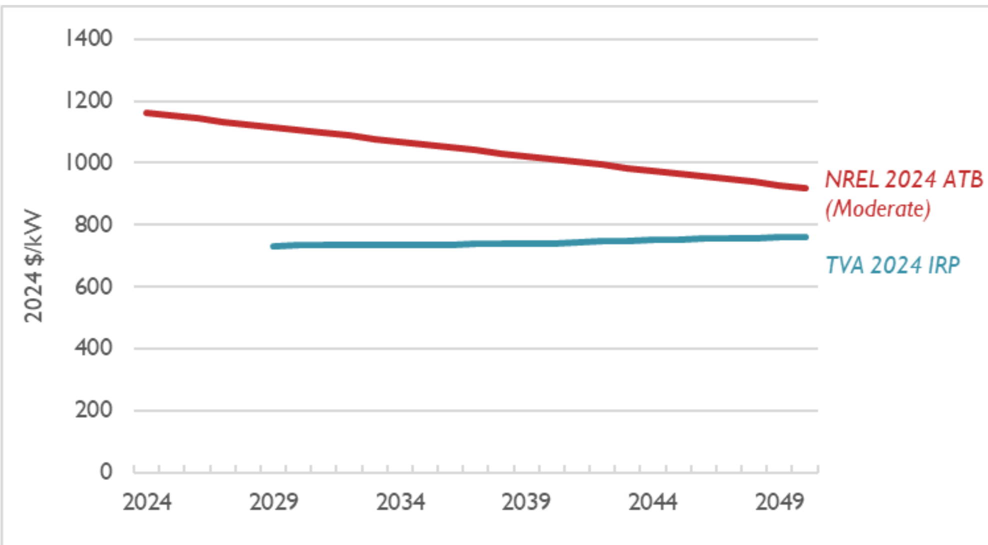
Figure 5. Storage cost trajectories for TVA compared to NREL ATB



TVA's cost assumptions for new gas resources substantially understate the likely cost of building new gas resources

Unlike for its renewable costs assumptions, for new gas combustion turbine resources TVA relied on cost assumptions that were below NREL's ATB Moderate case projections, as seen in Figure 6. Specifically, TVA's combustion turbine cost assumptions are 34 percent below NREL's Moderate case in 2029 and 17 percent below by 2050, as seen in Table 5. And over the IRP study period of 2030–2050, TVA's combustion turbine costs average 26 percent below NREL's Moderate projection. TVA's reliance on low combustion turbine costs and higher renewable cost assumptions can bias resource selection in the model in favor of building new gas and against building renewable resources. Additionally, as discussed above TVA did not run Scenario 6, which complies with EPA's 111 GHG rule, with NREL's Advanced cost decline trajectories.

Figure 6. Combustion turbine trajectories for TVA to NREL ATB



Sources: NREL ATB 2024, TVA Draft IRP "resource-cost-estimates.xlsx."

TVA's reliance on low costs for new gas resources results in substantially lower NPVRR results than if the company had used NREL ATB cost assumptions for new gas resources instead (Table 6). This means that TVA is likely understating the costs associated with its portfolios that rely on gas resources. Comparing the cost of the combustion turbine the model builds in TVA's Portfolios 6A and 6C, we find that the choice of cost trajectory impacts the NPV by between $0.5 and $1.1 billion. Correcting this cost assumption would reduce the NPVRR difference between Strategy C and Strategy A, which is between $2 and $4 billion across scenarios.

Table 6. NPVRR of combustion turbine resources under TVA and NREL ATB cost assumptions

Portfolio	Cost assumption	NPVRR *($Billion)*
6A	TVA	$2.5
	NREL ATB	$3.6
	Delta	**$1.1**
6C	TVA	$1.2
	NREL ATB	$1.7
	Delta	**$0.5**

The cost promoters that TVA uses for its resource strategies bring new renewable costs in line with the advanced trajectories

TVA also "promotes" resource selection (as discussed above) using two primary mechanisms, by either reducing resource costs by a certain percentage or introducing minimum resource build limits by a certain year that the model must obey. This forces the model to select certain resources and "promotes" these resources differently in each strategy. In each strategy, a resource either adopts no promotion, moderate promotion, or high promotion. Figure 7 shows the promotions that TVA included in each strategy for utility-scale resources, and Figure 8 shows the promotions for demand-side resources.

Figure 7. Resource promotions for utility-scale resources in each strategy

STRATEGY		Solar and Wind	Battery Storage	Long-duration Storage	Aero CTs and Recip Engines	Nuclear	CCS*
A	Baseline Utility Planning	Base	Base	Base	Base	Base	Base
B	Carbon-free Innovation Focus	Moderate: 15% cost reduction	Moderate: 15% cost reduction	Moderate: 15% cost reduction; 800 MW minimum by 2040	Base	High: 60% cost reduction (NREL moderate); 2,400 MW minimum by 2050	High: 25% cost reduction CCS 1,400 MW minimum by 2040
C	Carbon-free Commercial Ready Focus	High: 25% cost reduction; 200 MW/year minimum 2029-2050; annual solar limit increased by 25%	High: 25% cost reduction; 100 MW/year minimum 2029-2050; annual battery limit increased by 25%	High: 25% cost reduction; 1,600 MW minimum by 2040	Base	Base	Base
D	Distributed and Demand-side Focus	Base	High: Same as above	Base	High: 50% cost reduction	Base	Base
E	Resiliency Focus	Base	High: Same as above	Moderate: See above	High: Same as above	Moderate: 45% cost reduction; 1,200 MW minimum by 2040	Base

Source: TVA Integrated Resource Plan 2025, Draft Resource Plan at C-4.

Figure 8. Resource promotions for demand-side resources in each strategy

STRATEGY		Distributed Solar	Distributed Storage	Combined Heat and Power	Energy Efficiency	Demand Response
A	Baseline Utility Planning	Base	Base: 15% solar capacity match	Base	Base	Base
B	Carbon-free Innovation Focus	Moderate: 50% of marginal cost incentive	Moderate: 30% solar capacity match	Base	Moderate: Tier 2 or higher required	Moderate: Tier 2 or higher required
C	Carbon-free Commercial Ready Focus	Moderate: Same as above	Moderate: Same as above	Base	Base	Moderate: Same as above
D	Distributed and Demand-side Focus	High: 100% of marginal cost incentive	High: 50% solar capacity match	High: 100% of marginal cost incentive	High: Tier 3 required	High: Tier 3 required
E	Resiliency Focus	Moderate: Same as above	Moderate: Same as above	Moderate: 50% of marginal cost incentive	Base	High: Same as above

Source: TVA Integrated Resource Plan 2025, Draft Resource Plan at C-4.

The "promoted" renewable resource cost assumptions in TVA's Moderate and High promotion cases are in line with NREL's ATB Advanced case trajectories for solar, wind, and storage (

Figure 9, Figure 10, Figure 11).

Figure 9. TVA solar promotion cases cost trajectories compared to NREL Moderate and Advanced cases

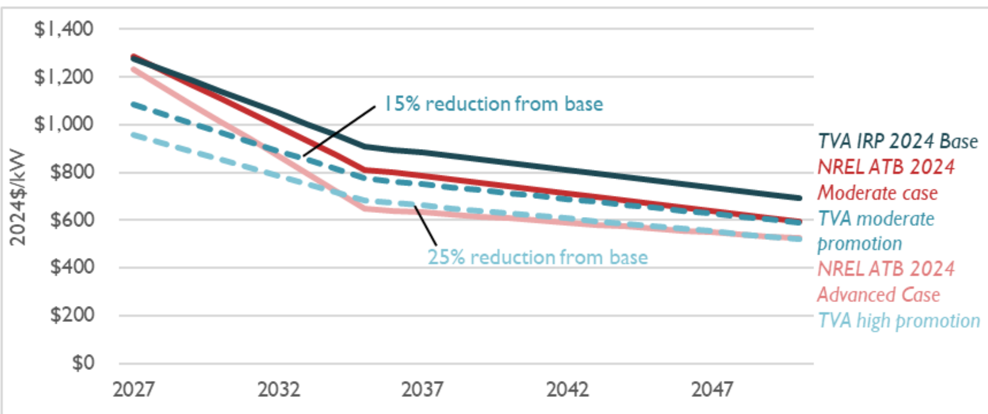


Figure 10. TVA wind (MISO) promotion cases cost trajectories compared to NREL Moderate and Advanced cases

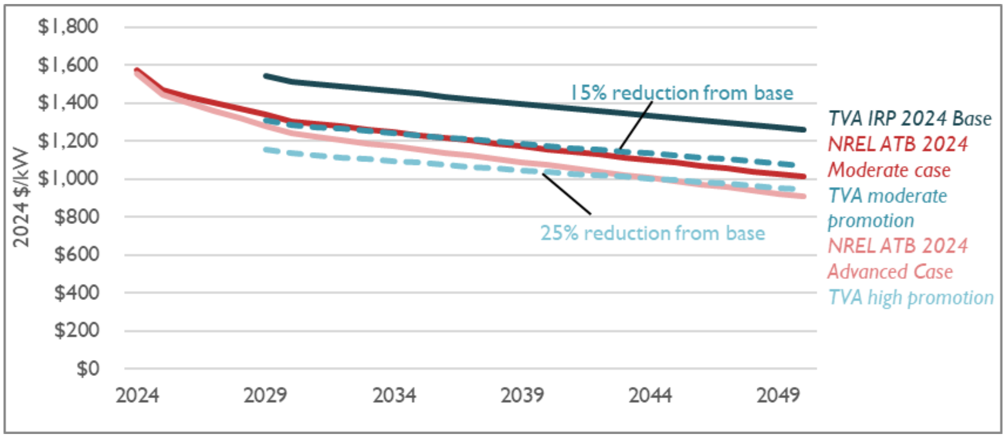
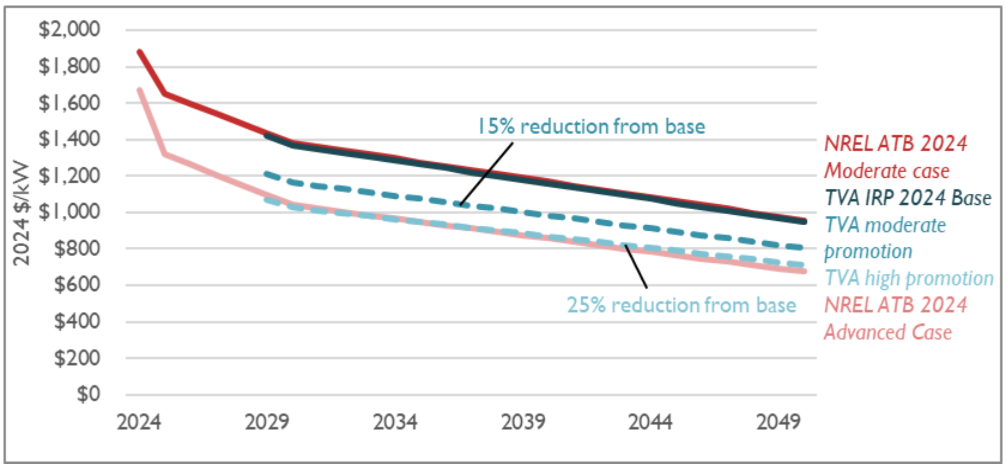


Figure 11. TVA storage promotion cases cost trajectories compared to NREL Moderate and Advanced cases



Recommendation

TVA should model technology costs for new gas resources that are more in line with industry estimates.

TVA should model NREL's Advanced cost trajectories in a wider range of scenarios to understand how lower renewable resource costs affect resource builds in a 111-compliant scenario. At the very least, TVA should model Scenario 6, which is 111 rule-compliant, with NREL's ATB Advanced cost decline trajectories.

4.5. TVA uses static and binding renewable build limits

In addition to introducing minimum build limits as part of TVA's promotion mechanism, TVA also enforces annual build limits for resources. Table 7 shows the annual build limits by resource type that TVA models for all its scenarios. Even if the MW constraints that TVA uses are not entirely unreasonable as a starting point, build limits should not be static and should change over time to reflect changes in market conditions. And where build limits are binding, TVA should be exploring the impact of relaxing the limits.

Table 7. Annual build limits by resource type

	Resources	Units	Annual Build Limits / Cumulative Build Limit	Unit Availability (First Year)
Solar	Solar (Ref Case)	*MW*	1,000	2027
	Solar (Highest promotion)	*MW*	1,850	2027
Wind	Midwest Wind	*MW*	1,000	2029
	Southeast High-hub wind	*MW*	1,000	2029
	HVDC wind	*MW*	3,000 / 3,000	2029
Storage	4-Hr battery	*MW*	500	2029
	4-Hr battery (Highest promotion)	*MW*	650	2029
	10-Hr battery	*MW*	500	2029
	10-Hr battery (Highest promotion)	*MW*	650	2029
Nuclear	APRWR	*Units*	1	2038
	Light Water SMR	*Units*	1	2033
	Gen IV SMR	*Units*	1	2041
Gas	Combined cycle	*Units*	2	2029
	Combustion turbine	*Units*	2	2029

Source: TVA Integrated Resource Plan 2025, Draft Resource Plan.

In every Scenario 6 portfolio, the model hits the solar cap of 1,000 MW and 1,250 MW (based on promotion levels) sometime in the early 2030s. Without this cap, the model would likely have built larger amounts of solar. When a model consistently builds resources up to its build limit, that indicates that the model has the capacity to economically build more of that resource. TVA should have conducted some model runs where it loosened the build constraints to allow the model to endogenously select resources on a least-cost basis. Currently, in Scenario 6 portfolios with 1,000 MW solar build limit, we see higher levels of natural gas resources being built because the model switches to gas once it reaches the annual solar limits.

For BESS, many portfolios hit the 500 MW or 650 MW cap (based on promotion strategies) in the latter parts of the modeling period. TVA should once again test how the model responds with a relaxed build limit later in the modeling period.

Recommendation

TVA should model a sensitivity that removes the solar build cap beyond 2030 and the BESS build limit later in the study period. TVA should also model sensitivities with build limits that relax over time.

TVA should justify its new gas resource costs and model scenarios with higher costs that are more in line with industry standard projections for combined cycle and combustion turbines gas resources.

5. TVA's own modeling results indicate that Strategy C represents the best balance of cost and risk minimization

In this section, we focus on the results from Scenario 6, which is the only scenario that incorporates the final 111 rule. Over the IRP planning horizon, TVA will likely face at least moderate levels of carbon regulation. Of the scenarios that TVA modeled, Scenario 6 best represents likely regulatory conditions that TVA will face going forward.

We recommend that TVA pursue Portfolio 6C—the Carbon-Free Commercial-Ready strategy optimized under Scenario 6—as its preferred portfolio. This portfolio results in the most solar compared to other strategies for Scenario 6 (19 GW by 2050, with an additional 3.8 GW of distributed solar) and it is one of the only Scenario 6 portfolios where the model builds wind (4.4 GW by 2050). As per its name, it relies on technologies that are currently deployed and available. This portfolio has the second-lowest PVRR of all the portfolios under Scenario 6, and it will offer GHG benefits while protecting ratepayers from risks related to technological uncertainty and exposure to fuel price volatility. The value of the public health and GHG benefits that Portfolio 6C provides more than outweigh its small (3 percent) increase in PVRR compared to Portfolio 6A.

In addition, we recommend that TVA select the most beneficial aspects of its other portfolios and incorporate them into the preferred portfolio. In particular, TVA should pursue the demand-side measures emphasized in Strategy D in tandem with its Strategy C resource builds to take advantage of the grid benefits they provide.

5.1. Strategy C results in more renewable and storage builds and fewer gas builds than Strategies A and B

Focusing on capacity additions over the next decade (2024–2035), Portfolios 6A, 6B, 6C, and 6D all add at least 10.1 GW of new renewable capacity, primarily utility-scale and distributed solar. Portfolio 6C, the Carbon-Free Commercial-Ready strategy, includes the most renewable capacity; it builds 11.0 GW of utility-scale solar, 2.3 GW of distributed solar, and 1.6 GW of wind by 2035. It also includes 2.9 GW of battery storage, compared to only 1.3 GW in the baseline planning portfolio (6A). The additional renewable and storage capacity in Portfolio 6C displaces the need for new gas, which is present in Portfolio 6A at nearly double the amount as in Portfolio 6C. Table 8 below summarizes cumulative capacity additions by resource type for Portfolios 6A, 6B, 6C, and 6D.

Portfolio 6B, which emphasizes innovative carbon-free technology, has roughly the same amount of incremental renewable capacity as 6A by 2035 (10.2 GW) but less battery storage and fewer gas combustion turbine additions. Instead, Portfolio 6B builds combined cycle with CCS capacity and an SMR.

Portfolio 6D includes more demand-side resources (energy efficiency and demand response) and distributed generation than the other portfolios. It includes 1.23 GW of demand-side resources by 2035 and 3.2 GW of distributed solar, compared to 0.9 GW and 1.4 GW in Portfolio 6A, respectively.

All the portfolios include the same hard-coded coal retirement dates. The model also chose to build 2.2 GW of gas CC capacity and 1.4 GW of aeroderivative combustion turbine capacity in all four portfolios.

Figure 12 and Figure 13 show annual incremental resource builds in portfolios 6C and 6A through 2050. In the last 15 years of the planning horizon (2036–2050), Portfolio 6A adds 10.4 GW of renewables (primarily utility-scale solar), 4.3 GW of battery storage, and 2.2 GW of gas combustion turbines. Portfolio 6C builds 20 percent more renewable capacity than Portfolio 6A during this time period; it adds a similar amount of solar capacity and also builds 2.8 GW of wind (compared to only 0.4 GW in Portfolio 6A).[24] The larger renewable builds in Portfolio 6C mean that it needs 21 percent less incremental gas capacity than Portfolio 6A post-2035.[25] In this time period, Portfolio 6B continues to favor new nuclear and builds 1.7 GW of SMR capacity.[26]

[24] Draft IRP data files, "incremental-capacity-tables-9-30-2024.xlsx."

[25] Id.

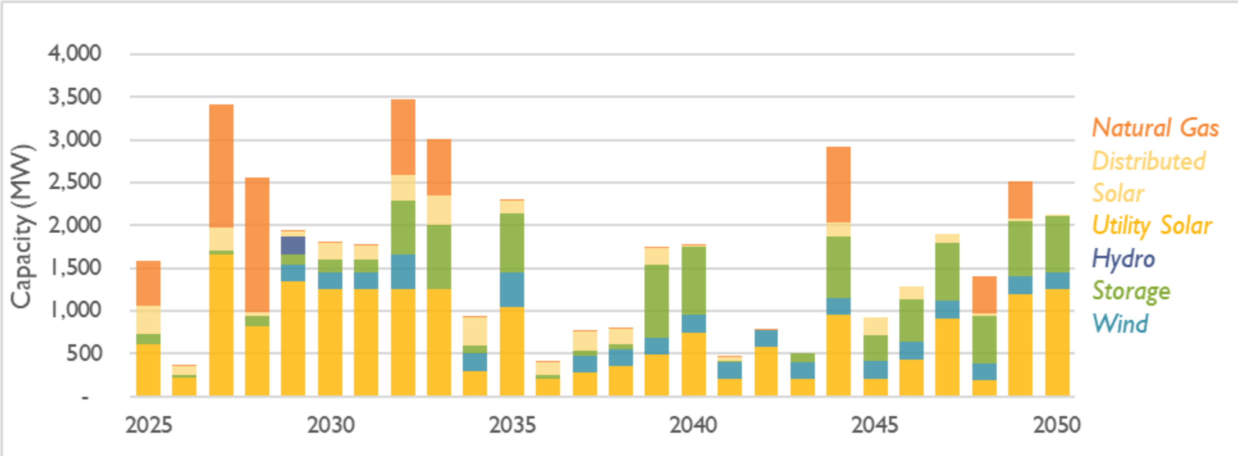
[26] Id.

Table 8. Cumulative capacity additions 2024–2035 in portfolios 6A, 6B, 6C, and 6D

	6A: Baseline Planning	6B: Carbon-Free Innovative Tech	6C: Carbon-Free Commercial-Ready	6D: Demand-Side and Distributed Generation
Renewables	**10.14**	**10.18**	**15.08**	**10.47**
Utility Solar	8.51	7.71	11.01	7.11
Distributed Solar	1.44	2.27	2.27	3.16
Wind	0.00	0.00	1.60	0.00
Hydro	0.20	0.20	0.20	0.20
Storage	**1.26**	**1.03**	**2.93**	**2.63**
Short-Duration Battery	1.08	0.43	2.33	1.18
Distributed Battery	0.18	0.60	0.60	1.45
Demand-side	**0.89**	**1.06**	**1.06**	**1.23**
Demand Response	0.86	1.00	1.03	1.16
Energy Efficiency	0.04	0.07	0.04	0.07
Nuclear	**0.00**	**0.57**	**0.00**	**0.00**
Light Water SMR	0.00	0.57	0.00	0.00
Gas	**6.88**	**6.76**	**5.11**	**5.16**
Gas combined cycle	2.15	2.15	2.15	2.15
Combined cycle with CCS	0.00	1.43	0.00	0.00
Frame combustion turbine	3.32	1.77	1.55	0.88
Aeroderivative combustion turbine	1.38	1.38	1.38	1.38
Distributed combined hear and power (CHP)	0.04	0.04	0.04	0.75

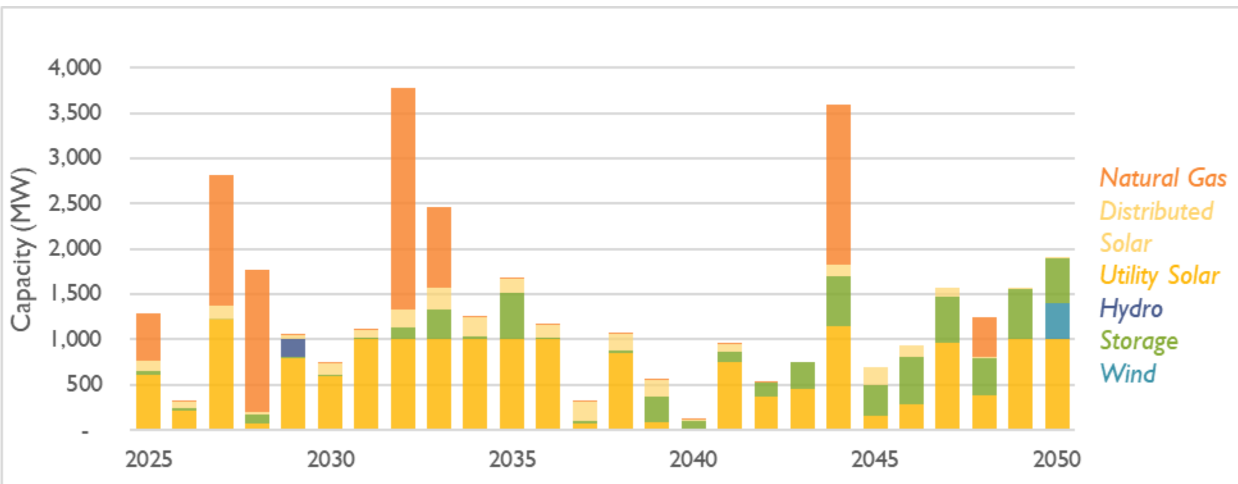
Source: Draft IRP data files, "incremental-capacity-tables-9-30-2024.xlsx."

Figure 12. Scenario 6 Strategy C incremental renewable builds



Source: Draft IRP "incremental-capacity-tables-9-30-2024.xlsx." Note that storage includes distributed battery builds.

Figure 13. Scenario 6 Strategy A incremental renewable builds



Source: Draft IRP "incremental-capacity-tables-9-30-2024.xlsx." Note that storage includes distributed battery builds.

5.2. TVA's scorecard shows that Strategy C offers cost and risk benefits compared to Strategy B

TVA's scorecard metrics show that the Strategy C, the Carbon-Free Commercial-Ready strategy, offers lower cost and risks compared to the other strategies TVA compared. This is particularly applicable to Strategy B, which emphasizes low-carbon technologies that are not yet commercial-ready (Table 9).

Table 9. Key scorecard metrics for portfolios 6A, 6B, and 6C

Portfolio	PVRR (Billions 2024$)	Risk Exposure (Billions 2024$)	Carbon Dioxide Emissions (Million tons)
6A	$156	$15.6	30
6B	$180	$13.7	24
% difference from 6A	15%	-12%	-20%
6C	$160	$13.1	25
% difference from 6A	3%	-16%	-17%

Source: TVA Integrated Resource Plan 2025, Draft Resource Plan at I-1, I-2, and J-1.

Of the five portfolios that TVA developed under Scenario 6, Portfolio 6C has the second-lowest PVRR. The only portfolio that has a lower PVRR is 6A, which is the portfolio that represents baseline utility planning. This makes sense, because 6A is the portfolio in which resource additions are fully optimized, since TVA did not include any cost promotions in Strategy A. Importantly, the PVRR of Portfolio 6C is only 3 percent higher than Portfolio 6A, and it would likely be lower cost than 6A if resource costs were to fall according to the Advanced NREL trajectory, which is not a scenario that TVA tested in its modeling.

Even if costs do not fall according to NREL's Advanced trajectory, Strategy C offers benefits to ratepayers over Strategy A that more than outweigh its 3 percent PVRR premium. Portfolios with more wind, solar, and battery storage have less generation from fossil fuel resources, which results in lower GHG emissions and lower toxic air pollutant emissions. This yields public health benefits and GHG emissions reduction benefits, as we discuss in more detail in the next section.

Strategy C also shields ratepayers from risk because it relies on commercially proven technologies such as solar, wind, and battery storage. TVA's risk exposure metric, which it calculated based on stochastic modeling, shows that 6C is the least financially risky of the Scenario 6 portfolios and offers a substantial benefit over baseline utility planning (16 percent reduction in the risk metric compared to portfolio 6A).[27] Solar cost and technological performance are established, even though costs are still declining. Additionally, due to the nature of solar PV, which does not rely on purchased fuel inputs, there is no risk of a future price increase once solar is installed. Because solar, wind, and battery storage are non-emitting, they reduce the risk to TVA ratepayers of future environmental compliance costs.

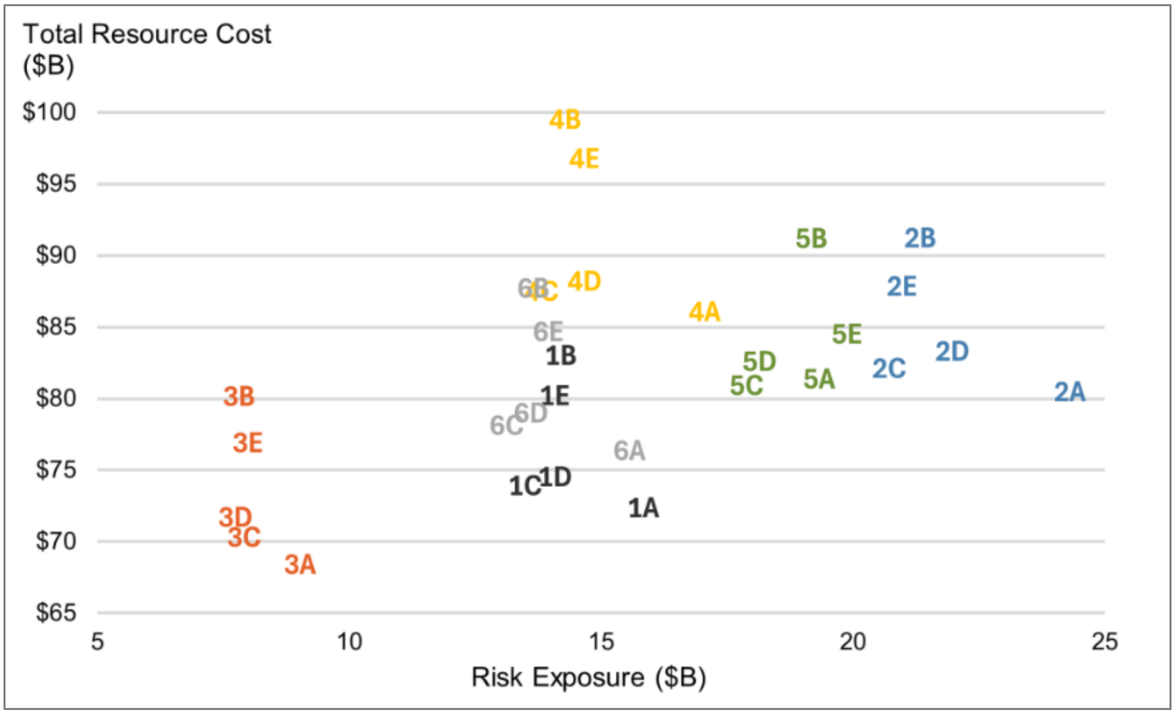
Strategy B is both more expensive and riskier than alternatives such as Strategies A and C, mainly because it relies on less proven technologies such as SMRs and gas with CCS. In Strategy 6, the PVRR of Portfolio 6B is 15 percent higher than 6A, while the risk is 12 percent lower. The technologies that Strategy B emphasizes, such as SMRs and gas with CCS, pose risks of cost-overruns and/or technological under-performance. It is not clear that TVA considered these risks in its stochastic analysis, meaning that

[27] TVA Integrated Resource Plan 2025, Draft Resource Plan at I-2.

costs could be even higher than TVA's modeling currently shows. Further, if CCS capture rates are lower than expected, GHG emissions could be higher. Reliance on combined cycle gas plants with CCS also leaves ratepayers exposed to fuel price volatility.

Strategy C's advantages over Strategy B are consistent across all six scenarios that TVA modeled (Figure 14), meaning that it is robust across different levels of load growth. Strategy C has the second-lowest or lowest total resource cost across all six scenarios, while Strategy B has the highest total resource cost across all scenarios. Strategy C also consistently scores as the least-risky option (except in Scenario 3, which uses an outdated version of the 111 rule).

Figure 14. Cost and risk tradeoff for TVA's modeled portfolios



Source: TVA Integrated Resource Plan 2025, Draft Resource Plan at 4-25.

Recommendation

TVA should pursue Portfolio 6C, the Carbon-Free Commercial-Ready strategy in a future with moderate GHG regulation, as the basis for its preferred portfolio, and it should focus its near-term investment on commercially deployed technologies such as solar PV and BESS. It should also incorporate cost-effective energy efficiency and demand response into its preferred portfolio.

6. SOCIETAL AND PUBLIC HEALTH IMPACTS ARE MINIMIZED UNDER THE COMMERCIAL-READY RENEWABLE STRATEGY C

TVA compared the portfolio results across several metrics but did not include social impacts from avoided GHG emission in its IRP scorecard. The company did calculate SCC values for the Environmental Impact Statement (EIS) that accompanies the IRP, but these were not included in the revenue requirement calculations. In addition, TVA did not evaluate public health impacts from avoided toxic air pollutants in any scenarios.

To understand the magnitude of social and health impacts expected from TVA's portfolio, we calculated the monetary impact of GHG emissions using the SCC for portfolios 6A and 6C. We then estimated the difference in public health impacts of Portfolios 6A and 6C using the COBRA model, published by EPA. COBRA is used to estimate health impacts and benefits from changes in nitrogen oxide, sulfur dioxide, and direct particulate matter emissions.

6.1. Portfolio 6C avoids $28 billion of carbon-related damages compared to Portfolio 6A, making 6C cheaper than 6A in PVRR terms

Power plant GHG emissions have long-lasting societal impacts that are not internalized or incorporated into traditional utility revenue requirement calculations.

The SCC quantifies the current and future damages associated with emitting carbon dioxide, methane, and nitrous oxide into the atmosphere. TVA conducted some SCC analysis for its draft EIS but did not incorporate the monetized fundings into its scoring of portfolios in the draft IRP.[28] We reviewed TVA's SCC methods and results and also calculated our own version. Based on our own analysis, we find that Portfolio 6C avoids $28 billion (in 2024$) of carbon-related damages compared to Portfolio 6A.[29]

In the EIS, TVA calculates the SCC for each portfolio for all emissions including upstream, combustion, ongoing non-combustion, and downstream emissions for 2024–2050. It uses two different SCC frameworks: the White House 2021 Estimates and the EPA 2023 Estimates. In our review, we focused on replicating the EPA SCC valuation.

Based on the EPA SCC valuation, TVA finds that the net present value (2024$) of the SCC for Portfolio 6A (baseline) is $158 billion, and for Portfolio 6C (Carbon-Free Commercial Ready) is $140 billion, a difference of $17.8 billion. This suggests that TVA sees Portfolio 6C as avoiding $17.8 billion of carbon-related damages compared to Portfolio 6A. This is an meaningful difference when viewed in the context

[28] We note that TVA also included, in its draft IRP, an SCC analysis specifically to estimate impacts of a carbon tax after 2034 in Scenarios 4 and 5.

[29] TVA's SCC results are available in TVA's GHG Life Cycle Emissions tables.

of the PVRR of each portfolio.[30] Portfolio 6A has a PVRR of $156 billion, and Portfolio 6C has a PVRR of $160 billion, making Portfolio 6C roughly $4 billion more expensive.[31] If TVA internalized its own SCC calculations, the difference would more than compensate for the higher expenses in Portfolio 6C, making Portfolio 6C the less expensive portfolio by $13.8 billion (Table 10).[32]

Table 10. PVRR comparison of Portfolios 6A and 6C with Social Cost of Carbon

	PVRR	PV Social Cost of Carbon (2024$)	PVRR with SCC
Portfolio 6A	$156 billion	$17.8 billion	$173.8 billion
Portfolio 6C	$160 billion	$0	$160 billion
Difference	($4 billion)	$17.8 billion	$13.8 billion
Less Expensive Portfolio	Portfolio 6A	Portfolio 6C	Portfolio 6C

On top of this, we found that TVA uses a higher discount rate than would be advisable to discount the carbon-related damages. Higher discount rates place less value on future harm than lower discount rates, and then undercount future damages. TVA was not transparent in providing its discount rate assumptions, but we reproduced TVA's analysis to back out its assumed discount rate.[33] Based on this analysis we found that TVA used a real discount rate of 4.64 percent. This is a full 2.64 percent higher than the social discount rate of 2 percent recommended by the White House Office of Management and Budget for use by federal agencies.[34,35] This results in TVA undercounting the incremental social harm of Portfolio 6A (baseline) by $9.8 billion (2024$) (Table 11) relative to if had used a lower (2 percent) discount rate.[36] This suggests that if TVA incorporated the results of the SCC analysis into its PVRR of

[30] This is a metric (in 2024$) TVA uses to assess various portfolios on being low-cost.

[31] TVA Integrated Resource Plan 2025, Draft Resource Plan Table 4-7: Scenario 6 Scorecard (Reference with Greenhouse Gas Rule).

[32] Similarly, the Total Resource Cost (TRC), another low-cost metric TVA uses to score the portfolios, would show Portfolio 6C as cheaper than Portfolio 6A with the SCC incorporated.

[33] We used Excel's "Solver" to calculate the discount rate that would give the 2024–2050 differences between the social cost of Portfolios 6A and 6C (2024$) an NPV of $17.8 Billion (using the unrounded numbers), which was TVA's NPV. This discount rate was 4.641%.

[34] White House Council of Economic Advisors, "Valuing the Future: Revision to the Social Discount Rate Means Appropriately Assessing Benefits and Costs," February 27, 2024, https://www.whitehouse.gov/cea/written-materials/2024/02/27/valuing-the-future-revision-to-the-social-discount-rate-means-appropriately-assessing-benefits-and-costs/.

[35] "White House Circular No. 4-A," November 9, 2023, https://www.whitehouse.gov/wp-content/uploads/2023/11/CircularA-4.pdf.

[36] We multiplied the lifecycle emissions (ST) for each of 6A and 6C by the 2023 EPA social cost values (provided in 2020$/MT but converted to 2024$/ST). The emissions data are found in TVA's GHG Life Cycle Emissions tables. The social cost values are from the "EPA Report: Social Cost of Carbon, Methane, and Nitrous Oxide under Executive Order 13990" referenced in TVA's GHG Life Cycle Emissions tables. We adjusted the dollar year to make the analyses comparable. We used TVA's inflation inputs from 2020–2024. We summed across carbon dioxide, methane, and nitrous oxide values to find the total annual social cost of emissions for 6A and 6C over 2024–2050, and then found the annual difference between the two portfolios. We then calculated the net present value of the stream of 2024–2050 costs using the 2 percent social discount rate.

portfolios and used an appropriate discount rate of 2 percent, Portfolio 6C would cost $23.6 billion less than Portfolio 6A (Table 12). As a federal entity, TVA should value future costs using the federal social discount rate.

Table 11. The present value of social costs is lower with Portfolio 6C (Carbon-Free Commercial Ready) versus Portfolio 6A (baseline)

	Recommended 2% Discount Rate	TVA 4.64% Discount Rate	Difference due to discount rate choice
Portfolio 6A (2024$)	$206 billion	$158.1 billion	$47.9 billion
Portfolio 6C (2024$)	$178.4 billion	$140.3 billion	$38.1 billion
Costs Avoided with Portfolio 6C over Portfolio 6A (2024$)	**$27.6 billion**	**$17.8 billion**	**$9.8 billion**

Table 12. PVRR comparison of Portfolios 6A and 6C with social cost of carbon at 2% discount rate

	PVRR of portfolio without SCC	PV SCC (2024$) at 2%	PVRR of portfolio with SCC at 2%
Portfolio 6A	$156 billion	$27.6 billion	$183.6 billion
Portfolio 6C	$160 billion	$0	$160 billion
Difference	(-$4 billion)	$27.6 billion	$23.6 billion
Less Expensive Portfolio	Portfolio 6A	Portfolio 6C	Portfolio 6C

More broadly, monetizing the SCC is aligned with TVA's stated purpose to address the "Valley's most important issues in energy, environmental stewardship, and economic development" – aims that require serious consideration of threats to the Valley's health and development.[37]

6.2. Public health benefits are driven by differences in emissions across portfolios

One subset of social impacts is health impacts. The COBRA model produces a range of estimated health outcomes and benefits. Specifically, the model provides a low and a high value to capture uncertainties in the impacts of changing air quality. The EPA uses data from peer-reviewed public health studies to develop the Low and High values.[38] The benefits shown reflect the national-level benefits that will be realized based on the portfolios adopted in the TVA region. This reflects benefits to residents of the TVA region and nearby states. Of the total benefits, around 30 percent are in Tennessee and 33 percent in other six states served by TVA (Alabama, Georgia, Kentucky, Mississippi, North Carolina, and Virginia).

[37] TVA, "Our History," https://www.tva.com/about-tva/our-history#:~:text=Signed%20in%201933%2C%20the%20Tennessee,the%20agricultural%20and%20industrial%20development.

[38] OAR US EPA, "COBRA Questions and Answers," Data and Tools, March 17, 2021, https://www.epa.gov/cobra/cobra-questions-and-answers.

Table 13. Public health benefits related to choosing Portfolio 6C instead of 6A

Health Metric	2030	2040	2050	Cumulative (2024–2050)
Benefits, Low Estimate (Millions 2024$)	$257	$170	$195	$4,288
Benefits, High Estimate (Millions 2024$)	$443	$262	$302	$6,825
Mortality Avoided, Low Estimate	16	11	12	271
Mortality Avoided, High Estimate	29	17	19	443

The health benefits result from different emissions levels in each portfolio, which are determined by the amount of combustion-based generation, primarily from coal, gas, and gas with CCS resources. Table 14 shows the difference in cumulative generation from 2024–2050 for each resource type, relative to the corresponding Strategy A portfolio. For example, Portfolio 6C has 235 TWh less gas generation than Portfolio 6A from 2024–2050. Portfolios with less generation from fossil-fuel-fired resources have higher health benefits. Since all the portfolios retire all coal generation by 2033, benefits beyond this year are due strictly to differences in gas plant generation levels.

Table 14. Difference in generation by resource type relative to Strategy A (TWh)

Scenario	Resource	Strategy B	Strategy C	Strategy D	Strategy E
1	**Gas**	-394	-335	-91	-135
	Coal	0	-4	-4	0
	Combined cycle with CCS	177	0	0	0
2	**Gas**	-455	-379	-60	-170
	Coal	-1	1	1	1
	Combined cycle with CCS	167	0	0	0
3	**Gas**	-221	-86	59	16
	Coal	-2	-1	-5	-3
	Combined cycle with CCS	-15	-176	-176	-176
4	**Gas**	-12	-35	-19	-14
	Coal	-1	-2	-5	-2
	Combined cycle with CCS	-23	-33	-5	-5
5	**Gas**	0	-31	-25	-3
	Coal	5	2	2	0
	Combined cycle with CCS	-6	-25	-11	4
6	**Gas**	-302	-235	-39	-90
	Coal	0	-6	-4	0
	Combined cycle with CCS	164	0	0	0

Source: Draft IRP data files, "total-energy-and-co2-emissions-tables.xlsx."

To convert the differences in generation into differences in particulate matter emissions, we calculated an emissions rate for each fuel, derived from EPA Emissions & Generation Resource Integrated Database (eGRID) data.[39] We divided the annual emissions for each particulate by the annual generation for plants of each fuel type in the TVA region to get an average emission rate for each fuel type. Then, we multiplied the generation numbers in Table 14 by this emissions rate to get the estimated differences in particulate matter emissions for each fuel and summed the coal and gas results to get the total differences in pollution. The results are shown in Table 15 below.

Table 15. Differences in emissions by year between Portfolio 6C and 6A (short tons)

Pollutant	2030	2033	2040	2045	2050
Particulate matter	-526	-250	-289	-287	-332
Sulfur dioxide	-1,146	-201	-232	-231	-267
Nitrogen oxide	-1,257	-997	-1,153	-1,146	-1,326

6.3. Public health benefits wash out the difference in PVRR between Portfolio 6C and 6A

To put the magnitude of health benefits in context, we compare the NPV of the cumulative benefits from the COBRA analysis to the difference in the PVRR between the portfolios. The difference in PVRR of Portfolios 6C and 6A is approximately $4 billion (Table 9). Assuming the EPA's 2 percent discount rate, the public health benefits gained by choosing 6C over 6A amount to between $3.2 billion and $5.2 billion. Those public health benefits are in the same range as the PVRR delta. This means that if TVA had considered the health impacts of the different portfolios as part of the overall portfolio cost, it would have found essentially no difference in cost between Portfolio 6A and 6C.

Table 16. NPV of cumulative health benefits between Portfolios 6C and 6A as a percentage of the difference in PVRR between Portfolios 6C and 6A

	2% Discount Rate, Low Estimate	2% Discount Rate, High Estimate	7% Discount Rate, Low Estimate	7% Discount Rate, High Estimate
NPV of Benefits (Millions 2024$)	$3,221.00	$5,155.47	$1,750.10	$2,840.42
% of PVRR Difference	81%	129%	44%	71%

Recommendation

TVA should include consideration of the social and health impacts of each portfolio in its evaluation metrics and quantify the difference between portfolios.

[39] OAR US EPA, "Emissions & Generation Resource Integrated Database (eGRID)," Collections and Lists, July 27, 2020, https://www.epa.gov/egrid.

TVA should quantify the social cost of GHG emissions associated with each of its portfolios and take these costs into account on its scorecard.

7. CONCLUSION

Synapse reviewed TVA's Draft IRP based on publicly available information and outlined a number of key recommendations for TVA to consider in finalizing its IRP. Our recommendations are focused on several aspects of the IRP: modeled Scenarios and Strategies, Modeling Inputs, and IRP Results.

For Scenarios and Strategies, Synapse finds that TVA should model a more representative range of scenarios that feature NREL's ATB Advanced resource cost assumptions, develop a long-term resource plan that offers a more comprehensive view of supply- and demand-side resources, and choose a preferred portfolio and a short-term action plan based on its resource additions. Additionally, in the Final IRP, TVA should present the NPV results of the portfolios both before and after the "promotion" adders are incorporated in post-processing to better communicate its results.

For Modeling Inputs, Synapse recommends TVA take a number of steps to increase precision and reduce bias in its modeling assumptions and methods. Synapse suggests more research to inform assumptions around variables such as data center load growth, more sensitivities such as one that removes the solar build cap, revisions to some cost trajectories such as those used for new gas resources, and more careful quantification of the costs and risks associated with advanced technologies such as CCS and SMRs. Please see the report for additional recommendations from the Model Inputs section.

For Final Results, Synapse finds that TVA should pursue Strategy C (Carbon-Free Commercial Ready) as the basis for its preferred portfolio. TVA should focus its near-term investments on commercially viable resources including solar PV and BESS. Finally, TVA should include consideration of the societal and health impacts, including the social cost of GHG emissions, of each portfolio in its evaluation scorecard.