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Cumberland Retirement EIS: Alternatives Evaluation

Enterprise Planning

April 2022

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TVA Asset Strategy Overview

TVA's asset strategy incorporates the strategic direction from the 2019 Integrated Resource Plan and continues to support affordable, reliable, and cleaner energy for the customers we serve.

Highlights from the asset strategy include:

Maintaining the existing low-cost, carbon-free nuclear and hydro fleets

Retiring aging coal units as they reach the end of their useful life, expected by 2035

Adding 10,000 MW of solar by 2035 to meet customer and system needs, complemented with storage

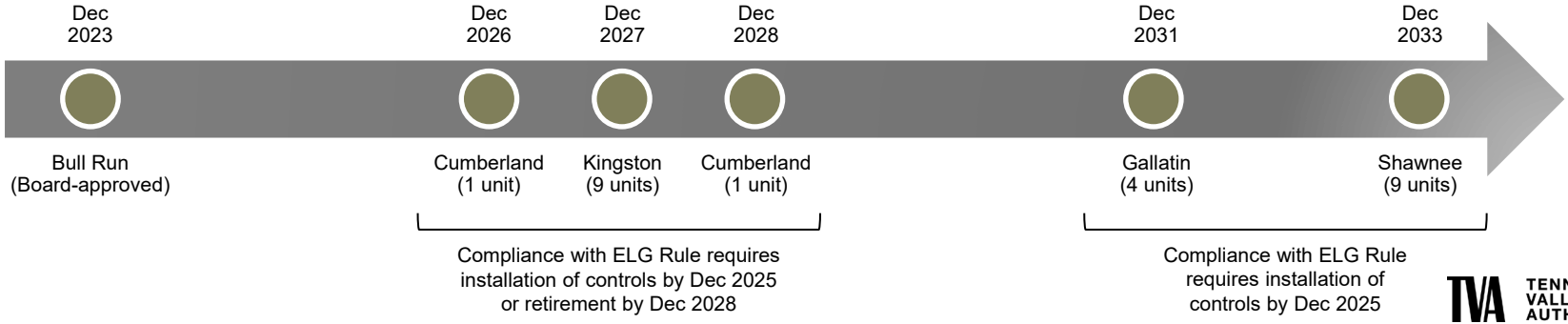
Using natural gas to enable needed coal retirements and solar expansion

Leveraging demand-side options, in partnership with local power companies

Partnering to develop new carbon-free technologies for deeper decarbonization

Coal Fleet End-of-Life Evaluations

- The 2019 IRP acknowledged the potential for coal retirements and recommended a near-term action to evaluate end-of-life dates for aging fossil units to inform planning.
- Evaluations assessed the cost, reliability, and environmental implications associated with continued operation of TVA's coal fleet and concluded that it is:
  - Among the oldest in the nation (Cumberland 1973, all other plants 1950s vintage);
  - Experiencing material condition and performance challenges, especially Cumberland and Kingston
  - Projected to have increasing performance challenges due to lack of portfolio fit;
  - Contributing to environmental, economic, and reliability risks
- Retirement planning assumptions were developed based on relative unit condition and fit, as well as the time required to build replacement generation, subject to further evaluation in environmental reviews under the National Environmental Policy Act (NEPA).



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Project Purpose and Need and Project Alternatives

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Project Purpose and Need

TVA's 2019 Integrated Resource Plan (IRP) acknowledged continued operational challenges for the aging coal fleet and included a recommendation to conduct end-of-life evaluations on TVA's remaining coal plants.

TVA's recent evaluations confirm:

The aging coal fleet is among the oldest in the nation and is experiencing deterioration of material condition and performance challenges.

TVA has developed planning assumptions for Cumberland Fossil Plant (CUF) unit retirements.

TVA proposes to retire one CUF unit as early as 2026, but no later than 2030, and the other unit as early as 2028, but no later than 2033, dependent on when replacement generation could be constructed and brought online.

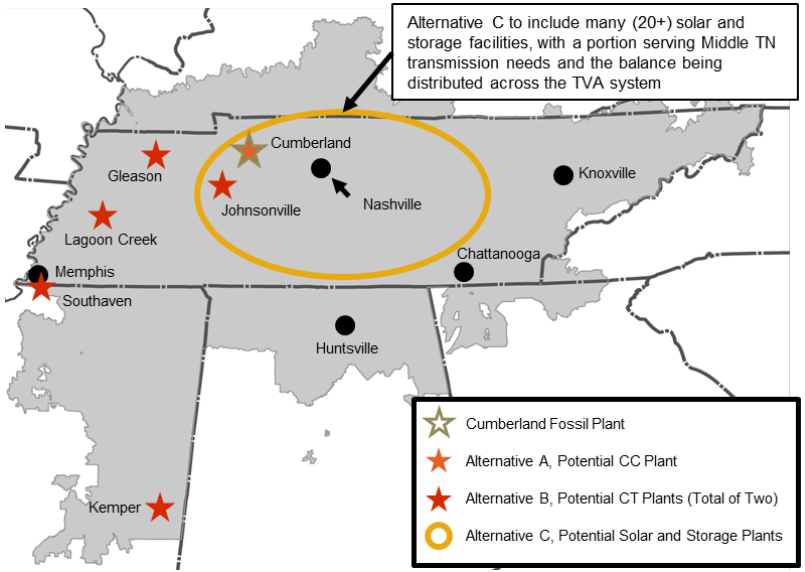
Project Action Alternatives

The Cumberland Fossil Plant (CUF) Retirement EIS includes various action alternatives, in addition to the no action alternative. To recover the generation capacity lost from retirement of the first CUF unit*, TVA staff evaluated the following alternatives for replacement generation:

A Retirement of CUF and construction and operation of a Combined Cycle Combustion Turbine (CC) Gas Plant on the CUF reservation

B Retirement of CUF and construction and operation of Two Simple Cycle Combustion Turbine (CT) Gas Plants at alternate locations

C Retirement of CUF and construction and operation of Solar and Storage Facilities, primarily at alternate locations



*All action alternatives include the demolition of CUF

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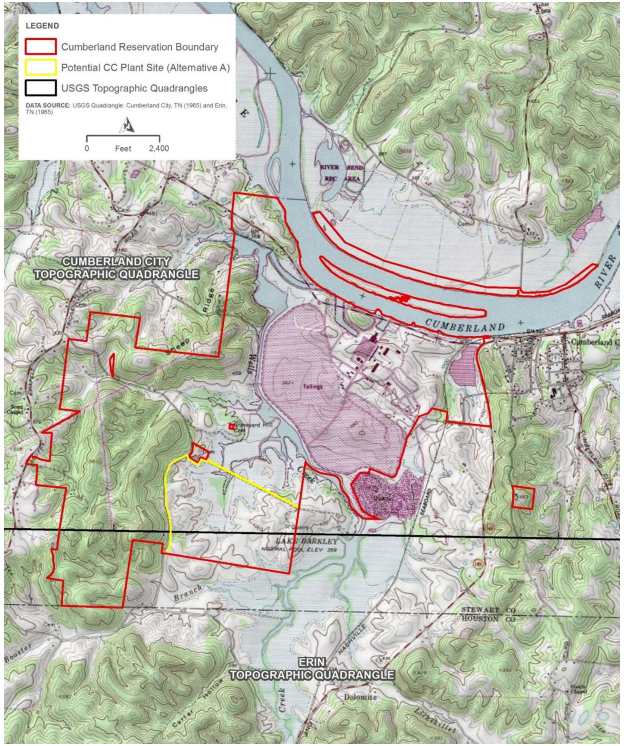
Alternative A: Retire CUF and Construct CC Gas Plant

- Retirement of one CUF unit as soon as 2026, but no later than 2030, and the other CUF unit as soon as 2028, but no later than 2033, with demolition to follow
- Construction and operation of a Combined Cycle (CC) Gas Plant on the CUF reservation to replace the output of the first unit, with later evaluation for the second unit's replacement
- CC plant would be associated with an estimated 32-mile pipeline lateral to secure fuel supply, with proposed route largely along an existing transmission line corridor
- The construction of the natural gas pipeline(s) under Alternative A would be subject to Federal Energy Regulatory Commission (FERC) jurisdiction and additional review will be taken by FERC in accordance with its own NEPA procedures.



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Alternative A: Combined Cycle Plant at Cumberland

- Combined cycle (CC) plants are effective in baseload or intermediate operations with high fuel efficiency, relatively low construction costs, and flexible operations
- CC plants can provide grid support, follow load, and are fully dispatchable year-round
- The ability of CC plants to ramp up and down throughout the day is increasingly important as TVA integrates about 10,000 MW of solar by 2035
- Alternative A includes a 1,450 MW CC plant to recover the dependable capacity of the first retiring CUF unit as well as account for modest load forecast increases
- The Cumberland Reservation offers several key benefits:
  - Existing TVA property
  - Existing transmission interconnection to the TVA system, which can largely be repurposed
  - Nearby to a major interstate natural gas pipeline with adequate capacity and potential to generally locate proposed pipeline lateral along existing transmission line corridor
  - Favorable air permitting prospects

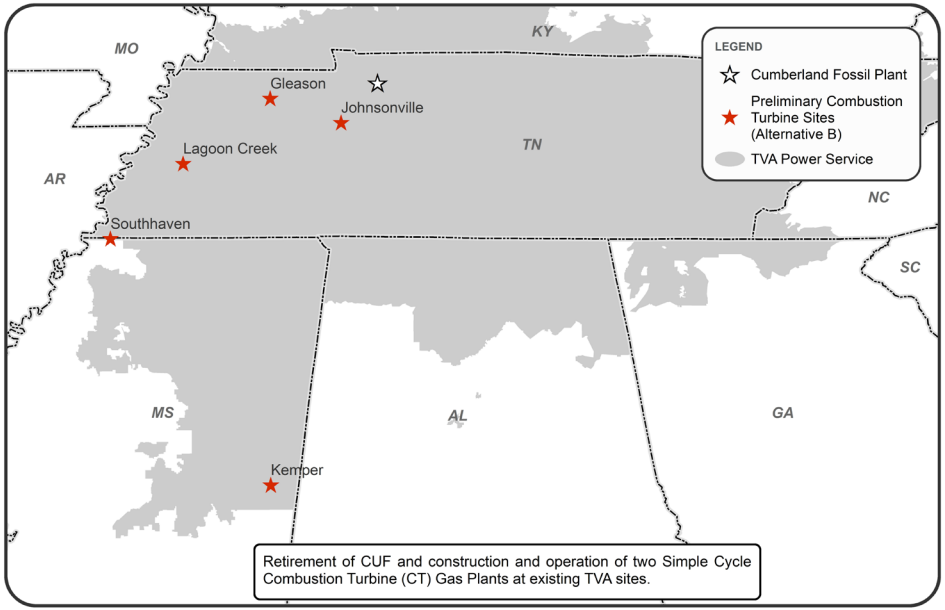
Alternative B: Retire CUF and Construct CT Gas Plants

- Retirement of one CUF unit as soon as 2026, but no later than 2030, and the other CUF unit as soon as 2028, but no later than 2033, with demolition to follow

- Construction and operation of two Simple Cycle Combustion Turbine (CT) Gas Plants to replace the output of the first unit, with later evaluation for the second unit's replacement

- Preliminary potential locations were TVA brownfield sites with existing gas generation and transmission interconnection

- Sites may require upgrades or expansions to pipeline laterals as well as transmission upgrades for interconnection



Alternative B: Combustion Turbine Plants at Johnsonville and Gleason

- Simple cycle combustion turbine (CT) plants are peaking units with the ability to start and ramp quickly, typically have the lowest installed capital cost per MW, and offer flexible operations
- CT plants can provide grid support and are fully dispatchable year-round
- CT unit flexibility and dispatchability is increasingly important as TVA integrates about 10,000 MW of solar by 2035
- Alternative B includes two CT plants with a combined total of 1,530 MW to recover the dependable capacity of the first retiring CUF unit as well as account for modest load forecast increases
- The Johnsonville and Gleason Reservations offer several benefits:
  - Existing TVA property
  - Existing transmission interconnection to the TVA system, which can reduce costs to interconnect new facilities
  - Existing natural gas pipeline infrastructure which can be used or upgraded to supply additional generation

Alternative C: Retire CUF and Construct Solar & Storage

- Retirement of one CUF unit as soon as 2026, but no later than 2030, and the other CUF unit as soon as 2028, but no later than 2033, with demolition to follow
- Construction and operation of many (20+) solar and storage facilities to replace the generation and capacity of the first unit, with later evaluation for the second unit's replacement
- Alternative uses generic site analysis and assumes procurement via competitive request for proposal (RFP) process with a power purchase agreement (PPA) structure*, subject to site-specific NEPA review
- It is anticipated that a portion of the storage facilities will need to be located in Middle Tennessee for regional grid support, with the balance located elsewhere in the Valley

*If this alternative is selected a portion of these facilities could be TVA constructed and operated as well, subject to site-specific NEPA review

Alternative C: Solar and Battery Storage Facilities

- Solar resources are becoming more competitive on a cost per MWh basis; however, they are not dispatchable and generation is intermittent in nature, varying by time of day, weather, and season
- Solar additions tied to a replacement of the first CUF unit would need to be in addition to the ~10,000 MW already included in TVA's base plans
- In order to provide dependable peak capacity needs for the TVA system, solar generation must be paired with dispatchable resources, such as storage or gas
- Battery energy storage systems (BESS) typically represent one of the lowest cost storage options today, with four-hour BESS systems providing an attractive balance of price, output, and duration
- The combination of utility-scale solar and battery storage would provide a carbon-free alternative to replace the energy and capacity of the first CUF unit
- Alternative C includes 3,000 MW of solar and 1,700 MW of battery storage to recover the generation and dependable capacity of the first retiring CUF unit as well as account for modest load forecast increases

Alternative C Development

- Solar evaluation
  - TVA Staff began by replacing the average annual energy output of a CUF unit with solar, with consideration for differences in annual capacity factor
  - Analysis indicated a need for ~3,000 MW of additional solar to replace the annual energy of the first CUF unit, on top of the ~10,000 MW of solar already included in the base plan

- Storage evaluation
  - The TVA system is dual-peaking, meaning that it experiences peak loads in both summer (typically late afternoon) and winter (typically early morning, just before dawn)
  - Battery storage (typically lithium-ion) is currently the lowest cost option for additional storage capacity, which would ensure TVA's winter capacity reserves are maintained with the retirement of the first CUF unit
  - Storage systems are energy-limited, with typical utility-scale battery systems configured for 4 hours at full output
  - TVA staff utilized the SERVM model to determine what level of storage would maintain industry standard reliability of 1 Loss-of-Load-Event (LOLE) in 10 years, with risk spread equally between summer and winter
  - Analysis indicates that ~1,700 MW of battery energy storage, paired with ~3,000 MW of additional solar capacity, will maintain a 0.1 LOLE with balanced seasonal risk with the retirement of a CUF unit*

**For reference, alternative A's CC option (as modeled) is 1,529 MW (winter, Net Dependable Capacity)*

Alternatives Considered, but Dismissed

Resource Option	Reasoning
Hydro Pumped Storage	Long-duration storage that is currently being studied by TVA for further evaluation and potential deployment in the early 2030s. Longer timelines to meet environmental requirements and for construction are incompatible with timeframe proposed for the first unit retirement at CUF.
Small Modular Reactors (SMR)	Potential to serve cost-effective baseload or load following needs in the future with low fuel costs, carbon-free generation, advanced passive safety systems, and anticipated cost reductions achieved by assembling components in a factory setting. Longer construction timeline and first of kind deployment risks are incompatible with the needs of this project.
In- and/or Out-of-Valley Wind	Wind can provide dependable capacity in both summer and winter, though intermittent. Was not selected due to low wind speeds in Tennessee Valley and higher transmission costs for out-of-Valley wind, both of which increase relative costs.
Energy Efficiency (EE)	EE is well-positioned to help TVA absorb load growth resulting from increased electrification of the economy; however, EE programs take time to scale and market, while also facing increasing costs for higher depth and penetration levels.
Demand Response (DR)	DR is well-positioned to help TVA absorb load growth resulting from increased electrification of the economy and allow TVA to offset physical capacity needs; however, they are limited in the number of calls available.

Distributed generation (e.g., distributed solar, storage, and/or wind) was also considered, however the cost for distributed generation is generally higher than utility-scale generation for the same type of resource. TVA has therefore determined that the combination solution of utility-scale solar paired with utility-scale storage as presented in Alternative C provides a feasible lower-cost solution.

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Evaluation Results and Preferred Alternative

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Evaluation Approach

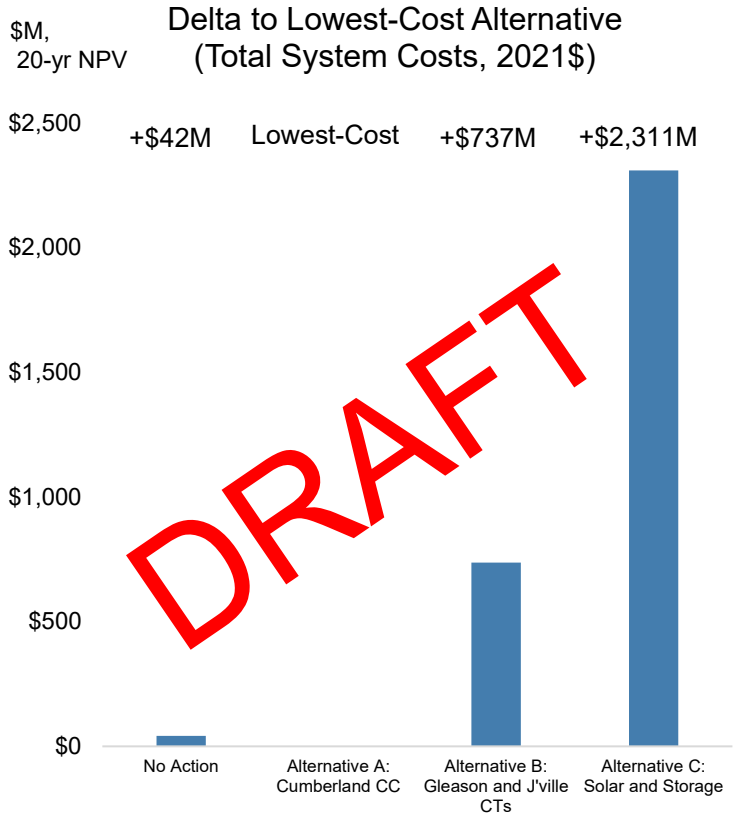
TVA staff utilized the FY22 Budget Power Supply Plan as the basis for the CUF Retirement EIS Alternatives analysis. For each alternative, a 20-year study was performed using TVA's expansion and production cost models.

Alternative	Retirements*	First CUF Replacement^
No Action	• No CUF retirements	• N/A
Alternative A	• 12/31/2026: CUF, 1 unit • 12/31/2028: CUF, 1 unit	• Cumberland CC (1,453 MW, Summer)
Alternative B	• 12/31/2026: CUF, 1 unit • 12/31/2028: CUF, 1 unit	• Johnsonville CT (875 MW, Summer) and Gleason CT (656 MW, Summer)
Alternative C	• 12/31/2026: CUF, 1 unit • 12/31/2028: CUF, 1 unit	• Solar PPA (3,000 MW) and Battery Storage (1,700 MW) • Projects are assumed to come online in phases over three years

**Retirement dates are assumed to on or before December 31st of the year indicated, replacement project must be in place at the time of retirement*

^Replacement generation for the second CUF unit will be further studied in a subsequent review, this study includes planning assumptions from the FY22 Budget

Total System Costs Comparison



- Total system costs include all capital, fixed, variable, and fuel costs associated with running the TVA system, as well as spending associated with requisite pipeline and/or transmission upgrades
- No Action Alternative incorporates additional spend at CUF to maintain reliability and meet known environmental compliance obligations (e.g., ELG Rule*); substantial risks related to evolving and future regulatory requirements and material condition remain
- Alternative A is the lowest-cost; it includes CC plant construction and operation, pipeline lateral costs, and limited transmission upgrades
- Alternative B includes CT plant construction and operation, minor fuel supply upgrades, and transmission upgrades; extensive 500kV system upgrades would result in a 2- to 4-year timeline impact
- Alternative C includes substantial solar and storage facility construction as well as extensive regional transmission upgrades; large number of required solar and storage projects results in a 3+ year timeline impact
- Timeline delays in alternatives B and C would also result in additional spend at CUF to maintain reliability and meet environmental compliance obligations (e.g., ELG Rule) until replacement generation is online

**Effluent Limitation Guidelines*

Carbon Rate Comparison

- All action alternatives significantly reduce system carbon intensity (lbs/MWh), compared to no action
- The highly efficient advanced-class CC in Alternative A reduces system carbon emissions by offsetting coal generation and by improving the combined fuel efficiency of the entire TVA gas fleet
- The efficient CT units in Alternative B reduce system carbon emissions by offsetting coal generation and by improving the combined fuel efficiency of the TVA peaking gas fleet
- Solar and storage facilities in Alternative C reduce system carbon emissions by offsetting coal generation, however the existing coal and gas fleets pick up some additional generation for battery charging or hours when solar is unavailable
- Once completed, Alternative C results in the lowest system carbon rate, followed closely by Alternative A then B

Alternative	FY30 Carbon Rate (lbs/MWh)*	FY30 Rate Reduction (2005 baseline) Compared to Alternative A*
No Action Alternative	434	-7 percentage points (worse)
Alternative A: Cumberland CC	338	n/a
Alternative B: Gleason and Johnsonville CTs	352	-1 percentage point (worse)
Alternative C: Solar and Storage	321	+1 percentage point (better)

**Vintage: FY22 Budget and associated alternative runs*

Planning is Grounded in Least-Cost Principles

In resource planning, TVA applies fundamental least-cost planning principles*:

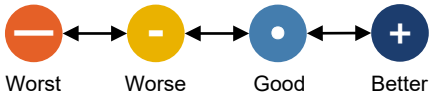
- Load varies hourly and seasonally, with weather a large driver, and highest peak loads are typically of short duration
- Resources have a variety of operational and economic characteristics and constraints, with tradeoffs that contribute to the best portfolio fit overall

In alignment with the Energy Policy Act of 1992

Least-Cost Planning Evaluation

Alternative	Low Cost	Risk Informed	Environmentally Responsible	Reliable	Diverse	Flexible
No Action Alternative	Cost risk associated with material condition and environmental compliance	Long-term fuel supply and regulatory risks	Results in highest system carbon rate, continued production of CCRs*	Challenged material condition; dependable year-round capacity	Contributes to balanced portfolio	Designed for baseload operations with little intra-hour flexibility
Alternative A: Cumberland CC	Lowest total system cost, most effective at serving large energy needs	Robust fuel supply chain, potential use of alternative fuels or CCS*, fastest online	Substantial system carbon rate reduction, assists in integration of renewables	Dependable year-round capacity; Middle TN transmission support	Lateral connection to major interstate pipeline with multiple supply sources	Supports baseload or intermediate needs with ability to operate flexibly
Alternative B: Gleason and Johnsonville CTs	Extensive transmission work and less fuel-efficient system overall	Robust fuel supply chain, potential use of alternative fuels; transmission timeline risk	Substantial system carbon rate reduction, assists in integration of renewables	Dependable year-round capacity	Lateral connections to major interstate pipelines with multiple supply sources	Supports peaking needs with fast ramp rates and ability to operate flexibly
Alternative C: Solar and Storage	Highest total cost; extensive transmission work and large number of solar & storage locations	Timeline risks with transmission build-out and land and resource procurement	Substantial system carbon rate reduction, lowest system carbon rate	Maintaining dependable year-round capacity requires storage and system upgrades	Contributes to balanced portfolio	Batteries support fast peaking needs and have a wide operating range

**CCS = Carbon Capture and Sequestration; CCR = Coal Combustion Residuals*



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Additional Considerations

- New gas contributes to TVA's ~80% carbon reduction path by enabling the retirement of the remaining coal plants by 2035, while emitting about 65-70% less CO2 than our aging coal plants
- Natural gas represents a highly flexible, reliable fuel source that helps enable high penetration levels of intermittent renewable resources
- In support of TVA's plan to add about 10,000 MW of solar by 2035, TVA currently has over 2,500 MW of solar either operating or contracted
- TVA is working to gain operational experience with battery storage technology through the deployment of a 20 MW battery storage project near Vonore, TN and 180 MW of storage paired with solar under contract, all planned to be online over the next several years
- TVA is also exploring pilot projects for additional short- and long-duration storage use-cases
- CC plants are positioned to further contribute to a net-zero future using alternative fuels, such as hydrogen, and/or carbon capture and sequestration (CCS) technology
- TVA is exploring partnerships with federal agencies and peer utilities to advance the research and development of both alternative fuels and CCS technology, which could enable their use at existing or future TVA gas facilities

Preferred Alternative

- TVA's financial and system analysis, using the least-cost planning framework along with consideration of the environmental impacts of the three alternatives, indicates that Alternative A, retirement of CUF and replacement of the first unit with a CC Plant at the CUF Reservation, is the Preferred Alternative
- Key considerations include:
  - Alternative A aligns with the 2019 IRP near-term actions to evaluate engineering end-of-life dates for aging fossil units to inform long-term planning and to enhance system flexibility to integrate renewables and distributed resources
  - Alternative A is the lowest-cost alternative and supports high reliability while greatly reducing carbon emissions compared to no action
  - Alternative A can be constructed on a TVA-owned brownfield site and largely leverage existing transmission infrastructure
  - Alternative A is a mature technology and can be built and operational sooner than other action alternatives, which reduces economic, reliability, and environmental risks

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