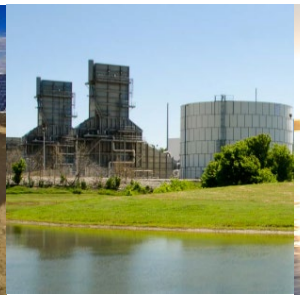
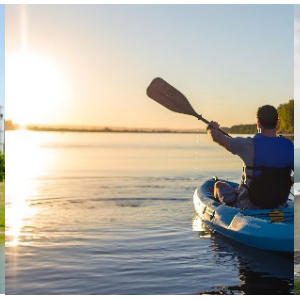
2019 Integrated Resource Plan

EXECUTIVE SUMMARY





TENNESSEE VALLEY AUTHORITY

Introduction

PURPOSE AND NEED

The Tennessee Valley Authority's 2019 Integrated Resource Plan (IRP) is a long-term plan that provides direction on how TVA can best meet future demand for power. It shapes how TVA will provide low-cost, reliable and clean electricity; support environmental stewardship; and foster economic development in the Tennessee Valley for the next 20 years. The plan is a crucial element for TVA's success in a constantly changing business and regulatory environment, and it will better equip TVA to meet many of the challenges facing the electric utility industry in the coming years to benefit the Valley. The IRP will enhance TVA's ability to create a more flexible power-generation system that can successfully integrate increasing amounts of renewable energy sources and distributed energy resources (DER) while ensuring reliability. The IRP also will inform TVA's next Long-Range Financial Plan.

TVA POWER SYSTEM

As the nation's largest public power provider, TVA delivers safe, reliable, clean, competitively priced electricity to 154 local power companies and 58 directly served customers. TVA's power portfolio is dynamic and adaptable in the face of changing demands and regulations. TVA's portfolio has evolved over the past decade to a more diverse, reliable and cleaner mix of generation resources, which today provides 54 percent carbon-free power. In Fiscal Year (FY) 2018, TVA efficiently delivered more than 163 billion kilowatt-hours of electricity to customers from a power supply that was 39 percent nuclear, 26 percent natural gas, 21 percent coal-fired, 10 percent hydro, and 3 percent wind and solar. The remaining one percent results from TVA programmatic energy efficiency efforts.

SUMMARY OF IRP PROCESS AND GOALS

TVA used an integrated, least-cost framework that considered multiple views of the future to determine how potential power-generation resource portfolios could perform in different market and external conditions. We conducted the IRP process in a transparent, inclusive manner that provided numerous opportunities for public education and participation. Stakeholders and the public provided invaluable input that helped shape the IRP. The analysis performed in this IRP study relied on industry-standard models and incorporated best practices while using an innovative methodology to more fully evaluate the role of distributed energy resources as resources in our power supply. Resource cost and performance input data were independently validated. TVA's goal with the IRP was to identify an optimal energy resource plan that performs well under a variety of future conditions, taking into account cost, risk, environmental stewardship, operational flexibility and Valley economics. Per the National Environmental Policy Act (NEPA), TVA also prepared an Environmental Impact Statement (EIS) to analyze the 2019 IRP's potential impacts on the environment, economy and population in the Tennessee Valley.

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TVA's 2019 IRP Recommendation

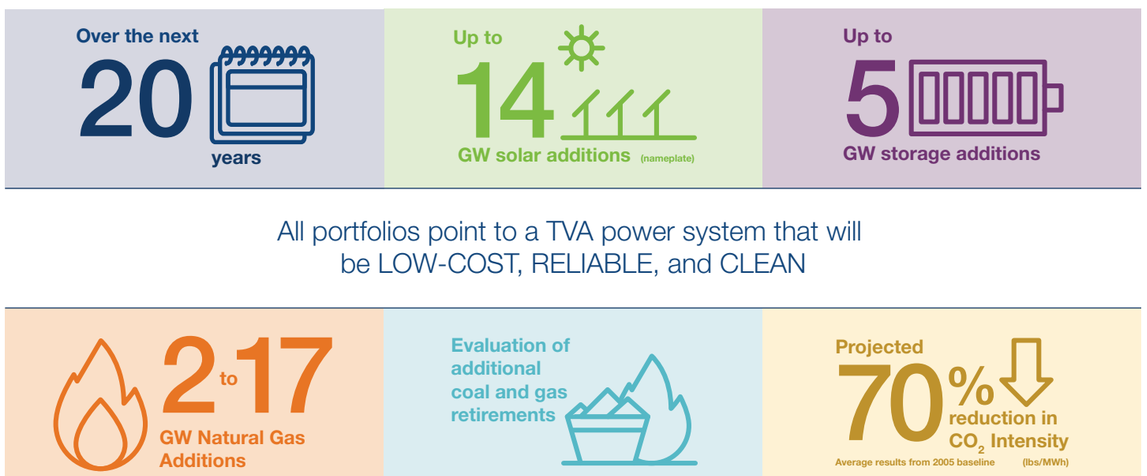
STUDY RESULTS

During the IRP process, TVA — with significant input from stakeholders and the public — considered a wide range of future scenarios, various business strategies and a diverse mix of power-generation resources to build on TVA's existing asset portfolio. IRP study results show:

- There is a need for new capacity in all scenarios to replace expiring or retiring capacity.
- Solar expansion plays a substantial role in all futures.
- Gas, storage and demand response additions provide reliability and/or flexibility.
- No baseload resources (designed to operate around the clock) are added, highlighting the need for operational flexibility in the resource portfolio.
- Additional coal retirements occur in certain futures.
- Energy efficiency (EE) levels depend on market depth and cost-competitiveness.
- Wind could play a role if it becomes cost-competitive.
- In all cases, TVA will continue to provide for economic growth in the Tennessee Valley.

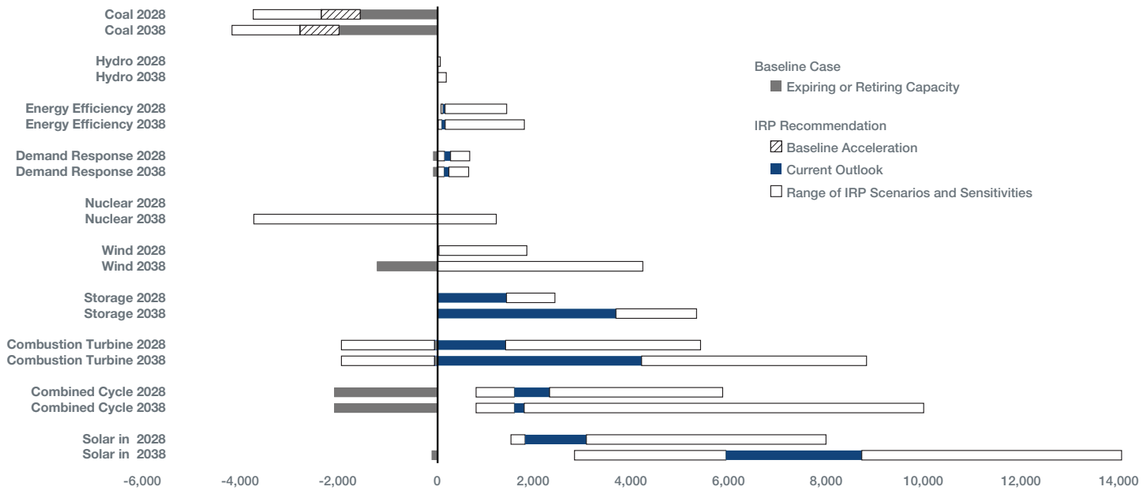
OBSERVATIONS

TVA has observed that the scenario, or future environment, it finds itself operating in will have more impact on overall results than the strategy or strategies it implements. TVA also recognizes that all strategies have positive aspects but also have unique tradeoffs to consider. If TVA needs to shift its resource mix, that need will be driven by these key variables: changing market conditions, more stringent regulations and technology advancements. Recognizing that a variety of future scenarios are possible and each strategy has positive aspects, all IRP results are included in the IRP Recommendation to provide flexibility for how the future evolves.



TVA's 2019 IRP Recommendation

Range of MW Additions and Subtractions by 2028 and 2038



Notes

- **MWs are incremental additions from 2019 forward. Board-approved coal retirements are excluded from the totals.**
- **Browns Ferry Nuclear Plant license is not extended in the No Nuclear Extensions Scenario (outside of TVA control).**
- **Upper bounds of potential natural gas and solar additions are driven by the Valley Load Growth Scenario.**
- **Solar and wind are shown in nameplate capacity; accelerated solar additions are reflected in the IRP Recommendation.**
- **Solar, gas, and storage ranges include utility-scale and distributed additions (where promoted in a strategy).**

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TVA's 2019 IRP Recommendation

TVA's recommended planning direction affirms its commitment to a diverse and flexible resource portfolio guided by the least-cost system planning mandate. The ranges shown, stated in megawatts (MW) of capacity, provide a general guideline for resource selections. In developing a Recommendation from the study, TVA elected to establish guideline ranges for key resource types (owned or contracted) that make up the target power supply mix. This general planning direction is expressed over the 20-year study period while also including more specific direction over the first 10-year period. Meeting the Valley's future needs in accordance with the resource technologies and ranges in this Recommendation will position TVA to continue to deliver low-cost, reliable and clean power to the people of the Tennessee Valley.

Coal: Continue with announced plans to retire Paradise in 2020 and Bull Run in 2023. Evaluate retirements of up to 2,200 MW of additional coal capacity if cost-effective.

Hydro: All portfolios reflect continued investment in the hydro fleet to maintain capacity. Consider additional hydro capacity where feasible.

Energy Efficiency: Achieve savings of up to 1,800 MW by 2028 and up to 2,200 MW by 2038. Work with our local power company partners to expand programs for low-income residents and refine program designs and delivery mechanisms with the goal of lowering total cost.

Demand Response: Add up to 500 MW of demand response by 2038 depending on availability and cost of the resource.

Nuclear: Pursue option for second license renewal of Browns Ferry for an additional 20 years. Continue to evaluate emerging nuclear technologies, including small modular reactors, (SMR) as part of technology innovation efforts.

Wind: Existing wind contracts expire in the early 2030s. Consider the addition of up to 1,800 MW of wind by 2028 and up to 4,200 MW by 2038 if cost-effective.

Storage: Add up to 2,400 MW of storage by 2028 and up to 5,300 MW by 2038. Additions may be a combination of utility and distributed scale. The trajectory and timing of additions will be highly dependent on the evolution of storage technologies.

Gas Combustion Turbine: Evaluate retirements of up to 2,000 MW of existing combustion turbines if cost-effective. Add up to 5,200 MW of combustion turbines by 2028 and up to 8,600 MW by 2038 if a high level of load growth materializes. Future CT needs are driven by demand for electricity, solar penetration, and evolution of other peaking technologies.

Gas Combined Cycle: Add between 800 and 5,700 MW of combined cycle by 2028 and up to 9,800 MW by 2038 if a high level of load growth materializes. Future CC needs are driven by demand for electricity and gas prices, as well as by solar penetration that tends to drive CT instead of CC additions.

Solar: Add between 1,500 and 8,000 MW of solar by 2028 and up to 14,000 MW by 2038 if a high level of load growth materializes. Additions may be a combination of utility and distributed scale. Future solar needs are driven by pricing, customer demand, and demand for electricity.

The IRP Recommendation meets the dual objective of ensuring flexibility to respond to the future while providing guidance on how our resource portfolio should change as the future unfolds.

Implementation

CONSIDERATIONS

With the implementation of the IRP Recommendation will come certain challenges. For example, the IRP Recommendation includes significant renewables expansion, which means it will become increasingly important to know the location of renewable resources, both utility and distributed scale, and how weather impacts solar generation. Early experience with battery storage on the system would provide additional insight to how the various storage-use cases might be employed to provide economic benefit and system flexibility, especially with increasing penetration of renewables. TVA will need to partner with local power companies and other stakeholders in the region to better understand the potential for distributed resources in the Valley and their locational value to inform resource decisions. Finally, the IRP Recommendation also includes more conventional resources, primarily gas-fired, and TVA will need to consider the implementation challenges in the areas of siting and permitting, both for the units themselves and associated transmission lines and gas pipelines.

In the process of developing the IRP, stakeholders raised a number of policy-related issues that are outside the scope of the IRP itself but will need to be considered as TVA moves toward implementation of recommendations from the IRP study. These considerations include continued evolution of programs that provide flexibility for customer-owned generation, evolution of federal/state energy and environmental policies, advancements in customer expectations and requirements for clean energy, and enhancing low-income equity and energy/environmental justice.

NEAR-TERM ACTIONS

The scenarios and strategies evaluated in the IRP provide insights to how TVA's resource portfolio may need to evolve as the future becomes clearer. The results indicate there are near-term actions that would provide benefit across multiple futures. The actions include:

RENEWABLES & FLEXIBILITY

- Add solar based on economics and to meet customer demand.
- Enhance system flexibility to integrate renewables and distributed resources.
- Evaluate demonstration battery storage to gain operational experience.

EXISTING FLEET

- Pursue option for license renewal for TVA's nuclear fleet.
- Evaluate engineering end-of-life dates for aging fossil units to inform long-term planning.

ENERGY USAGE

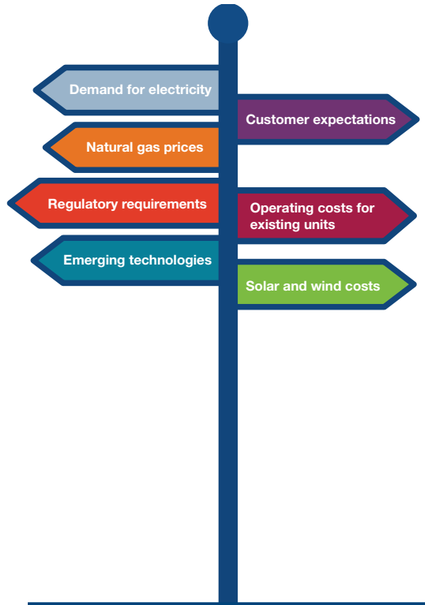
- Conduct market potential study for energy efficiency and demand response.
- Collaborate with states and local communities to address low-income energy efficiency.
- Collaboratively deploy initiatives to stimulate the local electric vehicle market.

DISTRIBUTION PLANNING

- Support development of Distribution Resource Planning for integration into TVA's planning process.

KEY SIGNPOSTS TO GUIDE DECISIONS IN THE LONGER TERM

As the future unfolds, TVA will monitor key signposts that will guide decisions in the longer term. The signposts relate to key variables that could have a significant influence on the future generation portfolio. These key signposts include:



TVA will closely monitor these key drivers related to changing market conditions, more stringent regulations, and technology advancements to inform appropriate actions within the recommended ranges and appropriate timing for initiating the next IRP.

How TVA Developed the Integrated Resource Plan: An 18-Month Process

OVERVIEW

Developing the 2019 IRP has been an approximately 18-month process that began in February 2018 and will conclude when a Record of Decision is released. The IRP process will have included the following activities:

- **Scoping,** which took place in winter/spring 2018 and identified issues important to the public and laid the foundation for developing the IRP.
- **Development of Model Input and Framework,** which occurred in spring/summer 2018 and included identifying and developing scenarios, resource options and business strategies to evaluate how a future portfolio might change under different conditions.
- **Analysis and Evaluation,** which took place in fall 2018 and included developing and evaluating the performance of the 30 resource portfolios.
- **Presentation of Initial Results,** which occurred in February 2019 with release of the draft IRP and EIS.
- **Public Comment Period,** which was held from February 15 to April 8, 2019.
- **Additional Analysis,** which was completed in response to stakeholder and public comments.
- **Completion of the Study**, which includes the IRP Recommendation, near-term actions and key signposts, and the final environmental assessment.
- **Publication of the Final IRP and EIS** on June 28, 2019, on TVA's website.
- **Expected Request for Approval** of the IRP Recommendation from the Board in August 2019.
- **Record of Decision** will be published after Board approval.

Developing the IRP

PLANNING APPROACH

Uncertainties and Scenarios
With input from the IRP Working Group, TVA designed scenarios that are outside of TVA's control but represent possible futures in which TVA may find itself operating. TVA created a list of uncertainties that could alter the future operating environment and affect the cost of electricity and/or mix of optimal resources. The scenarios are:

	SCENARIOS
1	**CURRENT OUTLOOK** which represents TVA's current forecast for these key uncertainties and reflects modest economic growth offset by increasing efficiencies;
2	**ECONOMIC DOWNTURN** which represents a prolonged stagnation in the economy, resulting in declining loads (customers using less power) and delayed expansion of new generation;
3	**VALLEY LOAD GROWTH** which represents economic growth driven by migration into the Valley and a technology-driven boost to productivity, underscored by increased electrification of industry and transportation;
4	**DECARBONIZATION** which is driven by a strong push to curb greenhouse gas emissions due to concern over climate change, resulting in high CO_2 emission penalties and incentives for non-emitting technologies;
5	**RAPID DER ADOPTION** which is driven by growing consumer awareness and preference for energy choice, coupled with rapid advances in technologies, resulting in high penetration of distributed generation, storage and energy management;
6	**NO NUCLEAR EXTENSIONS** which is driven by a regulatory challenge to relicense existing nuclear plants and construct new, large-scale nuclear. This scenario also assumes subsidies to drive small modular reactor (SMR) technology advancements and improved economics.

Strategies
With input from the IRP Working Group, TVA developed five strategies, which are business decisions or directions that TVA could employ in each scenario. As it relates to strategies in the IRP, the word "promote" means an incentive was modeled to make the resource more attractive for adoption or selection. The five strategies are:

	STRATEGIES
A	**BASE CASE** which represents TVA's current assumptions for resource costs and applies a planning reserve margin constraint. This constraint applies in every strategy and represents the minimum amount of capacity required to ensure reliable power;
B	**PROMOTE DISTRIBUTED ENERGY RESOURCES** which incents DER to achieve higher, long-term penetration levels. The DER options include energy efficiency, demand response, combined heat and power, distributed solar and storage;
C	**PROMOTE RESILIENCY** which incents small, agile capacity to maximize operational flexibility and the ability to respond to short-term disruptions on the power system;
D	**PROMOTE EFFICIENT LOAD SHAPE** which incents targeted electrification (by incentivizing customers to increase electricity usage in off-peak hours) and demand response (by incentivizing customers to reduce electricity usage during peak hours). This strategy promotes efficient energy usage for all customers, including those with low income;
E	**PROMOTE RENEWABLES** which incents renewables at all scales (from utility size to residential) to meet growing or existing consumer demand for renewable energy.

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MODELING ASSUMPTIONS AND CANDIDATE TECHNOLOGIES

TVA uses an industry standard model to derive an optimal capacity plan, considering the focus of each strategy evaluated in each scenario. Modeling assumptions, the framework of IRP planning, are the constraints and planning guidelines that are put into the model. The reliability constraint is especially critical, as it ensures we have enough capacity at all times to provide reliable electricity to customers. For the 2019 IRP, it also is crucial to understand how the system would operate with more renewables and DER on the system – driving a greater need for operational flexibility. TVA considered a broader range of mature and emerging technologies in this IRP, including some distributed energy technologies.

STAKEHOLDER & PUBLIC INVOLVEMENT

Throughout the IRP process, TVA engaged external stakeholders to understand diverse opinions and to challenge assumptions. TVA established the IRP Working Group, whose 20 members represent diverse interests in the Valley. The IRP Working Group met approximately monthly to review input assumptions and preliminary results and to enable its members to provide their respective views to TVA. TVA also presented IRP progress updates to the Regional Energy Resource Council (RERC), a federal advisory committee that provides advice to the TVA Board of Directors on a range of energy-related matters, including the IRP.

During a 60-day scoping period from February 15 through April 16, 2018, TVA obtained public comments on the scope of the effort to develop this IRP, which helped shape the draft IRP and EIS. After the release of the draft IRP and EIS on February 15, 2019, TVA provided a public comment period through April 8, 2019. TVA held meetings across the Tennessee Valley and an online webinar, and accepted public comments via mail, email, online and in-person at the meetings. Input was critical in shaping the IRP and EIS, and many of the sensitivity analyses that were performed were informed by stakeholder and public input.

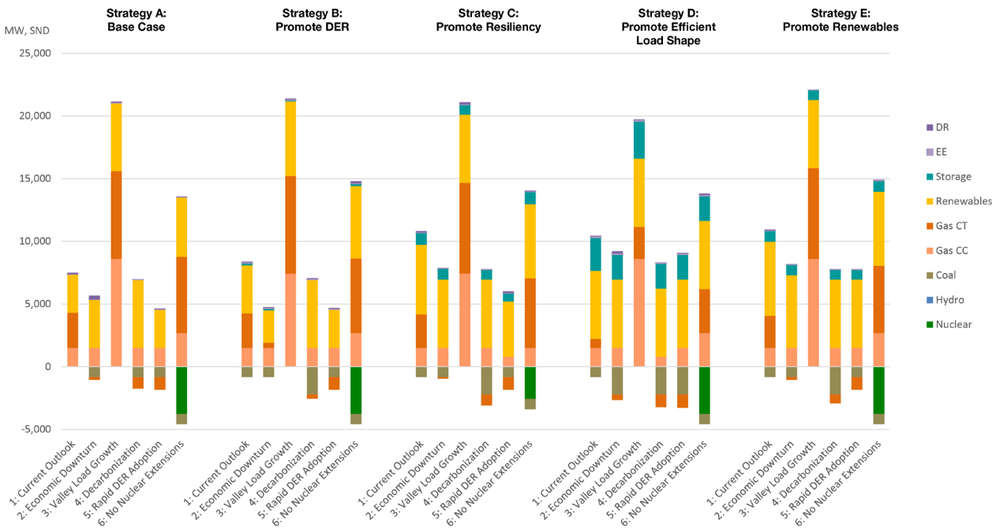
The IRP Working Group included representatives from:

- State and local governments
- Academia and research groups
- Advocacy groups
- Local power companies (LPCs)
- Economic development organizations
- Directly-served/ industrial customers

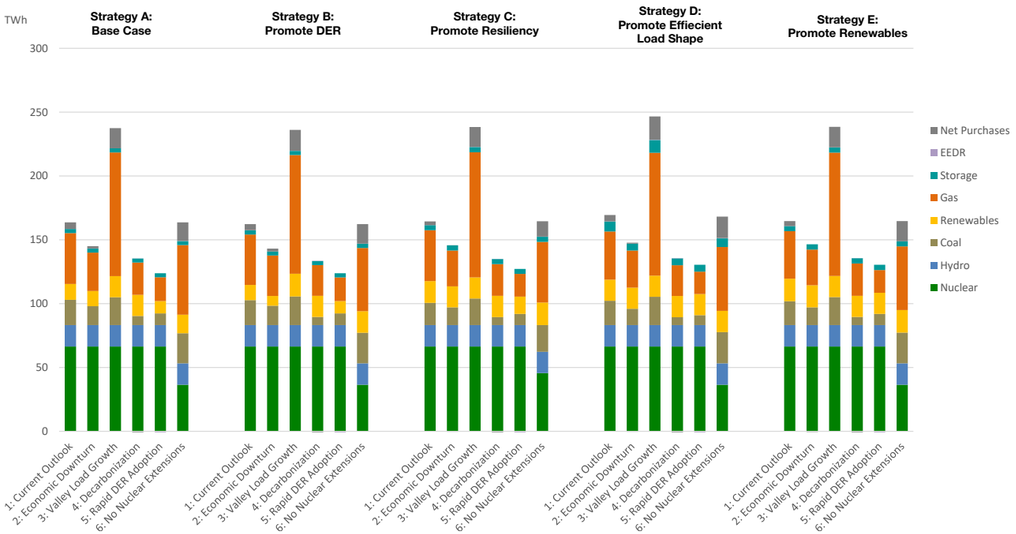
Developing the IRP

EVALUATING THE PORTFOLIOS

Incremental capacity by 2038 consists of additions of new energy resources and retirement of existing energy resources for the portfolios associated with each strategy.



Total Energy in 2038 by resource type in the portfolios associated with each strategy.



EVALUATING THE PORTFOLIOS

Each IRP case represents a combination of expectations about the future environment TVA operates in and potential strategies TVA could employ that result in unique resource portfolios. The modeling process resulted in 30 resource portfolios. The model analyzed how to achieve the lowest-cost portfolio with each strategy in each scenario, looking for the optimal solution within that particular combination. With input from the IRP Working Group and RERC, TVA identified 14 metrics that reflect desired goals and priorities in areas related to cost, risk, environmental stewardship, operational flexibility and Valley economics. The metrics were used to evaluate tradeoffs among the 30 resource portfolios.

Strategy Performance

	COST	RISK	ENVIRONMENTAL STEWARDSHIP		OPERATIONAL FLEXIBILITY	VALLEY ECONOMICS
			CO_2, Water, Waste	Land Use		
STRATEGY A: BASE CASE						All strategies have similar impacts on the Valley economy as measured by per capita income and employment
STRATEGY B: PROMOTE DER						
STRATEGY C: PROMOTE RESILIENCY						
STRATEGY D: PROMOTE EFFICIENT LOAD SHAPE						
STRATEGY E: PROMOTE RENEWABLES						

Good — Better — Best

Developing the IRP

SENSITIVITY ANALYSIS

When analyzing results from the draft IRP, TVA identified issues that warranted further evaluation prior to finalizing the study. In addition, TVA received helpful input from the IRP Working Group and the RERC, as well as from the public during the comment period. Many of the questions raised by TVA, stakeholders and the public focused on certain key assumptions that could influence results. To explore the impacts of changes in key assumptions and to inform the Recommendation, TVA evaluated sensitivities related to the following categories: natural gas prices; storage, wind, combined heat and power (CHP) and small modular reactor (SMR) capital costs; greater energy efficiency (EE) and demand response (DR) market depth; integration cost and flexibility benefit; pace and magnitude of solar additions; higher operating costs for coal plants; more stringent carbon constraints; and variation in climate.

Summary of 2019 IRP Sensitivities

SENSITIVITY CASE Base Case comparison is the Current Outlook unless otherwise noted	CAPACITY EXPANSION IMPACTS BY 2038 GREEN indicates increase and RED indicated decrease in resource						
	NUCLEAR	COAL	GAS	HYDRO	SOLAR	WIND	EEDR
Higher Natural Gas Prices				+55 MW	+2,050 MW		
Lower Natural Gas Prices			2,000 MW CT replaced by CC		-5,900 MW		
Lower Wind Costs			-1,100 MW		-3,100 MW	+4,200 MW	
Greater EE & DR Market Depth			-2,000 MW		-2,200 MW		+2,100 MW
Integration Cost & Flexibility Benefit			Minor timing differences		Minor timing differences		
Pace & Magnitude of Solar Additions					+1,100 MW		
Magnitude of Solar Additions (Valley Load Growth)			1,000 MW CC replaced by CT		+6,000 MW		
Higher Operating Costs for Coal Plants		-2,200 MW	+1,500 MW				
More Stringent Carbon Constraints (Decarbonization)		-2,000 MW accelerated	CC expansion accelerated	+175 MW			
Variation in Climate	Summer derates	Summer derates	CT expansion accelerated		+2,100 MW		

Note

- **Impacts shown in Summer Net Dependable MW, except for solar and wind that are shown in nameplate MW**

FORMING THE IRP RECOMMENDATION

The IRP results — including the 30 primary cases and the sensitivity cases — provide a robust set of potential resource additions and retirements. The final Recommendation is derived from this evaluation. The Recommendation takes into account customer priorities around power cost and reliability across different futures, along with environmental stewardship and Valley economics considerations. In developing a recommendation from the study, TVA elected to establish guideline ranges for key resource types (owned or contracted) that make up the target power supply mix. In order to distill the considerable number of cases evaluated through the original scenario and strategy analysis and the sensitivity cases, the Recommendation uses ranges that are centered on results obtained under the Current Outlook scenario. The other scenario and sensitivity results provide a sense of how the target power supply mix might change as the future changes. Recognizing that a variety of future scenarios are possible and each strategy has positive aspects, all IRP results are included in the Recommendation to provide flexibility for how the future evolves. Implementing the least-cost resource plan with all of these priorities in mind will help ensure TVA continues to fulfill its mission to serve the people of the Tennessee Valley.

The IRP and the Tennessee Valley Environment

PURPOSE OF THE EIS

TVA's EIS assesses the natural, cultural and socioeconomic impacts associated with the 2019 IRP. The five strategies are the basis for the alternatives discussed in the EIS. The Base Case serves as the No-Action Alternative, and the remaining four strategies are the Action Alternatives. The draft EIS analyzed and identified the relationship of the natural and human environment to each of the five alternative strategies. The final EIS includes an additional alternative, the 2019 Recommendation (Target Power Supply Mix). The portfolios associated with each of the five alternative strategies, as well as the 2019 Recommendation, are quantitatively and qualitatively evaluated to determine the environmental impact. This evaluation addresses systemwide topics, including

- Greenhouse gas emissions
- Fuel consumption
- Air quality
- Water quality and quantity
- Waste generation and disposal
- Land requirements
- Socioeconomic impacts
- Environmental justice.

Public comments on the draft EIS and draft IRP are addressed in the final EIS.

The primary study area described in the EIS includes the combined TVA service area; the Tennessee River watershed; and parts of the Cumberland, Mississippi, Green and Ohio Rivers in TVA's power service area. For some resources, such as air quality and climate change, the assessment area extends beyond the TVA region. For some socioeconomic resources, the study area consists of the 170 counties where TVA is a major provider of electric power and/or operates generating facilities.

The IRP and the Tennessee Valley Environment

ENVIRONMENTAL IMPACTS OF THE 2019 IRP

Under all the portfolios and the 2019 Recommendation, there is a need for new capacity, with a significant expansion of solar generation overall. Uncertainty around future environmental standards for carbon dioxide emissions, along with the outlook for loads and gas prices, are key considerations when evaluating potential coal retirements. Emissions of air pollutants, the intensity of greenhouse gas emissions (CO_2 intensity) and generation of coal waste decrease under all strategies. Strategies focused on resiliency, load shape and renewables have the largest amounts of solar and storage expansion and coal retirements, resulting in lower environmental impact overall but higher land use. For most environmental resources, the impacts are greatest for the No Action alternative. The exception is the land area required for new generating facilities, which is greater for the action alternatives, particularly strategies which focus on resiliency, load shape and renewables. Most of this land area would be occupied by solar facilities, which, compared to most other energy resources, have a relatively low level of impact to the land. Additional sensitivity analysis showed the potential for an extended range of resource additions and retirements, which generally resulted in reduced impacts to most environmental resources. The land area occupied by solar facilities, however, could greatly increase.

Conclusion

TVA finds considerable value in undertaking an IRP and EIS, and especially appreciates the input, review and insights of individuals on the IRP Working Group and the Regional Energy Resource Council. They spent considerable time helping TVA develop a robust plan that meets all the criteria outlined in its objectives. TVA values their involvement and the expertise they provided on behalf of their respective stakeholders in making this a better IRP.

As with any long-term plan, TVA's IRP reflects what we know today and can reasonably expect for the coming years. TVA and our employees across the Valley stand ready every day to carry out our three-part mission around energy, the environment and economic development. In an ever-changing world, TVA will do its best to continue to serve the people of the Tennessee Valley by providing low-cost, reliable and clean power in an environmentally responsible manner while promoting economic development across the Valley.


TVA