Integrated Resource Plan

2015 FINAL SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT
VOLUME 1

TENNESSEE VALLEY AUTHORITY

Document Type: EIS – Administrative Record
Index Field: Final Environmental Impact Statement
Project Name: Integrated Resource Plan
Project Number: 2014-2

Supplemental Environmental Impact Statement **July 2015**

Proposed action: Integrated Resource Plan

Lead agency: Tennessee Valley Authority

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Abstract: The Tennessee Valley Authority (TVA) proposes to update its 2011 Integrated Resource Plan (IRP) to determine how it will meet the electrical needs of its customers over the next 20 years and fulfill its mission of low-cost, reliable power, environmental stewardship and economic development. Planning process steps included: 1) determining the future need for power; 2) identifying potential supply-side options for generating power and demand-side options for reducing the need for power; 3) developing a range of planning strategies encompassing different approaches, targets and emphasized resources; and 4) identifying a range of future conditions (scenarios) used in evaluating the strategies. Capacity expansion plans (portfolios) were then developed for each combination of strategies and scenarios, and these are evaluated for financial, risk, environmental, system flexibility and economic criteria. Five planning strategies, A – Reference Plan, B – Meet an Emission Target, C – Focus on Long-Term, Market Supplied Resources, D – Maximize Energy Efficiency and E – Maximize Renewables, a No Action Baseline Case alternative, and the Target Power Supply, the preferred alternative based on a combination of A, B and C, are analyzed. Under all alternative strategies and the Target Power Supply, a minimal amount of new baseload generation is added, coal-fired generation decreases and reliance on renewable and demand-side resources increases. Emissions of air pollutants, the intensity of greenhouse gas emissions and generation of coal waste decrease under all strategies. For most environmental resources, the impacts are greatest for the No Action alternative except for the land area required for new generating facilities, which is greater for the action alternatives, particularly Strategy E.

Summary

INTRODUCTION

The Tennessee Valley Authority (TVA) has developed the Integrated Resource Plan (IRP) and associated programmatic supplemental environmental impact statement (SEIS) to address the demand for power in the TVA service area, the resource options available for meeting that demand, and the potential environmental, economic and operating impacts of these options. The IRP will serve as a roadmap for meeting the energy needs of TVA's customers over the next 20 years.

The Tennessee Valley Authority (TVA) is the largest producer of public power in the United States. With a generating capability of 37,000 megawatts, TVA provides wholesale power to 155 local power companies and directly sells power to 59 large industrial and federal customers. TVA's power system serves 9 million people in a seven-state, 80,000-square-mile region (Figure 1).

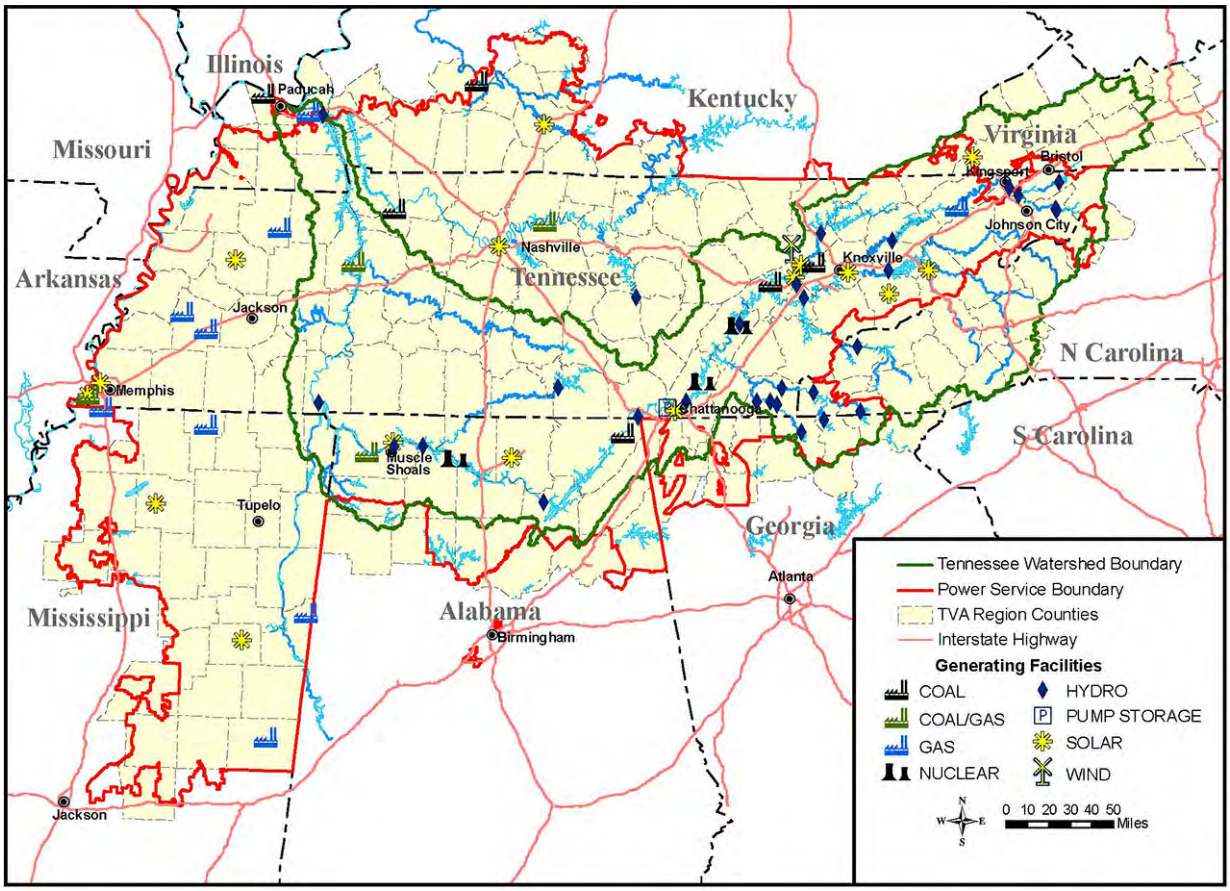

Figure 1 The TVA service area and generating facilities.

Summary

Purpose and Need

Like other utilities, TVA develops power supply plans. This planning process includes forecasting the demand for power and developing capacity expansion plans. TVA completed an IRP and associated EIS in 2011. Several changes in the power industry, both regionally and nationally, have led TVA to develop this new IRP and associated supplemental EIS. When completed, the new IRP will update and replace the 2011 IRP.

The purpose of the IRP and EIS processes is to evaluate TVA's current energy resource portfolio and alternative future portfolios of energy resource options at a least system-wide cost to meet the future electrical energy needs of the TVA region while taking into account TVA's mission of energy, environmental stewardship and economic development. Energy resource options include the means by which TVA generates or purchases electricity, transmits that electricity to customers and influences the end use of that electricity through energy efficiency and demand response programs. As part of the IRP and EIS processes, TVA evaluated the future demand for electricity by its customers, characterized potential supply- and demand-side options for meeting future demand and assembled these options into planning strategies and capacity expansion plans or portfolios. TVA then evaluated the strategies for several criteria including capital and fuel costs, risk, reliability, compliance with existing and anticipated future regulations, environmental impacts and flexibility in adapting to changing future conditions. Following public review of the Draft IRP and SEIS, TVA has considered and addressed the public comments on the Draft IRP and SEIS, conducted further evaluations and has issued the Final IRP and SEIS. These reports identify TVA's preferred resource planning strategy. TVA's Board of Directors will decide whether to approve staff's recommended plan or some other plan.

Public Participation

TVA conducted public scoping for the IRP and associated SEIS in October 2013 with the publication of the Notice of Intent in the Federal Register. TVA simultaneously issued news releases, posted notice on the project website and sent letters about the project to interested parties. During the 33-day scoping period, TVA held public scoping meetings at two locations and by webinar. About 45 people attended these meetings in person and about 50 participated by webinar.

TVA received a total of 1,156 individual scoping comments. About 96 percent of the comments were from individuals with the remainder from organizations, businesses and state and federal agencies. Most of the comments from individuals were form letters and emails submitted in response to two advocacy campaigns. Comments from the largest of these campaigns thanked TVA for recent coal plant retirement decisions, urged TVA to prioritize the use of solar and wind energy, increase energy efficiency efforts and work to reduce the local economic impacts of coal plant retirements. Comments from the other campaign cited the abundance and stable cost of coal, the high capacity factor of coal plants, the employment provided by the use of coal and coal's contribution of low and stable rates. Scoping comments addressed a wide range of IRP-related topics including potential energy resource options, impacts of power system operations and aspects of the integrated resource planning process. Results of the scoping process are available in the IRP EIS Scoping Report issued in June, 2014.

To gain additional input, TVA established an IRP Working Group to more actively engage stakeholders throughout the development of the IRP. The 18-member group is comprised of representatives of state agencies, the Department of Energy, distributors of TVA power,

industrial groups, academia, and energy and environmental non-governmental organizations. The members were expected to represent their constituencies and report to them on the IRP process, as well as provide input to TVA on the process. The group met at one- to two-month intervals beginning in November 2013. Additional information about the review group is available at http://www.tva.com/environment/reports/irp/index.htm. TVA held quarterly public briefings to educate the general public on the IRP planning process and to present results of major planning steps. Participants could attend these meeting in person or by web conference.

The Draft IRP and SEIS were issued for public review and comment in March 2015. TVA held seven public meetings during the comment period. Comments were also accepted through an online form, by email, and by letter. TVA received about 200 unique comment submissions from about 2,400 people. TVA carefully reviewed the comments and responded to them in a comment response report.

TVA'S RESOURCE PLANNING PROCESS

TVA chose to employ a scenario planning approach in the IRP. The major steps in this approach include identifying the future need for power, developing scenarios and strategies, determining potential supply-side and demand-side energy resource options, developing portfolios associated with the strategies and ranking the strategies and portfolios.

Need for Power

The need for additional power is based on forecasts of the demand for power over the next 20 years and the ability of TVA's existing energy resources to meet the forecasted demand. Demand forecasts are based on complex mathematical models that link electricity sales to regional economic activity, customer retention, the price of electricity, the price of substitute fuels and other factors for the residential, commercial and industrial sectors. The results are forecasts of peak load (the maximum amount of power used at a given point in time) and net system energy (the amount of power used over a specified time period). Forecasts are developed for baseline conditions (current outlook) and high- and low-demand scenarios (Figure 2).

Summary

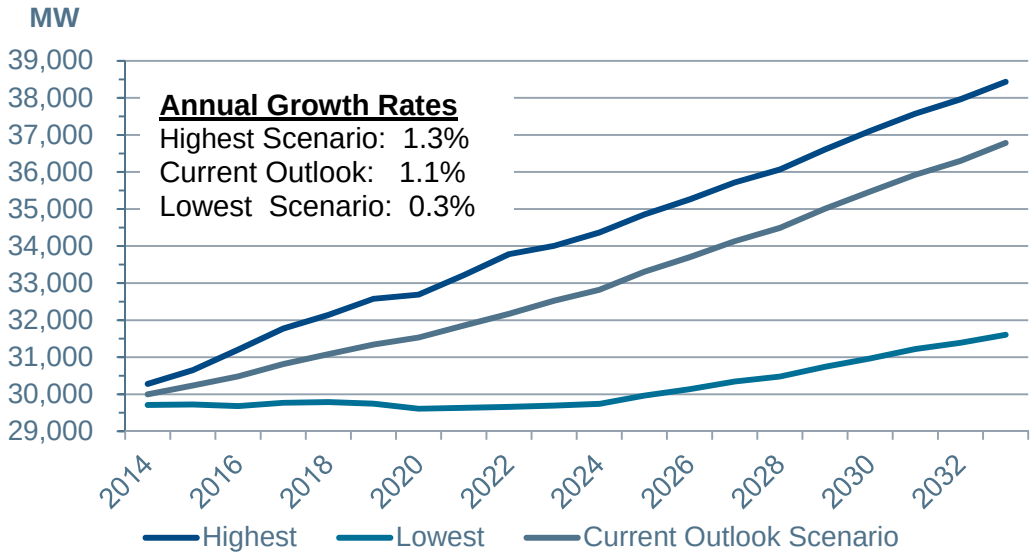

Figure 2 Peak load forecast through 2033 in megawatts (MW) for the IRP current outlook, high- and low-growth scenarios.

The next step in determining the need for power was to assess TVA's current generating mix and how the existing resources will change over the next 20 years. The largest components of TVA's 2014 energy resources, which total about 37,000 megawatts in capability, are coal-fired (34 percent of 2014 capability and 38 percent of 2014 generation) and nuclear (19 percent of 2014 capability and 33 percent of 2014 generation) generating facilities. The major changes to TVA's energy resources over the next few years will be the addition of Watts Bar Nuclear Plant Unit 2, the Paradise and Allen natural gas-fired combined cycle (CC) plants and the retirement of several coal-fired plants/units.

The last step in determining the need for additional power is to compare the existing energy resource portfolio with the forecasted need for power. The differences define the capacity gap (Figure 3) and the energy gap. The capacity gap includes a 15 percent reserve margin necessary to meet reliability standards.

Summary

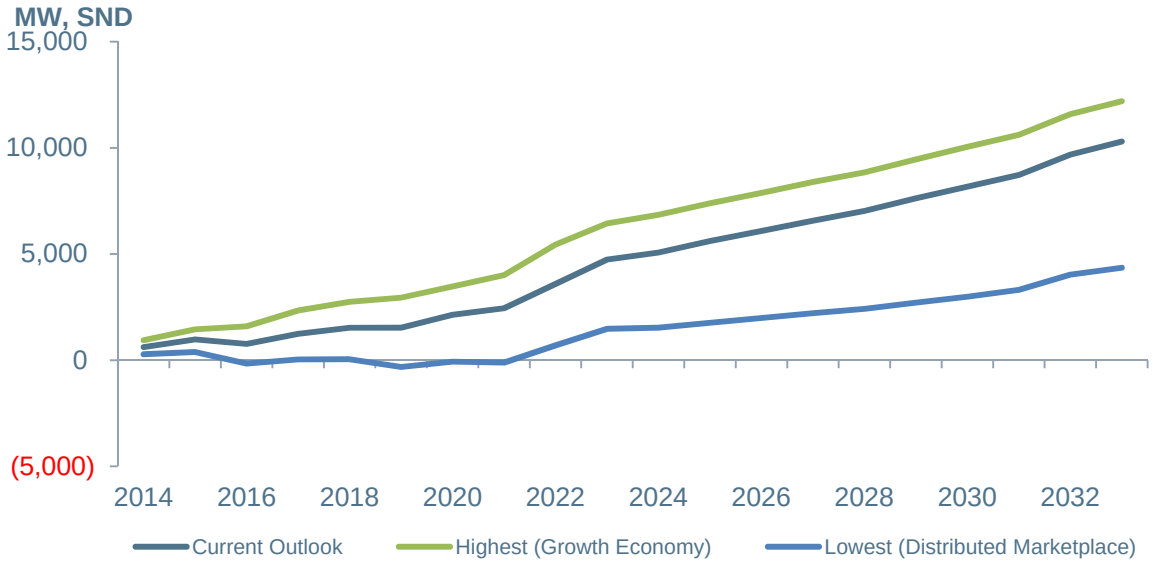

Figure 3 Capacity gap (in summer net dependable (SND) megawatts (MW)) for the IRP current outlook and high- and low-growth scenarios.

Scenario Development

With the assistance of individuals on the IRP Working Group, TVA developed a set of scenarios used in evaluating the performance of the resource strategies against potential future conditions. These conditions (uncertainties) address a range of economic, financial, regulatory, and legislative conditions, as well as social trends and adoption of technological innovations. Five unique scenarios were developed and are summarized in the following table.

Attributes of the Five Scenarios

Scenario	Description and Attributes
1 – Current Outlook	TVA's current forecasts • Power demand grows around 1.0%/year • Steady moderate increase in gas price • Steady slow increase in coal price, similar to other scenarios • CO_2 price imposed ca. 2022, gradually increasing
2 – Stagnant Economy	Flat to slightly negative economic growth, delaying the need for capacity expansion • Power demand less than Current Outlook • Steady increase in gas price, somewhat lower than Current Outlook • Lowest CO_2 price, not imposed until 2029

Summary

3 – Growth Economy	Highest economic growth with highest forecast energy sales and need for capacity expansion • Power demand grows 1.1 – 1.5%/year • Gas price increases rapidly ca. 2017 – 2020, then slower steady increase • CO_2 price imposed ca. 2022, somewhat higher than for Current Outlook and gradually increasing
4 – De-Carbonized Future	Increasing climate-driven effects create strong Federal push to curb GHG emissions with new legislated caps, penalties on utility industry CO_2 emissions, and incentives for non-emitting energy resources • Fairly rapid decrease in energy demand following GHG emission constraints, then steady growth at rates comparable to Current Outlook • Sharp increase in gas price ca. 2020, then levels off • Highest CO2 cost imposed ca. 2020, then gradual increasing
5 – Distributed Marketplace	Rapid advances in energy technologies and increased customer awareness resulting in high and rapid adoption of distributed generation and energy efficiency • Gradually decreasing growth in energy demand through ca. 2023, then slow growth, no significant overall demand growth • Gas price slightly lower than Current Outlook • CO_2 cost same as Current Outlook

Strategy Development

Five distinct planning strategies were developed and analyzed in the Draft IRP and SEIS, along with a baseline case representing the continuation of the 2011 IRP as modified by subsequent decisions by the TVA Board of Directors. The strategies describe a broad range of business options that TVA could adopt. Their attributes are assumed to be within TVA's control, and include the amounts of energy efficiency and demand response (EEDR); renewable energy, energy storage, nuclear capacity, and natural gas-fired capacity additions; coal plant retirements; limitations on the technology and timing of coal-fired capacity additions; and reliance on purchased power. The attributes of the five planning strategies and the baseline case are described in the table below.

Attributes of the Planning Strategies

Attributes	Planning Strategy					
	Baseline Case (No Action Alternative)	A – The Reference Plan	B – Meet an Emission Target	C – Focus on Long-Term, Market-Supplied Resources	D – Maximize Energy Efficiency	E – Maximize Renewables
Existing Nuclear	Operate existing units through end of period	Same as Baseline	Same as Baseline	Same as Baseline	Same as Baseline	Same as Baseline

Summary

Attributes	Planning Strategy					
	Baseline Case (No Action Alternative)	A – The Reference Plan	B – Meet an Emission Target	C – Focus on Long-Term, Market-Supplied Resources	D – Maximize Energy Efficiency	E – Maximize Renewables
New Nuclear	Browns Ferry EPUs and new nuclear selectable	Same as Baseline	Same as Baseline	Browns Ferry EPUs selectable; no new TVA-build nuclear; nuclear selectable as PPA	Browns Ferry EPUs selectable; no other new nuclear	Same as D
Existing Coal	Based on current fleet strategy; all coal units selectable for retirement and additional air emissions controls selectable for 7 Shawnee units	Same as Baseline	Same as Baseline	Same as Baseline	Same as Baseline	Same as Baseline
New Coal	Expansion allowed	Expansion allowed	Expansion allowed	Only coal PPA selectable	No expansion	No expansion
New Gas	Expansion allowed	Same as Baseline	Same as Baseline	No TVA gas expansion	Same as Baseline	Same as Baseline
EEDR	Scheduled inputs per 2011 IRP and 2015 power supply plan	EE and DR available for resource selection	Same as A	Same as A	EE required to be selected first	Same as A

Summary

Attributes	Planning Strategy					
	Baseline Case (No Action Alternative)	A – The Reference Plan	B – Meet an Emission Target	C – Focus on Long-Term, Market-Supplied Resources	D – Maximize Energy Efficiency	E – Maximize Renewables
Utility Scale Renewables	Expansion under current programs	Expansion under current programs and new selectable renewable options	Same as A	Same as A	Same as A	Aggressive renewable energy target enforced to promote growth in renewable resources first through current programs or new selectable options
New Energy Storage	Selectable expansion options	Same as Baseline	Same as Baseline	Same as Baseline	Same as Baseline	Same as Baseline
Hydroelectric	Hydro PPA selectable	Hydro PPA and expansion options selectable	Same as A	Same as A	Same as A	Same as A

Portfolio Development

Potential 20-year capacity expansion plans or resource portfolios were developed for each combination of a planning strategy and scenario. A major input to the portfolio development was the definition of the supply-side and demand-side energy resource options that can become components of the portfolios. These options included existing and potential future TVA generating facilities, existing and potential future EEDR programs and existing and potential future power purchase agreements. They were evaluated according to their technological maturity, commercial availability, availability to TVA either within the TVA region or importable through market purchases, economics and ability to contribute to TVA objectives of reducing emissions of air pollutants, including greenhouse gases. In addition to TVA's existing generating facilities, resource options evaluated include advanced coal plants with and without carbon capture and sequestration, natural gas-fueled combustion turbine and combined cycle plants, construction of new nuclear plants, new hydro units at existing dams and run-of-river hydro options, pumped hydro and compressed air energy storage plants, wind, solar photovoltaic and biomass generation, and EEDR programs.

The portfolios were developed with a capacity planning model that solves for the "optimum" combination of resource options to meet projected demand/energy requirements over the 20-year planning period at a system-wide least cost. An optimized portfolio has the lowest net

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Present Value of Revenue Requirements while meeting energy balance, reserve, operational, environmental and other requirements. The portfolios are then evaluated using an hourly production costing program to determine detailed revenue requirements and near- and long-term system average costs. Additional metrics developed to rank the portfolios include financial risk, CO_2 emissions, water consumption, coal waste generation and changes in regional personal income. These metrics were used to compare the planning strategies and their associated portfolios.

ALTERNATIVE STRATEGIES

Strategies A–E represent the action alternatives and the Baseline Case represents the No Action Alternative. The capacity expansion plans developed for each of these alternative strategies are summarized below. In these descriptions, the stated capacities are net summer dependable capacities except for wind and solar generation, which are nameplate capacities. Due to the intermittent nature of wind and solar generation, their net summer dependable capacities are significantly less than nameplate capacities. For the other energy resources, the difference between net summer dependable capacities and nameplate capacities is relatively small.

The energy resource options included in the capacity expansion plans include the following:

- Demand response (DR)
- Energy efficiency (EE)
- Natural gas-fired generation, including TVA-built combustion turbine (Gas CT) and combined cycle (Gas CC) plants and gas-fueled generation purchased under long-term power purchase agreements (Gas CT PPA and Gas CC PPA)
- Hydroelectric generation, both at TVA dams (Hydro) and purchased under long-term power purchase agreements (Hydro PPA)
- Wind energy purchased under long-term power purchase agreements from the Midwest and Dakotas (Wind MISO) and from the southern Great Plans and transmitted to TVA by high voltage direct current line (Wind HVDC)
- Solar energy generated by utility-scale 1-axis tracking photovoltaic facilities (Solar Tracking) and by utility-scale fixed tilt photovoltaic facilities (Solar Fixed).

Baseline Case – No Action Alternative

The Baseline Case is the continued implementation of the current 2011 IRP under conditions described by the Current Outlook Scenario. Energy efficiency and renewable energy expansions are scheduled inputs with fixed capacities instead of the discrete selectable units in the other alternative strategies.

Figure 4 shows the cumulative capacity expansions by resource type, as well as the overall capacity mix and energy mix at the end of the planning period for the Baseline Case. The primary sources of new generation are natural gas-fueled, from six new 786-MW CT plants beginning in the early 2020s and one new 1,005-MW CC plant in the early 2030s. Additional air pollution control equipment would be installed on the seven less controlled (i.e., without FGD and SCR systems) Shawnee Fossil Plant coal units in the mid-2020s. No additional coal

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retirements beyond those already announced would occur. Demand response would average about 360 MW until 2030 and then decline to 0. Energy efficiency would increase by about 70–120 MW per year to a total of 2,026 MW by 2033. Non-hydro renewable energy increases would be relatively modest and restricted to the Renewable Standard Offer (RSO) and Solar Solutions Initiative (SSI) programs. Total non-hydro renewable generation would decline late in the planning period due to the expiration of PPAs.

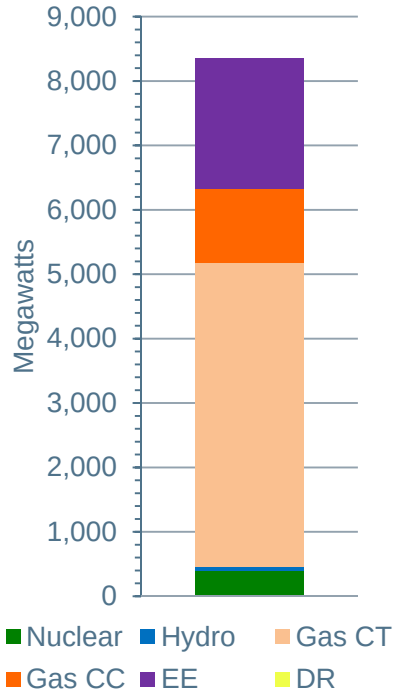

Figure 4 No Action Alternative capacity expansion by resource type.

Strategy A – The Reference Plan

Strategy A is TVA's traditional least-cost optimization plan developed without any targets for particular types of energy resources. Solar capacity expansion is capped at 300 MW/year and 4,000 MW of total capacity; no other unique constraints are placed on the selection of energy resources. Following is a summary of the five capacity expansion plans developed for Strategy A. Capacity additions by resource type are illustrated in Figure 5.

Summary

Figure 5 Strategy A capacity additions through 2033 by resource type for the five scenarios.

- Demand Response (DR) – Expansion of existing capacity from 322 MW (Scenarios 2 and 5) to 515 MW (Scenario 1).
- Energy Efficiency (EE) – Expansion to an average of about 2,720 MW by 2033 with some variation among the scenarios in the timing of the expansion.
- Natural Gas-fired Generation – New CT plants added under all scenarios, with the number ranging from one plant at the end of the planning period under Scenario 4 to five to six new plants beginning in the early 2020s under Scenarios 1, 2 and 3. No new CC plants would be built. Varying amounts of power from CT and CC plants would be acquired by short-term market purchases, primarily early in the planning period for CCs and from the early 2020s on for CTs.

Summary

- Coal – Under Scenarios 1, 2, 4 and 5, the seven less controlled units at Shawnee continue to operate until 2025 when they are retired. Under Scenario 3, they are controlled and operate through the end of the planning period. Under Scenarios 4 and 5, Kingston Fossil Plant is retired in the early 2020s and all Shawnee units are retired in the mid-2020s. The operating coal capacity at the end of the planning period in 2033 would be 6,610–7,506 MW under Scenarios 1, 2 and 3 and about 5,000 MW under Scenarios 4 and 5.
- Wind – Under Scenario 1, wind energy generated by 1,800 MW of wind capacity in the southern Great Plains/Texas would be imported to TVA via HVDC transmission; this quantity would double under Scenarios 3 and 4. An additional 1,600 MW of wind capacity in the MISO area would be acquired under Scenario 4. Wind energy additions begin in 2020 under Scenario 4, and occur near the end of the planning period under Scenarios 1 and 3.
- Solar – At least 2,200 MW of utility scale, tracking solar PV is added under all scenarios; under Scenarios 3 and 4, almost twice that amount is added. The solar additions start in the early 2020s under Scenarios 1, 3 and 4, and in the mid-2020s under Scenarios 2 and 5. For all scenarios, solar capacity increases fairly uniformly through the end of the planning period.
- Hydroelectric – New hydro capacity is provided by installation of two new units at TVA dams under all Scenarios. Hydro PPAs are also selected under Scenarios 3 and 4.

Strategy B – Meet an Emission Target

Strategy B contains the target of reducing system-wide direct emissions of CO_2 by 50 percent (to 557 lbs/MWh) by 2033 and by 80 percent by 2050 from 2005. This strategy is not designed to analyze compliance with any proposed GHG emissions reduction legislation or regulation, such as the former American Clean Energy and Security Act of 2009 or the currently proposed Clean Power Plan. Instead, it is designed to compare energy resource portfolios constructed to achieve the specified CO_2 reduction targets with other portfolios developed without this constraint. Solar capacity expansion is capped at 300 MW/year and at 4,000 MW of total capacity; no other constraints beyond the emissions targets are placed on the selection of energy resources. Following is a summary of the five capacity expansion plans developed for Strategy B. Capacity additions by resource type are illustrated in Figure 6.

- Demand Response (DR) – Expansion varies from 271 MW under Scenario 2 to 575 MW under Scenario 1.
- Energy Efficiency (EE) – Expansion to an average of about 2,730 MW by 2033 with some variation among the scenarios in the timing of the expansion.
- Natural Gas-fired Generation – New CT plants added under all scenarios, with the number ranging from one 786-MW plant at the end of the planning period under Scenario 4 to five – six new 786-MW plants beginning in the early 2020s under Scenarios 1, 2 and 3. No new CC plants would be built. Varying amounts of power from CT and CC plants would be acquired by short-term market purchases, primarily early in the planning period for CCs and from the early 2020s on for CTs.

Summary

Figure 6 Strategy B capacity additions through 2033 by resource type for the five scenarios.

- Coal – The same coal retirements described for Strategy A would occur under Strategy B on the same schedule. The operating coal capacity at the end of the planning period in 2033 would be the same as Strategy A with 6,610–7,506 MW under Scenarios 1, 2 and 3, and about 5,000 MW under Scenarios 4 and 5.
- Wind – The wind capacity additions would be similar to those for Strategy A and on approximately the same schedule, except for an additional 1,000 MW under Scenario 1 and 800-1,600 MW of additional MISO wind under Scenarios 3 an 4, respectively.
- Solar – Most solar capacity additions would be similar to those for Strategy A and on approximately the same schedule.
- Hydroelectric – Hydroelectric capacity additions are the same as for Strategy A.

Summary

Strategy C – Focus on Long-Term, Market-Supplied Resources
Strategy C is designed to constrain capital spending by TVA and, instead of building its own new generating plants, TVA would meet most new capacity needs by market purchases and PPAs. There would be no constraints on TVA spending for EE and DR programs. As in Strategies A and B, solar capacity expansion is capped at 300 MW/year and at 4,000 MW of total capacity. Following is a summary of the five capacity expansion plans developed for Strategy C. Capacity additions by resource type are illustrated in Figure 7.

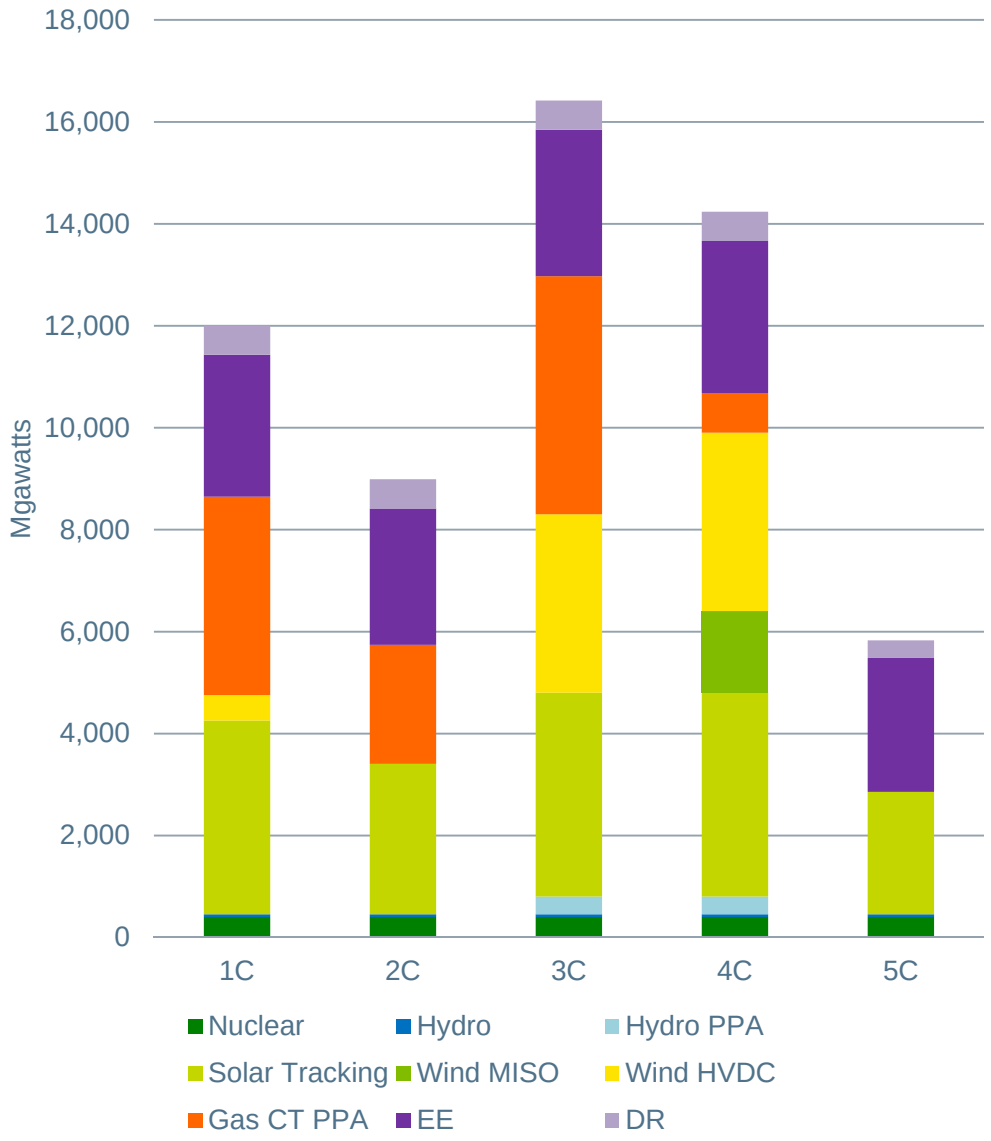

Figure 7 Strategy C capacity additions through 2033 by resource type for the five scenarios.

- Demand Response (DR) – Expansion of about 350 MW under Scenario 5 and about 575 MW under the other scenarios.

Summary

- Energy Efficiency (EE) – Expansion to around 2,750 MW with variation among the scenarios in the timing of the expansion.
- Natural Gas-fired Generation – No new TVA-built CC or CT plants. Under Scenarios 1-4, TVA would enter into PPAs for the purchase of power from CT plants, with quantities ranging from 778 MW (i.e., equivalent to one new CT plant) under Scenario 4 to 4,668 MW (six new CT plants) under Scenario 3. No gas generation is added under Scenario 5. Varying amounts of power from CT and CC plants would be acquired by short-term market purchases, primarily early in the planning period for CCs and from the early 2020s on for CTs.
- Coal – Strategy C maintains more coal capacity than Strategy A and B. Under Scenarios 1, 2 and 3, additional emission controls are added to the seven Shawnee units in the mid-2020s and no additional retirements occur. Under Scenarios 4 and 5, the seven Shawnee units are retired in the mid-2020s. Under Scenario 4, Kingston is retired in 2020. Coal generating capacity in 2033 totals 5,249 MW for Strategy 4; 6,610 MW for Strategy 5; and 7,506 MW for Scenarios 1, 2 and 3.
- Wind – As with Strategies A and B, no wind capacity is added under Scenarios 2 and 5. The additions under Scenarios 3 and 4 are similar to Strategy A and the addition under Scenario 1 is much less at only 500 MW.
- Solar – Solar capacity additions are generally similar to those for Strategy A and on approximately the same schedule except for modest increases under Scenarios 1 and 2.
- Hydroelectric – Hydroelectric capacity additions are similar to Strategies A and B except for addition of the 40-MW spill hydro option under Scenario 3 and 4.

Strategy D – Maximize Energy Efficiency

Strategy D focuses on increasing energy efficiency by requiring it be selected first for meeting future energy needs in the least-cost manner. As in Strategies A, B and C, solar capacity expansion is capped at 300 MW/year and at4,000 MW of total capacity. Following is a summary of the five capacity expansion plans developed for Strategy D. Capacity additions by resource type are illustrated in Figure 8.

- Demand Response (DR) – Expansion to 500–575 MW in 2033 under all scenarios.
- Energy Efficiency (EE) – Expansion to 4,624 MW in 2033 under all scenarios. The rate of EE expansion is similar to Strategy A over the first decade and then accelerates.
- Natural Gas-fired Generation – No new CT plants are constructed under Scenario 5. New CT plants are constructed under the other scenarios, with one 786-MW plant under Scenario 4, two 786-MW plants under Scenario 2, four 786-MW plants under Scenario 1 and four 786-MW and one 590-MW plant under Scenario 3. No new CC plants are constructed under any scenario. Varying amounts of power from CT and CC plants would be acquired by short-term market purchases, primarily early in the planning period for CCs and from the early 2020s on for CTs.
- Coal – Under all scenarios, seven Shawnee units are retired in 2025 and under Scenarios 4 and 5, all nine Shawnee units are retired in 2025. Kingston is retired in 2020 under Scenarios 4 and 5 and Paradise Unit 3 is retired in 2020 under Scenario 4. 2033 coal capacities are 4,187 MW for Scenario 4, about 5,000 MW for Scenario 5, and 6,610 MW for Scenarios 1–3.
- Wind – The only wind additions are 3,500 MW under Scenarios 3 and 4.

Summary

- Solar – Compared to Strategy A, the solar capacity addition is somewhat less for Scenarios 1, 3 and 4, considerably less for Scenario 5, and slightly more for Scenario 2.
- Hydroelectric - Hydroelectric capacity additions are similar to Strategies A and B except that Scenario 4 does not include the hydro PPA.

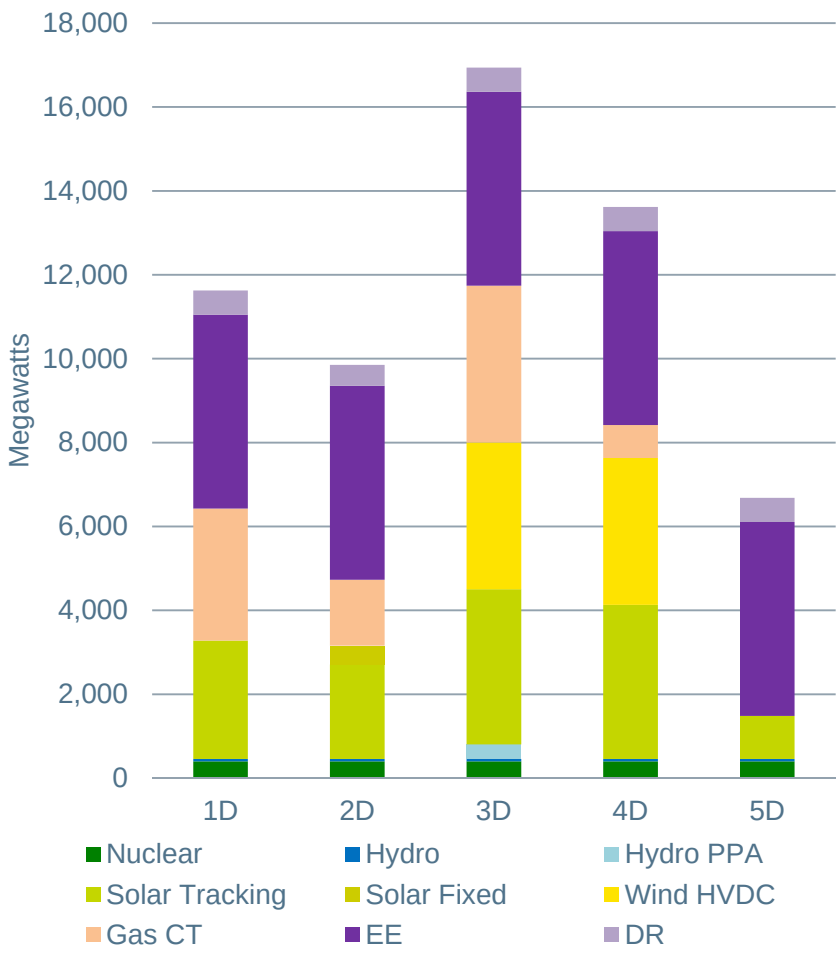

Figure 8 Strategy D capacity additions through 2033 by resource type for the five scenarios.

Strategy E – Maximize Renewables

Strategy E focuses on increasing generation by renewable resources by requiring renewables be selected to meet a renewable energy target in the least-cost manner. Generation from TVA's existing hydroelectric system is included in this target. Unlike the other strategies, the allowable solar capacity growth rate is set at 500 MW/year with a maximum total of 8,000 MW. Following is a summary of the five capacity expansion plans developed for Strategy E. Capacity additions by resource type are illustrated in Figure 9.

- Demand Response (DR) – DR expansion averages 470 MW for Strategies 1 – 4; 273 MW are added under Scenario 5.

Summary

Figure 9 Strategy E capacity additions through 2033 by resource type for the five scenarios.

- Energy Efficiency (EE) – Expansion averages 2,668 MW by 2033 in Scenarios 1–4, with a lower amount of 1,900 MW under Scenario 5.
- Natural Gas-fired Generation – Lower CT plant expansion with one new 786-MW plant under Scenario 4, two new 786-MW plants under Scenarios 1 and 2, and four new CT plants under Scenario 3. No new CT plants are constructed under Scenario 5 and no new CC plants are constructed under any scenario. Varying amounts of power from CT and CC plants would be acquired by short-term market purchases, primarily early in the planning period for CCs and from the early 2020s on for CTs.
- Coal – Strategy E has the greatest overall reduction in coal capacity. The seven less controlled Shawnee units are retired in the mid-2020s under all scenarios. Under Scenarios 4 and 5, the two controlled Shawnee units are also retired in the mid-2020s. Kingston is retired in the early 2020s under Scenarios 2, 4 and 5, as are Bull Run fossil

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plant under Scenario 5 and Paradise Unit 3 under Scenario 4. Coal capacities range from 4,128 MW under Scenario 5 to 6,610 MW under Scenario 1.

- Wind – Strategy E has the largest wind capacity additions, with large quantities of both HVDC and MISO-area wind under all scenarios. Wind capacity additions start early in the planning period and increase throughout.
- Solar – As with wind, Strategy E has the largest solar capacity additions, which start early in the planning period and increase throughout. Total solar additions range from 5,850 MW under Scenario 5 to 7,800 MW under Scenario 3.
- Hydroelectric – The hydro PPA and run-of-river options are selected for all scenarios. The existing dam space addition options are added in Scenarios 1-4.

The Recommended Target Power Supply Mix

During and following the public review of the Draft IRP and SEIS, TVA staff began the process of developing the recommended Target Power Supply mix. It was guided by the overall IRP development objectives and the goals of identifying a power supply mix that is low cost, reliable, risk-informed, diverse, environmentally responsible, flexible, and consistent with least-cost planning criteria of the TVA Act. TVA performed additional detailed modeling, termed sensitivity analyses, of several topics related to nuclear generation, energy efficiency, demand response, renewable energy capacity ratings and costs, energy resources not selected in the power supply plans, and key factors in the scenarios.

Based on comparisons of the metrics, the results of the sensitivity analyses, and stakeholder comments, TVA elected to establish guideline ranges for key resource types (TVA-owned or contracted) that make up the recommended Target Power Supply mix (Figure 10). This general planning direction covers the 20-year planning period while providing more specific direction over the first 10-year period. The recommended ranges, shown as the thick solid bars in Figure 10, are based on Strategies A, B and C and the Current Outlook Scenario, which TVA considers its best estimation of the future. The thin lines in Figure 10 represent the ranges associated with the other scenarios for Strategies A, B and C. The low end of the range for energy efficiency and demand response extends beyond that encompassed by Strategies A, B and C to account for TVA's current trajectories for these programs and uncertainties.

Summary

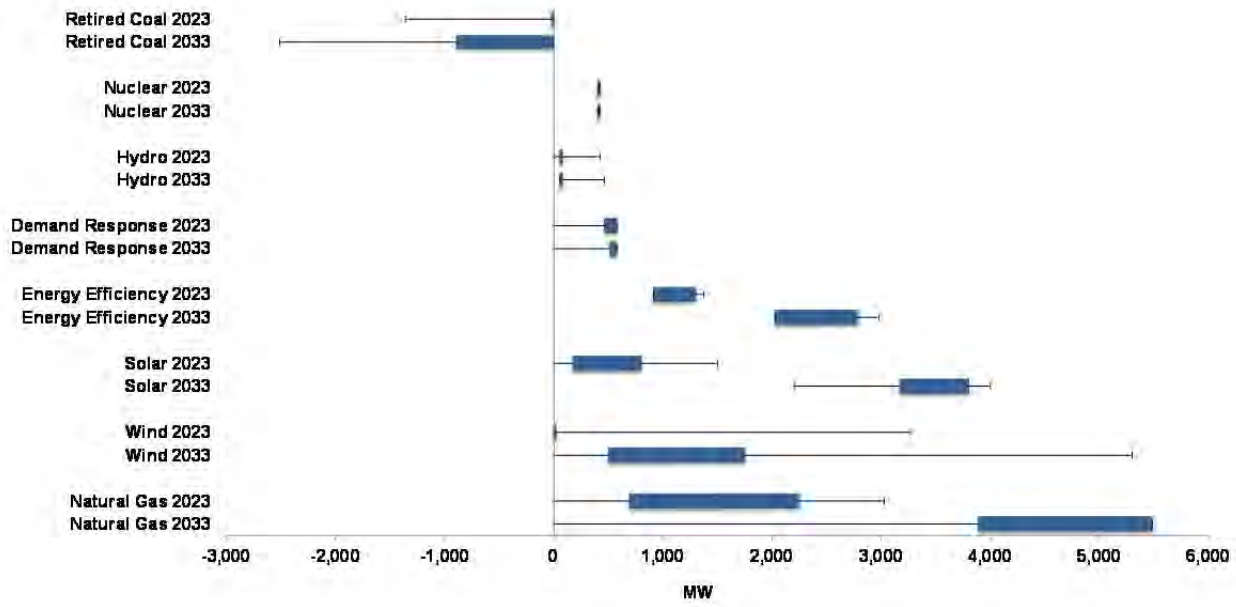

Figure 10 Range of resource additions by 2023 and 2033 in the recommended Target Power Supply.

The implementation of this Target Power Supply will result in a diverse portfolio and provide TVA the flexibility to make energy resource decisions, consistent with least-cost planning, that fall within the power supply ranges depicted in Figure 10. As the IRP is implemented, TVA will closely monitor key variables including changes in the load forecast, the price of natural gas and other commodities, the pricing and performance of energy efficiency and renewable resources, and impacts from future policy or breakthrough technologies to help determine whether adjustments should be made to the recommended ranges. Following is a summary of the Target Power Supply by resource type:

- Coal – Retire units at Allen, Colbert, Johnsonville, Paradise, and Widows Creek as previously announced. Evaluate the potential retirement of Shawnee in the mid-2020s if additional environmental controls are required. Consider retirements of fully controlled units if cost-effective.
- Nuclear – Complete Watts Bar Unit 2 and pursue extended power uprates at all three Browns Ferry units by 2023. Continue evaluation of small modular reactors as part of technology innovation efforts and look for opportunities for cost-sharing to render them more cost-effective.
- Hydro –Pursue an additional 55 MW of hydro capacity at TVA facilities and consider additional hydro opportunities where feasible.
- Demand Response – Add 450–575 MW of demand reduction by 2023 and similar amounts by 2023, dependent on availability and cost of this customer-owned resource.
- Energy Efficiency – Achieve savings of 900–1,300 MW by 2023 and 2,000–2,800 MW by 2033. Work with TVA local power company partners to refine delivery mechanisms, program designs, and program efficiencies with the goal of lowering total cost and increasing deliveries of efficiency programs.

Summary

- Solar – Add 150–800 MW of large-scale solar by 2023 and 3,150–3,800 of large scale solar by 2033. Solar additions will be highly dependent on pricing, performance, and integration costs.
- Wind – Add 500–1,750 MW by 2033, dependent on pricing, performance, and integration costs. Given the variability of wind expansion in the scenarios, evaluate accelerating wind expansion into the first 10 years if operational characteristics and pricing result in lower cost options.
- Natural Gas (combustion turbine and combined cycle) – Add 700–2,300 MW by 2023 and 3,900–5,500 MW by 2033. The key determinants of future natural gas needs are its pricing and the pricing of energy efficiency and renewable generation. The range of natural gas expansion is somewhat larger than that described above for Strategies A, B and C because it assumes TVA's acquisition of some natural gas facilities from which it is currently purchasing power. The power being generated by these facilities is already factored into TVA's demand forecasts and any TVA acquisitions would not otherwise noticeably affect the environmental impacts of the Target Power Supply.

AFFECTED ENVIRONMENT

The primary study area, hereinafter called the TVA region, is the combined TVA power service area and the Tennessee River watershed. This area comprises 202 counties and approximately 59 million acres. In addition to the Tennessee River watershed, it covers parts of the Cumberland, Mississippi, Green and Ohio Rivers where TVA power plants are located. 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.

Climate and Greenhouse Gas Emissions – The TVA region has a generally mild climate. Both annual average temperature and precipitation vary from year to year. Annual average temperatures increased by 0.4–0.5ºF per decade from 1981–2010, and according to most climate models, are projected to continue increasing through the end of the century. Precipitation shows greater variation than temperature; while annual precipitation shows no long-term trend, the frequency of very heavy precipitation events has increased. This increase is projected by climate models to continue. Wind speeds in the TVA region have decreased in recent decades.

In 2013, CO_2 emissions from generation of the power marketed by TVA totaled 77.4 million tons; TVA-owned generating facilities emitted 72.2 million tons of CO_2. Since 1995, CO_2 emissions from generation of the power marketed by TVA have decreased by 32 percent. Under the Baseline Case, they are projected to decrease to about 61 million tons.

Air Quality – Air quality in the TVA region has greatly improved in recent decades and most of the region is classified as in attainment with national ambient air quality standards. TVA's coal plants are the largest source of sulfur dioxide (SO_2) emissions in the TVA region and its fossil-fueled generating facilities are regionally important sources of other air pollutants. Emissions of air pollutants from TVA facilities have greatly decreased, with a 94 percent decrease in sulfur dioxide emissions since 1974; a 91 percent decrease in nitrogen oxides (NOx) emissions since 1995; a 79 percent decrease in hazardous air pollutants since 1999; and a 71 percent decrease

in mercury emissions since 2000. Further decreases in emissions of air pollutants will occur as TVA retires coal plants and installs advanced emission control systems on other coal plants that will continue to operate.

Water Resources – Much of the TVA region has abundant water resources and their quality is generally good. Power generation affects water resources by discharging treated liquid wastes, by using water directly to generate electricity in hydroelectric plants, and by using water to produce steam and cool generating plants. The use of water for power plant cooling is the largest single water use in the TVA region, although relatively little water is consumed. TVA's coal-fired and nuclear plants predominantly operate with open-cycle cooling, where large volumes of water are withdrawn from a river or reservoir, circulated through the plant and discharged back to the river or reservoir. The CC plants use closed-cycle cooling, where a smaller quantity of cooling water is withdrawn and evaporated in cooling towers. The Watts Bar Nuclear Plant and Paradise Fossil Plant operate with full or partial closed-cycle cooling. Water sources for the CC plants are groundwater, surface waters and reclaimed wastewater. Pending coal plant retirements will reduce water use by TVA and changes to coal plant ash storage processes will reduce the potential for water quality impacts.

Land Resources – The TVA region encompasses nine ecoregions and its land resources are diverse. They include large numbers of plant communities, diverse wildlife populations and a variety of endangered and threatened species. About 53 percent of the region is forested and about 41 percent is farmland. The TVA power system affects land resources through site selection for power plants, transmission lines, fuel procurement, air emissions and waste management. TVA's existing power plant reservations, excluding the hydroelectric plants associated with multi-purpose reservoirs, occupy about 25,000 acres. The actual area disturbed by facility construction and operations totals about 17,400 acres.

Wastes – In 2013, the TVA coal plants produced about 2.9 million tons of ash and slag and about 2.2 million tons of scrubber waste. The production of these coal combustion residuals has decreased in recent years with the retirement of coal units and will continue to decrease through 2020. About 21 percent of these wastes were beneficially reused. The remainder is stored at or near the plant sites. TVA uses both dry and wet storage for these wastes and is in the process of converting to only use dry storage. The nuclear plants produce about 650 tons of high-level radioactive waste, almost all spent fuel that is stored on the plant sites. This quantity will increase by about 15 percent once Watts Bar Nuclear Plant Unit 2 begins operation.

ANTICIPATED ENVIRONMENTAL IMPACTS

All of the alternative strategies have several common features that affect their anticipated environmental impacts. The only new baseload generation added is the extended power uprate of the three Browns Ferry Nuclear Plant units, a component of all alternative strategies. All alternative strategies result in decreases in coal-fired generation and increases in the reliance on energy efficiency and renewable resources. All alternative strategies also add varying amounts of new natural gas-fueled generation which, with one exception, is CT plants to meet peak loads. TVA will conduct the appropriate National Environmental Policy Act reviews of subsequent actions to implement the selected strategy. These reviews, tiered from this programmatic EIS, will include assessments of site-specific characteristics such as endangered and threatened species, wetlands, historic properties, scenery, and environmental justice.

Summary

Emissions of SO_2 , NOx, mercury, and CO_2 , CO_2 intensity (i.e. emissions rate) and generation of coal combustion residuals all decrease significantly throughout the planning period under all alternative strategies and the Target Power Supply, primarily due to reduced coal-fired generation. These reductions are largest under Strategy E due to its greater substitution of renewable generation for fossil-fueled generation, and are smallest for the No Action Alternative which maintains the most fossil-fueled generation. Water consumption also decreases, although by smaller proportions. Production of nuclear spent fuel increases at the beginning of the planning period and then remains fairly constant for all alternative strategies and the Target Power Supply. Natural gas consumption would increase by almost 80 percent between 2014 and 2033 under the No Action Alternative, remain about the same under Strategies A and B and the Target Power Supply, and decrease 5–10 percent under Strategies C–E.

Socioeconomic impacts, as quantified by the change to per capita income of TVA service area residents attributable to the cost of operating the TVA power system, are minimal. Relative to Strategy A, it would decrease by 0.03 percent under the No Action Alternative, remain unchanged under Strategies B and E and the Target Power Supply, and increase by 0.01 percent under Strategy C and 0.02 percent under Strategy D. The differences among strategies in regional employment associated with the capacity expansion plans are also small and greatest for the more labor-intensive Strategy D with an 0.08 percent increase relative to Strategy A, and lowest for Strategy B with no change relative to Strategy A.

Land requirements for implementing the alternative strategies, and thus the potential for affecting land resources, vary more than other quantified environmental resources. Land required for siting the new generating resources in the capacity expansion plans range from about 3,625 acres for the No Action Alternative to about 25,000 acres for Strategy D, 29,000 acres for Strategies A–C and 56,000 acres for Strategy E. These land requirements include the facility footprints, access roads and transmission system infrastructure at the facility site. Solar PV facilities, which occupy large areas of land relative to their generating capacity, are the largest contributor to the land requirements. Solar facilities do not, however, typically result in long-term impacts to the site, unlike most other types of generation. When the life cycle land requirements (i.e., incorporating the fuel and waste cycles) of nuclear and fossil-fueled generation are considered, the No Action Alternative has the highest land requirements of about 60,000 acres and the other alternatives have similar land requirements of about 42,000 acres. These life cycle land requirements do not include wind, solar and hydroelectric generation which do not have comparable fuel and waste cycles.

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1.0 Introduction

The Tennessee Valley Authority (TVA) is updating its comprehensive plan for meeting the future electrical energy needs of the Tennessee Valley. TVA's current Integrated Resource Plan (IRP) and supporting Final Programmatic Environmental Impact Statement (EIS) were released in March 2011. The IRP is TVA's plan for meeting the electricity needs of its customers over the next 20 years at the lowest system-wide cost – taking into account TVA's energy, environment, and economic development mission.

TVA has prepared this Final Supplemental Programmatic Environmental Impact Statement (SEIS) in accordance with the National Environmental Policy Act (NEPA) 42 USC §§ 4321 et seq., Council on Environmental Quality (CEQ) regulations for implementing NEPA 40 C.F.R Parts 1500-1508, and TVA's procedures for implementing NEPA. It updates and supplements TVA's 2011 IRP EIS.

1.1 The Tennessee Valley Authority

The Tennessee Valley Authority was established by an act of Congress in 1933. As stated in the TVA Act, TVA is to "improve the navigability and to provide for the flood control of the Tennessee River; to provide for reforestation and the proper use of marginal lands in the Tennessee Valley; to provide for agricultural and industrial development of said valley; [and] to provide for the national defense…." Fundamental to this mission was the construction of a series of hydroelectric dams, other generating resources, and an electrical transmission system which brought abundant and inexpensive electricity to the TVA region. This power system has grown to serve more than 9 million people in a seven-state, 80,000-square mile region that includes most of Tennessee and parts of Alabama, Georgia, Kentucky, Mississippi, North Carolina, and Virginia (Figure 1-1).

TVA is the largest public power producer in the United States. Dependable generating capability on the TVA power system is about 37,000 megawatts (MW). TVA generates most of this with three nuclear plants, 10 coal-fired plants, nine combustion-turbine (CT) plants, five combined cycle (CC) plants, 29 hydroelectric dams, a diesel generator plant, a pumped-storage plant, a methane-gas co-firing facility, and several small photovoltaic facilities. A portion of delivered power is provided through long-term power purchase agreements.

Electricity is transmitted to 155 local power companies (LPCs, consisting of municipal-owned utilities and cooperatives) and 59 large industrial and federal installations. Except for these large direct-served industrial and federal installations, TVA is a wholesaler of electricity. The LPCs deliver most of the electricity that TVA generates to end-users, including smaller industries, businesses, public buildings and residences. This power is delivered through a network consisting of approximately 16,200 miles of transmission line; 511 substations, switchyards and switching stations; and 1,278 individual customer connection points. Chapter 3 presents a more detailed description of the TVA power system.

The TVA Act requires the TVA power system to be self-supporting, to be operated on a nonprofit basis, and to sell power at rates as low as feasible. TVA receives no funding from taxpayers. Amendments to the TVA Act in 2004 changed the structure of the TVA Board of Directors from three full-time members to nine part-time members with the responsibility to

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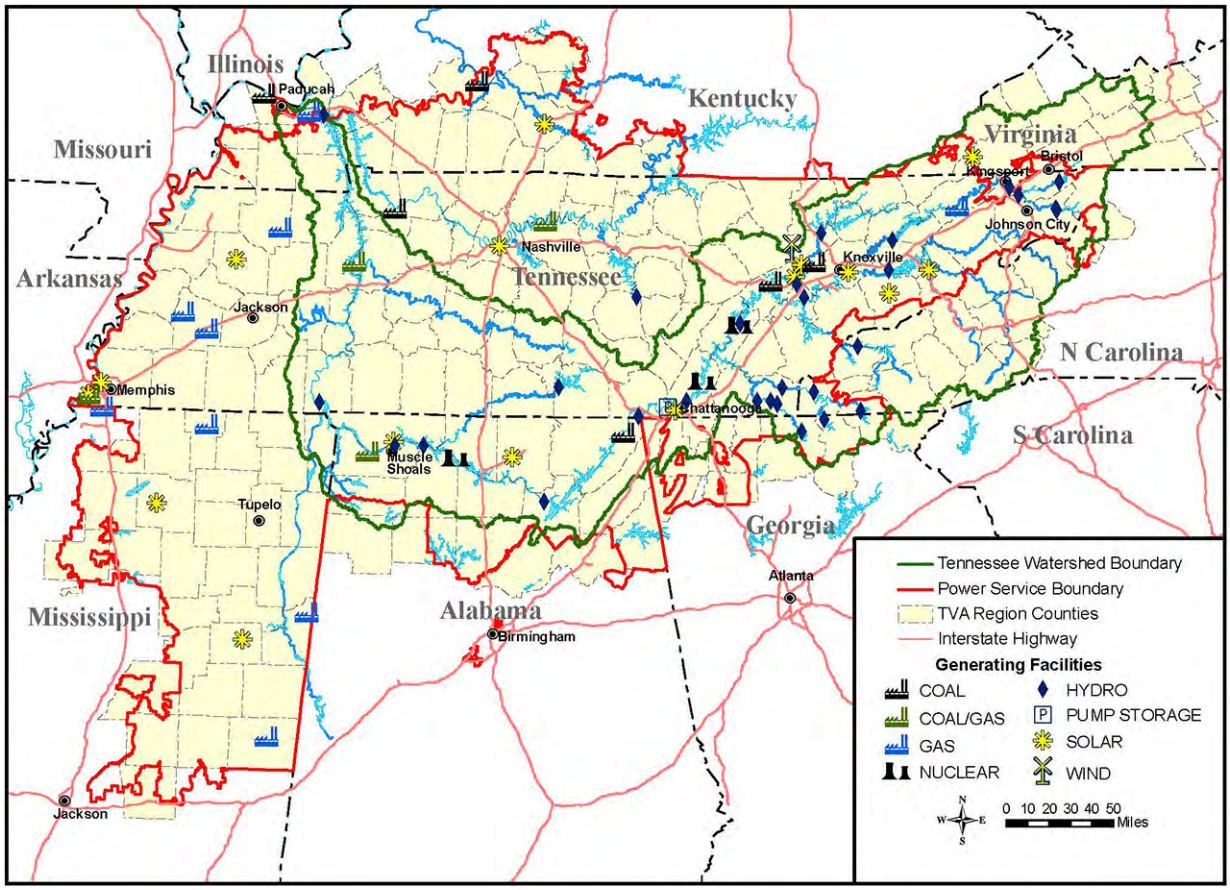

Figure 1-1 The TVA region.

"affirm support for the objectives and missions of [TVA], including being a national leader in technological innovation, low-cost power, and environmental stewardship." The amendments also created a full-time chief executive officer. Directors are nominated by the president of the United States and confirmed by the U.S. Senate to serve five-year terms.

1.2 History of the TVA Power System

At the time of TVA's establishment in 1933, the Tennessee Valley region was suffering from the Great Depression, flooding along the Tennessee River and erosion of the region's natural resources. From its beginning, TVA was charged with the integrated development of the region with emphasis on flood control, navigation and power production. Consistent with these purposes, TVA was also to provide a range of other public benefits, including the proper use of reservoir lands, the conservation and development of the natural resources of the region, and the enhancement of the economic and social well-being of residents. As described by President Franklin Roosevelt, TVA was created as "a corporation clothed with the power of government but possessed of the flexibility of a private enterprise" (Roosevelt 1933). TVA is a federal agency in corporate form.

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To meet its objectives of flood control, navigation and power production, the newly formed TVA took over the operation of Wilson Dam and began constructing a series of hydroelectric dams on the Tennessee River and its tributaries. The first new TVA dam to be completed was Norris Dam in 1936. By that time, four other dams were under construction.

Simultaneous with this was the construction of a network of transmission lines to make electricity available across the region. Early transmission system developments included the construction of the Wilson-Wheeler-Norris line, TVA's first long-distance high-voltage line; the construction of lines connecting to the newly completed hydroelectric plants; and, the integration of numerous existing transmission lines purchased by TVA. By 1939, this transmission system included about 4,200 miles of transmission lines. A large proportion of these were 44-kV lines with shorter lengths of 110-kV and 154-kV lines. These lines connected to a network of local electrical distributors that constructed and operated low-voltage lines that served end-users. TVA also directly supplied a few large industrial end-users. This early generation transmission and distribution system provided abundant and inexpensive electricity, a major tool for attracting industry and improving the quality of life in the region.

The construction of hydroelectric dams greatly accelerated during World War II to provide power for critical war industries. At its peak in 1942, 12 hydroelectric projects and the coal-fired Watts Bar Steam Plant were under construction. Over 1,800 miles of new transmission lines, a large proportion of them 154-kV and 161-kV, were constructed during this period.

By the late 1940s, the rapid growth in the demand for electricity was about to exceed the capacity of TVA's dams, Watts Bar Steam Plant and a few small steam plants acquired by TVA. TVA began planning several large coal-fired steam plants and started constructing the first of these in 1949. Cumberland, the newest of these large steam plants, was completed in 1973. The steam plants incorporated several technology advancements, including the largest, first-of-its-kind, coal-fired units in the world.

Early in this period, TVA faced increasing difficulty in securing federal appropriations to build these single-purpose plants. In 1959, Congress passed legislation to make the TVA power system self-financing, a situation that continues to this day. This legislation also established a statutory "fence" that prohibited TVA from selling power beyond its service area, with the exception of those neighboring electric companies with which TVA already had power exchange agreements. This fence was modified by the Energy Policy Act of 1992 by prohibiting the Federal Energy Regulatory Commission from requiring TVA to transmit electricity from suppliers outside the fence to customers inside the fence; this modification limits the ability of other utilities to serve TVA customers over TVA's transmission system.

TVA became the largest power producer in the U.S. during the 1950s. The TVA transmission system also greatly expanded during this period, due largely to the need to transmit electricity from the new steam plants. Over 4,300 miles of new transmission lines were constructed, mostly 154-kV and 161-kV lines. The 154-kV lines were soon routinely operated at 161-kV. TVA installed its first microwave communication systems and began using electronic data processing equipment to manage system operations during this era.

The 1960s were years of unprecedented economic growth in the Tennessee Valley, with TVA power rates among the lowest in the country. To meet the need for more power, TVA expanded its generating resources through an ambitious program of nuclear plant construction. This

program originally called for 17 nuclear units at seven plant sites. TVA began construction of the first nuclear plant, Browns Ferry, in 1966, and its three units began commercial operation between 1974 and 1977. TVA completed the two-unit Sequoyah Nuclear Plant in 1982.

The large increase in generating capacity led to the construction of a network of extra-high voltage 500-kV lines to economically and reliably transmit large amounts of power within the TVA service area and to exchange power with neighboring utilities. TVA built an experimental 6-mile long 460-kV line in 1959 to gain experience with construction methods and costs. TVA then completed the world's first 500-kV line, a 155-mile line from Johnsonville Fossil Plant to an interconnection with Arkansas Power and Light near Memphis, Tennessee, in 1965. Over the next two decades, TVA built several other 500-kV transmission lines.

The 1970s brought significant changes in the economy and the demand for electricity. These started with the international oil embargo in 1973 and continued with rapidly rising fuel costs later in the decade. The average cost of electricity in the Tennessee Valley increased fivefold from the early 1970s to the early 1980s. With energy demand dropping and construction costs rising, TVA canceled the four-unit Hartsville Nuclear Plant and the two-unit Phipps Bend and Yellow Creek Nuclear plants. Completion of the two-unit Watts Bar and Bellefonte Nuclear plants was deferred. The passage of several major environmental laws during this period also affected TVA and the utility industry.

During the 1970s and 1980s, TVA constructed or participated in several innovative and/or experimental plants:

- The Raccoon Mountain Pumped-Storage Plant near Chattanooga was completed in 1978. This facility works like a large battery by pumping water from Nickajack Reservoir to a mountaintop reservoir during periods of low demand, and then reversing the water flow to generate electricity during periods of high demand.
- After operating an experimental 20-MW atmospheric fluidized bed combustion (AFBC) pilot unit at Shawnee Fossil Plant in the early 1980s, TVA completed a 160-MW AFBC unit at Shawnee in 1989, the first commercial-scale unit of its kind.
- TVA was a partner with the Department of Energy and Commonwealth Edison in a project to develop and construct the Clinch River Breeder Reactor near Oak Ridge, Tennessee, but this project was delayed and then canceled in 1983.
- In 1981, TVA began work on the Murphy Hill Coal Gasification Plant in northeast Alabama with funding from the Synthetic Fuels Corporation. This plant, designed to convert coal into liquid fuels, was canceled after Congress stopped funding the Synthetic Fuels Corporation and additional funding did not materialize.

As energy costs across the nation continued to climb in the 1970s and early 1980s, TVA introduced programs to encourage customers to reduce their electricity use. These programs focused on energy conservation and peak load reduction and helped TVA's existing generating resources meet the increased demand for energy. To become more competitive, TVA began aggressively improving the efficiency and productivity of its operations while cutting costs. In the late 1980s, TVA began a period of rate stability that would last for a decade. TVA also halted several of its energy conservation programs.

In 1985, the Browns Ferry and Sequoyah Nuclear plants were shut down due to safety concerns. The two Sequoyah units were restarted in 1988. After extensive modifications, TVA

restarted Browns Ferry units 2 and 3 in 1991 and 1995 respectively, and Unit 1 in 2007. Following a long period of deferred construction, Watts Bar Nuclear Plant Unit 1 was completed and began generating electricity in 1996. TVA resumed work on Watts Bar Unit 2 in 2007, with plans to begin commercial operation in 2015.

As the electric utility industry moved toward restructuring in the 1990s, TVA began preparing for competition. TVA further cut operating costs, reduced its workforce and increased the generating capacity of some its plants. TVA began a program to modernize its hydroelectric plants by automating their operation and replacing aging equipment, which resulted in an increase in their generating capacity. In the mid-1990s, TVA completed the *Energy Vision 2020* IRP and adopted short- and long-term action plans to serve the energy needs of the region and to be competitive in a deregulated market. Since then, TVA has increased its natural gas-fueled generating capacity by about 7,800 MW and implemented a clean-air strategy to greatly reduce emissions from its coal-fired plants. TVA also has continued to build about 150 miles of new transmission lines annually, and many new customer delivery points. In 2008, TVA completed its first major 500-kV transmission line since the 1980s.

In 2008, TVA developed its Environmental Policy (TVA 2008a), which is organized in six environmental areas that encompass the variety of issues faced by TVA:

- Climate change mitigation
- Air quality improvement
- Water resource protection and improvement
- Waste minimization
- Sustainable land use
- Natural resources management

The policy objective is to provide cleaner, reliable and still-affordable energy, support sustainable economic development in the Tennessee Valley and engage in proactive environmental stewardship in a balanced and ecologically sound manner.

In the last few years, TVA completed the 2011 IRP that replaced the *Energy Vision 202*0 IRP. It has added over 1,500 MW of wind generating capacity through power purchase agreements and is steadily increasing its solar generating capacity through the Renewable Standard Offer program and other initiatives. In 2011, to resolve disputes over violations of the New Source Review requirements of the Clean Air Act, TVA entered into a Federal Facilities Compliance Agreement with the Environmental Protection Agency (EPA) and a similar judicial consent decree with four states and three environmental advocacy organizations. These agreements require TVA to continue to reduce its emissions of air pollutants by retiring some coal-fired generating units and installing additional air pollution control equipment, repowering to burn renewable biomass or retiring several other units over time through 2019. These actions are described in more detail in Chapter 3. The agreements also require TVA to implement certain energy efficiency and demand-reduction programs.

1.3 Purpose and Need for Integrated Resource Planning

Like other utilities, TVA develops long-range power supply plans. This planning process includes forecasting the demand for power and developing capacity resource plans. In 1995, TVA developed the comprehensive *Energy Vision 2020* integrated resource plan with extensive

public involvement in response to Section 113 of the Energy Policy Act of 1992 (now the least-cost system-wide planning provision of the TVA Act). In 2011, TVA completed a new updated IRP (TVA 2011b) and associated Final EIS (TVA 2011a). When completed, this IRP will update and replace the 2011 IRP.

The purpose of the IRP and EIS processes is to evaluate TVA's current energy resource portfolio and alternative future portfolios of energy resource options in a system-wide least-cost manner to meet future electrical energy needs of the TVA region, while taking into account TVA's energy, environment, and economic development missions. TVA is developing this updated IRP because several of the assumptions used in the 2011 IRP have changed, including reduced demand for electricity, greater availability and lower cost of natural gas, and increased regulatory actions.

1.4 The Integrated Resource Planning Process

The basic least-cost integrated resource planning process that TVA employed consisted of seven steps:

1. Scoping – Through interaction with the public and expert TVA staff, TVA identified important issues to be considered in the planning process. The results of the public scoping are described in more detail below in Section 1.5 – Scoping and Public Involvement.
2. Develop Study Inputs and Framework – Much of the IRP analysis involves sophisticated computer modeling. In this step, model inputs are determined for topics out of TVA's control, such as the forecasted need for power, fuel prices, environmental and other legislation, and construction and materials costs. These inputs are organized into various scenarios that portray possible future "worlds" that TVA may find itself in.

   Another phase of this step is development of various resource planning strategies where TVA varies amounts and and types of energy resource additions under its control, such as energy conservation and demand reduction programs, renewable energy, nuclear generation and energy from other producers. The five scenarios and five strategies are described in more detail in Chapter 2 – TVA's Resource Planning Process.
3. Analyze and Evaluate – Once the model inputs and framework are developed, a two-phase modeling process produces least-cost energy resource plans, and associated plan costs and other evaluation metrics. A unique capacity expansion plan or portfolio was produced for each of the 25 combinations of strategies and scenarios. The results of this modeling are described in Chapter 6 – Alternatives.
4. Present Initial Results and Gather Feedback – The Draft IRP that incorporates the results of the modeling and the associated Draft SEIS was completed and issued for review by the public.
5. Incorporate Feedback and Perform Additional Modeling – After the close of the public comment period, TVA reviewed all comments and prepared responses to them. TVA conducted additional analyses in response to public comments and internal feedback.
6. Identify Preferred Resource Planning Strategy – Based on the public comments and results of any additional analyses, TVA identify a preferred strategy. This is documented in the Final IRP and this Final SEIS. The Final SEIS contains responses to the public comments in Volume 2.

7. Approval of Preferred Resource Planning Strategy – No sooner than 30 days after the publication of the Notice of Availability of this Final SEIS in the *Federal Register*, the TVA Board of Directors will be asked to approve the preferred strategy. The board's decision will be described and explained in a Record of Decision.

The following objectives guide TVA's development of the IRP:

- Deliver a plan aligned to mandated least-cost planning principles.
- Lessen risk by adopting a diverse portfolio of supply and demand-side resources.
- Deliver clean energy and lower environmental impacts.
- Consider increased use of renewables, energy efficiency and demand response resources.
- Ensure the portfolio delivers energy in a reliable manner.
- Create a reliable method for measuring energy efficiency.
- Provide flexibility to adapt to changing market conditions and future uncertainty.
- Improve credibility and trust through a collaborative and transparent approach.
- Integrate stakeholder perspectives throughout the process.

1.5 Scoping and Public Involvement

NEPA regulations require an early and open process for deciding what should be discussed in an EIS. This scoping process involves requesting and using comments from the public and interested agencies to help identify the issues and alternatives that should be addressed in the EIS, as well as the temporal and geographic coverage of the analyses.

1.5.1 Scoping

Although scoping is not required when an EIS is supplemented, TVA began a 33-day public scoping process for the IRP and associated EIS with the issuance of media releases, newspaper advertisements, a notice on the project website http://www.tva.com/environment/reports/irp/index.htm, and by notices sent to participants involved in the development of the 2011 IRP. The IRP website materials included background information; a form for submitting scoping comments; addresses for submitting comments by mail, email, or fax; and, information on public scoping meetings. The Notice of Intent to prepare the supplemental EIS was published in the *Federal Register* Oct. 31, 2013. The scoping period closed on Nov. 22, 2013.

TVA held two public scoping meetings:

- Oct. 24, 2013, in Knoxville, Tennessee.
- Nov. 6, 2013, in Memphis, Tennessee.

Each public meeting was simultaneously broadcast on the Internet in webinar format. During each meeting, TVA staff described the process of developing the IRP and associated EIS, and then responded to questions from both the in-person and online audiences. Attendees were also encouraged to submit comments on comment cards and through an online comment form.

About 85 people attended the scoping meetings in person and by webinar. Attendees included members of the general public, representatives from state agencies and local governments, TVA power distributors, non-governmental organizations and other special interest groups. TVA

personnel introduced the proposed action and answered questions about the planning process, the EIS, the TVA power system, potential energy resources and environmental topics.

TVA received 1,156 individual scoping comments. About 20 scoping meeting attendees submitted comments during the meetings. Thirty email comments were received from individuals and organizations, and an additional 73 comments were submitted through the TVA website. About 96 percent of the comments were from individuals, with the remainder from organizations (19), businesses (21) and state and federal agencies (3).

Most of the comments from individuals were form letters and emails submitted in response to advocacy campaigns. The majority of these, 979, were submitted through a Sierra Club/Tennessee Environmental Council campaign. About 50 comment forms were submitted through a campaign initiated by Mississippi-based entities associated with mining coal and generating electricity from coal. Scoping comments were received from individuals or entities in all seven states in the TVA region, with the majority (78 percent) from Tennessee. Comments also were received from individuals or entities in seven states outside the TVA region. The scoping comments are summarized below and described in more detail in the IRP EIS Scoping Report, issued June 2014 and available on the IRP website (TVA 2014a).

The Sierra Club/Tennessee Environmental Council campaign comments thanked TVA for recent coal plant retirement decisions, urged TVA to prioritize the use of solar and wind energy, increase energy efficiency efforts and work to reduce the local economic impacts of coal plant retirements. The Mississippi campaign comments cited the abundance and stable cost of coal, the high capacity factor of coal plants, the employment provided by the use of coal and coal's contribution to low and stable rates.

Other scoping comments, including those from the scoping meetings, addressed a wide range of IRP-related topics categorized as follows:

Energy Resource Options
Most of the comments that mentioned potential energy resource options addressed the benefits and/or drawbacks of various energy options, including nuclear, coal-fired, and natural gas-fired generation, as well as solar and wind renewable generation. Numerous comments encouraged increased energy efficiency efforts, while a small number of comments encouraged increasing other demand-reduction options, including demand response and combined heat and power. Several comments requested that TVA fully and fairly evaluate all potential energy resources.

Impacts of Power System Operations
Many of the comments addressed the negative and/or beneficial environmental and economic impacts of the use of various energy resource options. These included air pollutants, greenhouse gas emissions and climate change, spent nuclear fuel and disposal of coal ash. Several comments also mentioned impacts resulting from mining, particularly surface mining, of coal and hydraulic fracturing for producing natural gas. Commenters requested that TVA assess the vulnerability of TVA's power system to climate change, as well as the effects of climate change on TVA's power demand forecasts. Several commenters also requested that TVA conduct more detailed analyses of the local and regional economic impacts, including employment.

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Integrated Resource Planning Process

Several comments addressed aspects of the integrated resource planning process. Comments on scenarios included the incorporation of the effects of climate change, varying approaches to incorporating regulation of greenhouse gas emissions, the evaluation of future fuel prices, particularly for natural gas, and the impacts of current and anticipated environmental regulations. Comments on strategies included maximizing renewable generation and energy efficiency, phasing out the use of fossil fuels, transmission grid upgrades and increased distributed generation. Other planning process comments addressed the valuation of renewable energy resources, the removal of constraints on quantities of renewable energy, energy efficiency and demand response, and incorporating the external health and environmental costs of all energy resources. Many commenters emphasized the use of least-cost analysis and that TVA is sensitive to the adopted plan's effects on ratepayers.

1.5.2 Public Briefings

In addition to the public scoping described above, TVA held public briefings on March 26, 2014, in Chattanooga, Tennessee, June 18, 2014 in Knoxville, and November 3, 2014, in Knoxville. Participants could attend in-person or by webinar. The briefings consisted of presentations by TVA staff on the status of the IRP and a moderated question-and-answer session. Topics discussed at the public briefings included an introduction to the integrated resource planning process, load forecasts, resource options, development of scenarios and strategies, and evaluation metrics. Attendance at the briefings averaged about 20 people in-person and about 50 people by webinar. Recordings of the sessions and the presentation materials were posted on the project website.

1.5.3 IRP Working Group

TVA established an IRP Working Group to more actively engage stakeholders throughout the IRP development process. The 18-member group is composed of representatives of state agencies, the Department of Energy, distributors of TVA power, industrial groups, academia, and energy and environmental non-governmental organizations. The members were expected to represent their constituency and report to them on the IRP process, as well as give input to TVA on the process. The group first met in November 2013 and met almost monthly through much of the plan development period. The group met a total of 14 times. Additional information about the review group is available at www.tva.com/environment/reports/irp/index.htm.

1.5.4 Other Public Involvement

After the close of the scoping period, TVA received comments related to the IRP from two advocacy campaigns. In the spring of 2014, TVA received almost 1,000 postcards through a Tennessee Sierra Club campaign. The message on these cards was similar to that of the Sierra Club / Tennessee Environmental Council email campaign during the public scoping. In the fall of 2014, TVA received over 5,000 form emails through the "takeactionTN" campaign, promoted by the Tennessee Electric Cooperative Association and America's Electric Cooperatives. These comments advocated an "all-of-the-above" approach to energy generation, opposed greenhouse gas regulations proposed by the EPA, expressed concern over reliance on nuclear and natural gas generation, and emphasized low-cost and reliability.

TVA staff also gave several presentations on the development of the IRP to various organizations.

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1.5.5 Public Review of the Draft IRP and SEIS

The Draft IRP and SEIS were issued for public review on March 9, 2015 and the notice of their availability was published in the Federal Register on March 13, 2015. This initiated the public comment period which closed on April 27, 2015.

The Draft IRP and SEIS were posted on the project website. Printed copies and/or CDs containing electronic files of the documents were mailed to certain federal agencies and to others upon request. Others on the project contact list, including several state and federal agencies, organizations, and numerous individuals, were mailed or e-mailed notifications of the availability of the documents and instructions on how to submit comments.

TVA accepted comments submitted through an electronic comment form on the project website, and by mail and email. During the comment period, TVA held seven public meetings (Table 1-1) to describe the project and to accept comments on the Draft IRP and SEIS. TVA staff presented an overview of the planning process and draft results. Attendees then had the opportunity to make comments and ask questions about the project. A panel of TVA staff responded to the questions. Two of the meetings were simultaneously broadcast online as webinars and TVA responded to comments and questions submitted by webinar participants in the same manner as those from in-person attendees. About 400 people attended the public meetings in person and by webinar.

Table 1-1 Public meetings held in 2015 following release of Draft IRP and SEIS.

Date	Location
March 19 2015	Chattanooga, TN*
April 6, 2015	Knoxville, TN*
April 9, 2015	Huntsville, AL
April 14, 2015	Tupelo, MS
April 15, 2015	Memphis, TN
April 21, 2015	Nashville, TN
April 22, 2015	Bowling Green, KY

*Meeting also broadcast by webinar.

TVA received about 200 comments signed by more than 2,400 individuals, which included letters, form postcards, emails, form emails, oral statements, and submissions through the project website. These were carefully reviewed and synthesized into about 180 individual comments. These comments and TVA's responses to them are provided in Volume 2 of this Final SEIS. TVA also considered the comments as it developed the Target Power Supply alternative that has been added to the Final IRP and SEIS.

1.6 Statutory Overview

In addition to Section 113 of the Energy Policy Act of 1992, several federal laws and executive orders are relevant to TVA's integrated resource planning. Those that are specific to the natural, cultural and socioeconomic resources potentially affected by the TVA power system are described below. This section begins with a detailed description of the National Environmental Policy Act and then lists other potentially applicable laws and executive orders.

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National Environmental Policy Act

This supplemental EIS has been prepared by TVA in accordance with the National Environmental Policy Act (NEPA) of 1969 (42 United States Code [U.S.C] §§ 4321 et seq.), regulations implementing NEPA promulgated by the Council on Environmental Quality (40 Code of Federal Regulations [C.F.R] Parts 1500 to 1508), and TVA NEPA procedures. TVA's Board of Directors will consider the analyses in this SEIS and IRP when it selects the resource plan to be implemented.

NEPA requires federal agencies to consider the impact of their proposed actions on the environment before making decisions. Actions, in this context, can include new and continuing activities that are conducted, financed, assisted, regulated or approved by federal agencies, as well as new or revised plans, policies, or procedures. For major federal actions with significant environmental impacts, NEPA requires that an EIS be prepared. This process must include public involvement and analysis of a reasonable range of alternatives.

According to CEQ regulations, a programmatic EIS is appropriate when a decision involves a policy or program, or a series of related actions by an agency over a broad geographic area. Due to the comprehensive nature of the IRP, this supplemental EIS meets that criterion. The environmental impacts of the alternative actions are, therefore, addressed at a regional level, with some extending to a national or global level. The more site-specific effects of actions that are later proposed to implement the IRP will be addressed in subsequent tiered environmental reviews.

The Draft SEIS was distributed to interested individuals; groups; and, federal, state, and local agencies for their review and comment. Following the close of this public comment period, TVA responded to the substantive comments received on the Draft SEIS and incorporated any required changes into the Final SEIS. The completed Final SEIS has been placed on TVA's website, and notices of its availability were sent to those who received the Draft SEIS or submitted comments on the Draft SEIS. TVA also sent the Final IRP and SEIS to the Environmental Protection Agency, which will publish a notice of its availability in the *Federal Register*. The TVA Board will be asked to make a decision regarding this study no sooner than 30 days after the publication of this notice of availability. TVA will then issue a Record of Decision which will include (1) the decision; (2) the rationale for the decision; (3) alternatives that were considered; (4) the alternative that was considered environmentally preferable; and, (5) associated mitigation measures and monitoring, and enforcement requirements.

Other Laws and Executive Orders

Several other laws and executive orders are relevant to the construction and operation of electric power systems (Table 1-3). These laws and orders may affect the environmental consequences of an alternative plan, or measures needed during its implementation. Most of these laws also have associated implementing regulations. 4.0 Affected Environment describes the regulatory setting for each resource in more detail. 7.0 Anticipated Environmental Impacts discusses applicable laws and their relevance to this analysis.

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Table 1-2 Laws and executive orders relevant to the environmental effects of power system planning, construction, and operation.

Environmental Resource Area	Law / Executive Order
Water Quality	Clean Water Act
Groundwater	Safe Drinking Water Act
	Resource Conservation and Recovery Act
Air Quality	Clean Air Act
Wetlands	Clean Water Act
	Executive Order 11990 – Protection of Wetlands
Floodplains	Executive Order 11988 – Floodplain Management
Endangered and Threatened Species	Endangered Species Act
Cultural Resources	National Historic Preservation Act
	Archaeological Resource Protection Act
	Native American Graves Protection and Repatriation Act
Environmental Justice	Executive Order 12898 – Federal Actions to Address Environmental Justice in Minority and Low-Income Populations
Land Use	Farmland Protection Policy Act
Coal Mining	Surface Mining Control and Reclamation Act
Waste Management	Resource Conservation and Recovery Act
	Comprehensive Environmental Response, Compensation, and Liability Act
	Toxic Substances Control Act

1.7 Relationship with Other NEPA Reviews

Several NEPA reviews are relevant to TVA's integrated resource planning:

River Operations Study Final Environmental Impact Statement
Published in 2004, this EIS (TVA 2004) evaluated potential changes in TVA's policy for operating its reservoir system. The new operating policy adopted by TVA established a balance of reservoir system operating objectives to produce a mix of benefits that is more responsive to the values expressed by the public. The changes include enhancing recreational opportunities while avoiding unacceptable effects on flood risk, water quality and TVA electric power system costs. This EIS contains a detailed description of TVA's hydroelectric generating facilities and is incorporated by reference.

Adoption of PURPA Standards for Energy Conservation and Efficiency Environmental Assessment
This 2007 environmental assessment (TVA 2007a) evaluates TVA's proposed adoption of standards established by the Public Utilities Regulatory Policies Act of 1978, as modified by the Energy Policy Act of 2005, for Smart Metering, Net Metering, Fuel Diversity, Fossil Fuel Generation Efficiency, and Interconnection. TVA decided to adopt the first three standards without changing its operations, and to adopt modified versions of the last two standards. Some of these standards are relevant to the integrated resource planning process.

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Environmental Impact Statements and Environmental Assessments for Generating Facilities and Transmission Lines

Since the early 1970s, TVA has issued numerous EIS and environmental assessments describing the anticipated impacts of the construction and operation of new generating facilities, major upgrades to generating facilities, new transmission lines and substations, and power purchase agreements. Most of those that have been issued since 2002 are available at www.tva.com/environment/reports/index.htm. Several of these were used as sources of information for the impact analyses in Chapter 7. Recent examples include:

- The 2007 EIS on the completion of Watts Bar Nuclear Plant Unit 2 (TVA 2007b).
- The 2010 environmental assessment for the construction of a combined cycle plant at John Sevier Fossil Plant (TVA 2010a).
- The 2010 EIS on the completion of a nuclear generating unit at the Bellefonte site in northeast Alabama (TVA 2010b).
- The 2013 environmental assessment for the installation of air pollution control equipment at Gallatin Fossil Plant (TVA 2013a).
- The 2013 environmental assessment of a new combined cycle plant and retirement of two coal units at Paradise Fossil Plant (TVA 2013b).
- The 2013 environmental assessment for the purchase of power from two large solar farms in southwest Tennessee (TVA 2013c).
- The 2013 environmental assessment of a new 500-kV substation and associated transmission line connections in Cumberland County, Tennessee (TVA 2013d).
- The 2014 environmental assessment for the purchase of power from three small solar farms in Starkville, Mississippi (TVA 2014b).
- The 2014 environmental assessment for the purchase of power from a landfill gas generating plant at Bristol, Virginia (TVA 2014c).
- The 2014 environmental assessment of a new combined cycle plant and retirement of coal units at Allen Fossil Plant (TVA 2014d).
- The 2014 environmental assessment of a 16-mile transmission line in northeast Mississippi (TVA 2014e).
- The 2014 programmatic environmental assessment for small solar photovoltaic generating facilities (TVA 2014f).

1.8 EIS Overview

This Final Supplemental EIS consists of 10 chapters:

Chapter 1 – Introduction—The purpose and need for the IRP SEIS, the decision to be made; history of the TVA power system; an overview of integrated resource planning, the scoping process and public involvement.

Chapter 2 – TVA's Resource Planning Process—The integrated resource planning process; evaluation metrics; the need for power assessment; scenario and strategy development.

Chapter 1 – Introduction

Chapter 3 – The TVA Power System—TVA customers, sales, and power exchanges; TVA-owned generating facilities; purchased power; energy efficiency and demand response programs; the transmission system.

Chapter 4 – Affected Environment—Natural, cultural, and socioeconomic environments potentially affected by the alternative actions.

Chapter 5 – Energy Resource Options—Supply (e.g., generating facilities) and demand-side (e.g., energy efficiency and demand response programs) potentially comprising the power portfolios.

Chapter 6 – Alternatives—The alternative/strategy development process; the alternative strategies assessed in this EIS; and a comparison of the alternative strategies.

Chapter 7 – Anticipated Environmental Impacts—Anticipated environmental impacts of each of the options used in the final alternative strategies, environmental impacts of each alternative strategy over the 20-year planning period.

Chapters 8-10: Lists of cited literature, preparers and EIS recipients, followed by the glossary and index.

2.0 TVA's Resource Planning Process

TVA used a scenario planning approach to develop the IRP. The major steps in this approach are identifying the future need for power, developing scenarios and strategies, determining potential supply-side and demand-side resource options; developing portfolios associated with the strategies, and ranking the strategies and portfolios. This chapter describes the need for power analysis, the development of scenarios, strategies and portfolios, and the metrics used to evaluate the portfolios. The potential resource options are described in Chapter 5, and the alternative strategies and their associated portfolios are described in Chapter 6.

2.1 Need for Power Analysis

In determining the need for power, TVA forecast the demand for power, determined the reserve capacity needs, identified the current power supply resources available to meet this demand during the 2014-2033 planning period, and used the difference in supply and demand to identify the capacity and energy gaps. The long-term energy and peak demand forecasts are developed from individual forecasts of residential, commercial and industrial sales. These forecasts serve as the basis for the power system and financial planning activities.

Capacity is the instantaneous maximum amount of energy that can be supplied by a generator or collectively by the power system. For long-term planning purposes, capacity can be specified in several ways such as nameplate (the maximum technical output of the generator as designed), capability (the maximum dependable output without restrictions), and summer net dependable (the maximum output expected at the time of the summer peak). Capacity is measured in watts; common units are kilowatts (kW, one thousand watts), megawatts (MW, one million watts) and gigawatts (GW, one billion watts).

The term energy is used in power planning to describe the amount of power delivered in a specified time period.

Peak demand, also known as peak load, is the maximum rate of electricity use, typically measured in terms of capacity and expressed in MW. The TVA system is dual-peaking with high demand occurring in both the summer and winter months. For several decades, the annual winter peak was higher than the summer peak. More recently, the annual summer peak has often been higher than the winter peak. This pattern is expected to continue.

Capacity factor is a measure of the actual amount of energy delivered by a generator compared to the maximum amount it could have produced. Baseload plants (see Section 2.2.5) such as nuclear and large coal plants have high-capacity factors and generate large amounts of energy for long time periods. Plants that are used infrequently such as combustion turbines have low-capacity factors and provide relatively little energy. Because the energy they generate is often delivered at times of peak demand (and high cost), combustion turbines and other peaking resources are highly valued.

Demand-side resources (also known as energy efficiency and demand response (EEDR) resources (see Section 3.5) can also be measured in terms of capacity and energy. Even though these resources do not generate power, their effect on the system is similar as they represent power that is not required or power use that can be shifted from high-demand periods to low-demand periods.

2.1.1 Load Forecasting Methodology

TVA's load forecasting uses the best available data and both econometric and end-use models. Econometric models link electricity sales to several key market factors, such as the price of electricity, the price of competing energy sources (e.g., natural gas) and growth in economic activity. These models are used to forecast electricity sales growth in the residential, commercial and industrial sectors. Underlying trends within each sector, such as the use of various types of equipment or processes, changes in energy efficiency over time and equipment replacement rates, play a major role in forecasting energy use. To capture these trends, TVA uses a variety of end-use forecasting models. For example, in the residential sector, energy use is forecast for space heating, air conditioning, water heating and several other uses. In the commercial sector, categories including lighting, cooling, refrigeration and space heating are examined.

Forecasting is inherently uncertain, so TVA supplements its modeling with industry analyses and studies of specific major issues. This is part of an effort to improve TVA's understanding of the Valley load and economy, and produce accurate forecasts. TVA also produces alternative regional forecasts such as the high and low forecasts that define a range of possible loads with a 90 percent confidence that the true forecast will fall within this range.

Of the many key inputs to the load forecasts for the residential, commercial and industrial sectors, the most important are economic activity; customer retention; price of electricity; and prices of substitute sources of energy, particularly natural gas.

Economic Activity - TVA produces forecasts of regional economic activity for budgeting and long-range planning purposes. These forecasts are built from county-level economic forecasts to accurately model the prevailing economic conditions in the TVA service area.

The economy of the TVA service area has historically been more dependent on manufacturing than the U.S. as a whole, with industries such as pulp and paper, aluminum and chemicals drawn to the region because of the availability of natural resources and reliable, inexpensive electricity. For several decades, however, the manufacturing share of non-farm employment in the TVA region has steadily declined at a rate comparable to the rest of the U.S. Unlike the rest of the U.S., manufacturing's share of the region's economic output has remained relatively steady at about 18 percent since 1980. Although many of the labor-intensive manufacturing industries have moved overseas, more labor- and energy-efficient industries have maintained the regional value of manufacturing economic output. This relatively high dependence on manufacturing tends to make the regional economy more sensitive to general economic conditions impacting the demand for manufactured goods.

Customer Retention - Over the last 25 years, the electric utility industry has undergone a fundamental change in much of the country. In many states, an environment of regulated monopoly has been replaced with varying degrees of competition. While TVA has long-term contracts with the 155 local power companies (LPCs), it is not immune to competitive pressures. Most of these contracts allow LPCs to give TVA five years' notice of contract cancellation, after which they may procure power from other sources. Many of TVA's large, directly served industrial customers have the option to shift production from plants served by TVA to plants in territories served by other utilities with lower power rates. Additionally, large industrial operations could (and to some extent, do) generate some or all of their own power, an increasingly attractive option with low natural gas prices.

Price of Electricity - Forecasts of the price of electricity are based on long-term estimates of TVA's total costs to operate and maintain the power system and the markups charged by the LPCs that distribute TVA power. Forecasts of these total revenue requirements are based on estimates of key costs such as fuel, operations and maintenance, capital investment and interest. The high and low electricity price forecasts are derived from variations in these same factors.

Price of Substitute Fuels - Electricity is a major source of energy, and some of its energy services can be obtained from other sources. The potential for substitution between the use of electricity and other fuels, primarily natural gas, depends on relative prices, the ability of other fuels to provide comparable services and the physical capability of the consumer to change fuels. Changes in the TVA price of electricity relative to the price of natural gas and other fuels influence consumers' choices of fuels for appliances, space heating, and commercial and industrial processes. While other substitutions are possible, natural gas prices serve as the benchmark for determining substitution impacts in the load forecasts.

2.1.2 Forecast Accuracy

The accuracy of the forecasts is measured in part by the difference between the forecast and the actual demand (weather normalized) expressed as percent error. The mean absolute percent errors of TVA's forecasts of net system energy requirements and peak loads for the fiscal year 1999–2014 period were 1.8 percent and 3.1 percent, respectively. The energy forecast errors include an unusually large error (7.6 percent) in 2009 as the full severity of the impact of the Great Recession on energy demand was not yet realized. Forecast accuracy is described in more detail in IRP Section 4.1.2.

2.1.3 Peak Load and Net System Energy Forecasts

To deal with the uncertainty inherent in forecasting, TVA developed a range of forecasts, each corresponding to a different scenario (see Section 2.3 for more details on the scenarios). Forecasts of peak load and net system energy for the baseline Current Outlook Scenario and the scenarios with the highest demand (the Growth Economy Scenario) and lowest demand (the Distributed Marketplace Scenario) are shown in Figure 2-1.

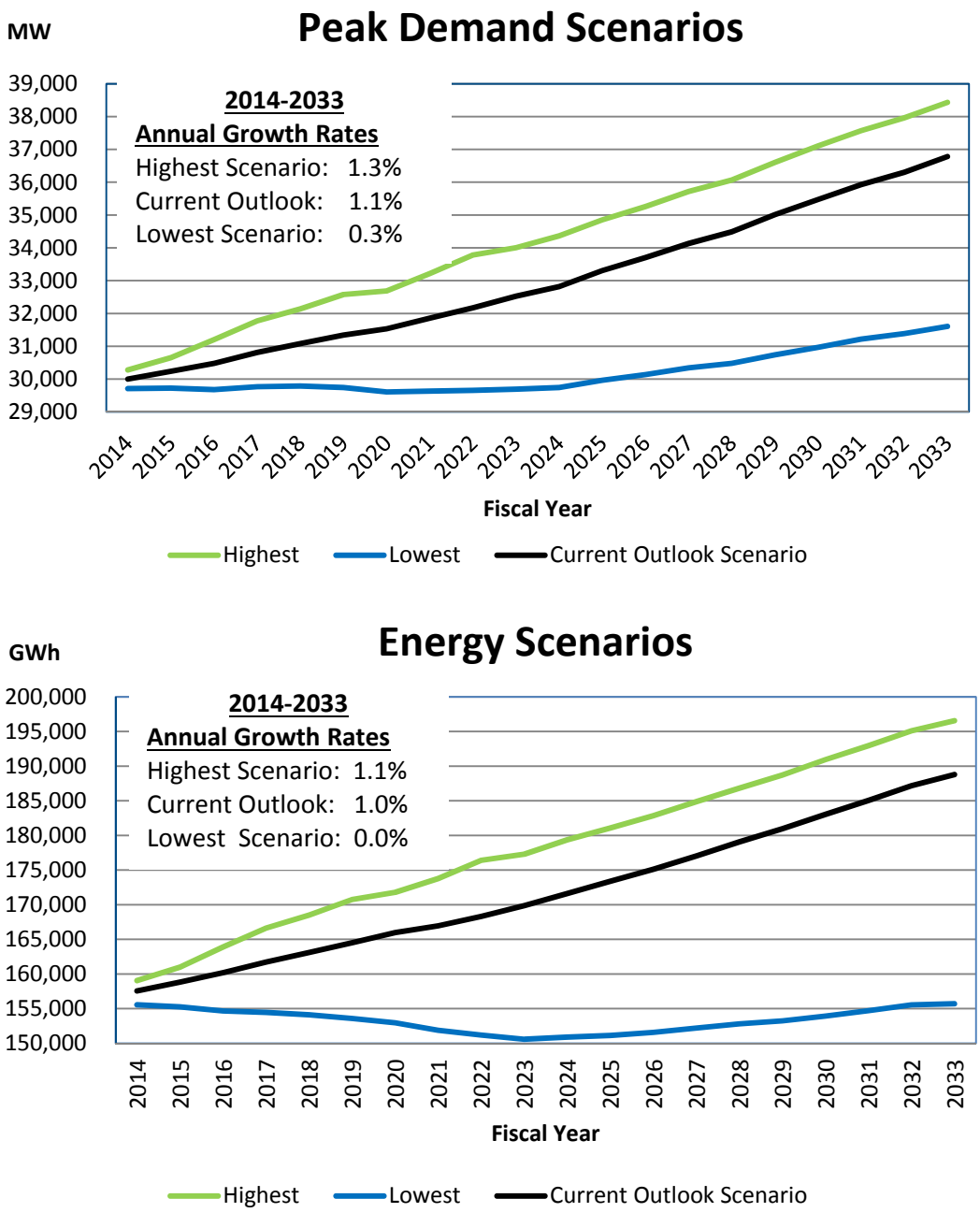

Figure 2-1 Fiscal year 2014-2033 peak demand (top) and net system energy (bottom) forecasts for the baseline Current Outlook Scenario and high- and low-growth scenarios.

In the Current Outlook Scenario, both peak demand and energy grow at relatively steady rates averaging 1.1 and 1.0 percent per year, respectively. Under the low-growth Distributed Marketplace Scenario, peak demand growth is relatively flat over the next decade and grows at an annual rate of 0.3 percent over 20 years. Energy demand under the low-growth scenario decreases during part of the forecast period and shows no long-term growth. Under the high-

growth Growth Economy Scenario, peak demand and energy grow at annual rates of 1.3 and 1.1 percent, respectively.

2.1.4 Reserve Capacity Needs

To ensure that enough capacity is available to meet peak demand, including the ability to quickly respond to unforeseen events such as the forced outage of large generating units, TVA maintains more generating capacity than needed to meet peak demand. This reserve capacity must be large enough to cover the loss of the largest single operating unit (contingency reserves), be able to respond to moment-by-moment changes in system load (regulating reserves) and replace contingency resources should they fail (replacement reserves). Total reserves must also be sufficient to cover uncertainties such as unplanned unit outages, undelivered purchased capacity, and load forecasting error, including the difference between actual weather and the forecast weather.

TVA's current planning reserve margin is 15 percent above peak load and is applied during both the summer and winter seasons. This margin is based on analysis of the uncertainty of unit availability, transmission capability, weather-dependent unit capabilities, cost of additional reserves, and other factors, including TVA's tolerance for risk.

2.1.5 Power Supply Resources

TVA's generation supply consists of a combination of TVA-owned resources, budgeted and approved projects (such as new plant additions and uprates of existing plants), and power purchase agreements (PPAs). PPAs are contractual rights to the capacity and/or output (energy) of generating facilities not owned by TVA. The generation supply (Chapter 3) includes a diverse portfolio of coal, nuclear, hydroelectric, natural gas and renewable resources, as well as market purchases designed to provide reliable, low-cost power and minimize the risk of disproportionate reliance on any one type of resource. Following is a categorization of generating facilities based on their degree of utilization.

Baseload Resources - Baseload generators are primarily used to meet continuous energy needs by operating at full capacity for long time periods. They have lower operating costs but higher capital costs than other generating facilities, and are typically larger coal units and nuclear plants. Some energy providers consider combined cycle plants for incremental base load generation needs. High natural gas prices, when compared to coal and nuclear fuel prices on a unit basis, have historically made natural gas-fired combined cycle plants a more expensive option for large continuous generation needs. This is changing as natural gas supplies increase and prices become more competitive. Baseload resources can have capacity factors of over 90 percent.

Intermediate Resources - Intermediate resources are primarily used to fill the gap in generation between baseload and peaking needs. They are required to change their output as the energy demand increases and decreases over time, both during the course of a day and seasonally. Intermediate units are more costly to operate than baseload units but less costly than peaking units. This type of generation typically comes from combined cycle plants and smaller coal units, and can also come from TVA's hydroelectric plants during periods of adequate precipitation. Intermediate resources also provide back-up and balance the supply of energy from intermittent wind and solar generation. Wind and solar generation can also be an intermediate resource when combined with the use of energy storage.

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Peaking Resources - Peaking units are only expected to operate during short duration high-demand periods. They are essential for maintaining system reliability requirements, as they can ramp up quickly to meet sudden demand or supply changes. Typical peaking resources include natural gas-fired combustion turbines, conventional hydroelectric generation and pumped hydro storage, and, under some conditions, renewable resources. Peaking resources often have capacity factors of less than 5 percent.

Storage Resources - Storage units usually serve the same power supply function as peaking units, but use low-cost off-peak electricity to store energy for later generation at peak times. TVA's Raccoon Mountain pumped storage plant is an example of a storage unit that pumps water to a reservoir during periods of low demand and releases it to generate electricity during periods of peak demand. Consequently, a storage unit is both a power supply source and an electricity user.

Figure 2-2 illustrates the uses of peaking, intermediate and baseload generation. Although these categories are useful, the differences between them are not always distinct. For example, a peaking unit may be called on to run continuously for a longer time period like an intermediate or base load unit, although it is less economical to do so. Similarly, some baseload units are capable of operating at different power levels, giving them some of the characteristics of an intermediate or peaking unit. This IRP considers strategies that take advantage of this range of operations.

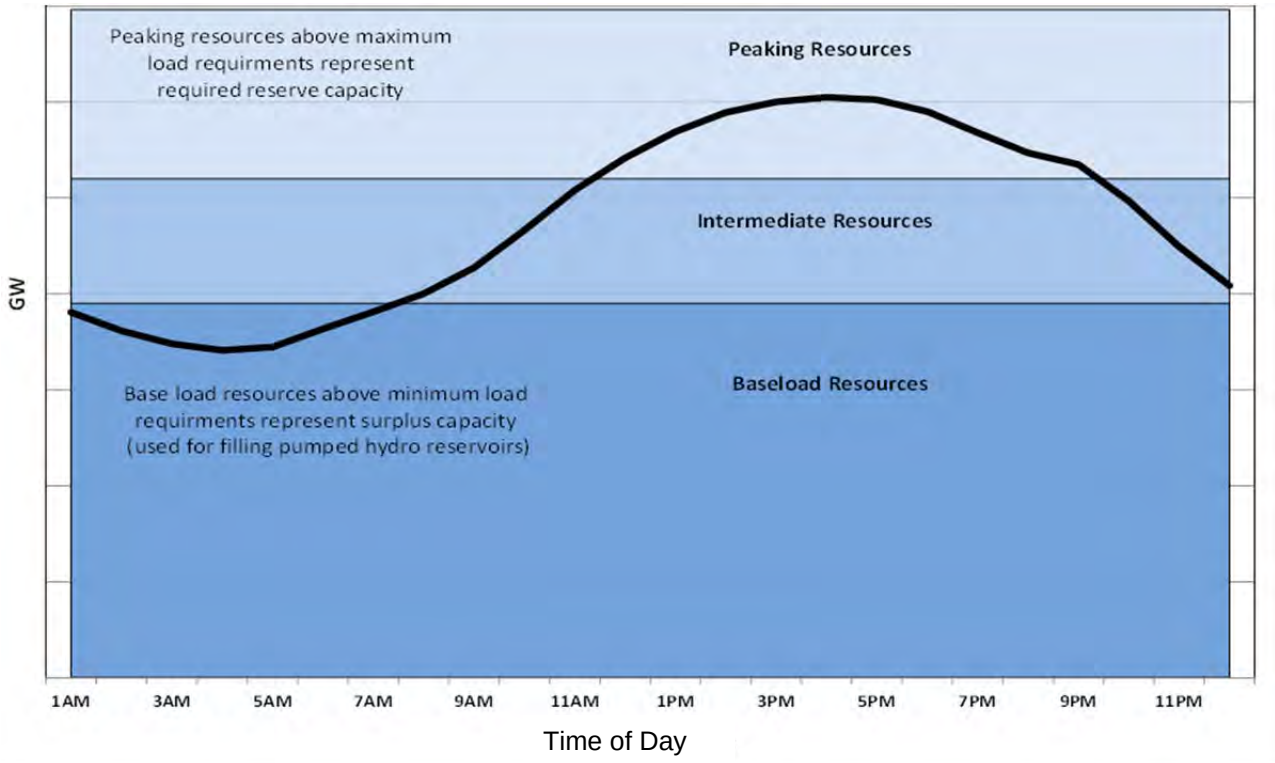

Figure 2-2 Representative summer day load shape and use of peaking, intermediate and baseload generation.

2.1.6 2014 Resource Mix

TVA's 2014 resource mix consisted of a wide range of supply-side technologies and demand-side resources to meet the needs of its customers. Approximately 53 percent of TVA's electricity was generated by fossil fuels, with 40 percent from coal and 13 percent from natural gas. Nuclear plants produced about 33 percent and hydroelectric plants approximately 10 percent. Most of the remainder was from other renewable (wind, biomass-fueled and solar) generating facilities and avoided generation from demand-side programs. TVA owns the majority of the facilities providing the capacity and generating the power that it markets. A portion of the capacity and energy is provided by non-TVA facilities under long-term PPAs. See Chapter 3 for a more detailed description of TVA's generating facilities, PPAs and demand-side programs.

Figure 2-3 shows the changing composition of existing resources through 2033. It shows only those resources that currently exist or are under contract (such as PPAs), as well as changes to existing resources (such as retirements and uprates) and additions of new resources that are planned and approved. The total capacity of existing resources decreases through 2033 primarily because of the retirement of coal-fired generating units. Total capacity also decreases when PPAs, mostly for combined cycle generation, expire.

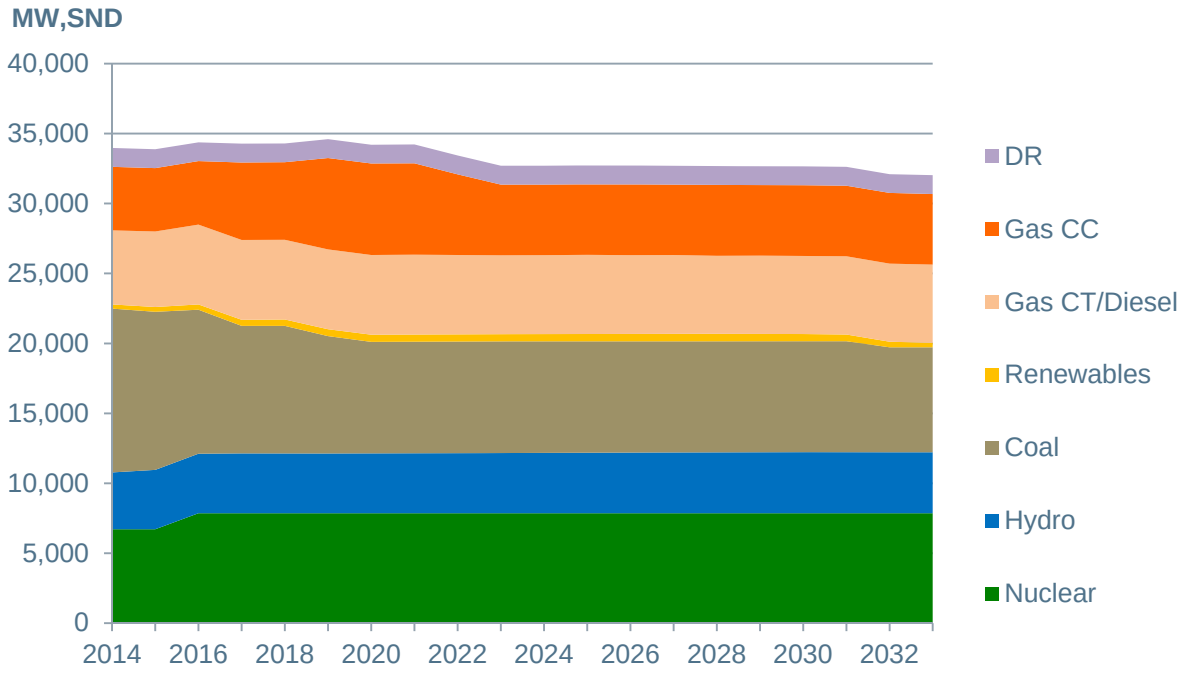

Figure 2-3 2014–2033 firm capacity under the 2014 baseline portfolio.

2.1.7 Assessment of Need for Power

The capacity gap is defined as the difference between the existing firm capacity (Figure 2-3) and the load forecasts (Figure 2-1) adjusted for interruptible customer loads plus reserve requirements. The energy gap is the amount of energy provided by existing and planned resources minus the energy required to meet net system requirements for serving the load over the entire year. It includes the energy consumed by the end-users plus transmission and distribution losses. Figure 2-4 shows the resulting capacity and energy gaps for the baseline Current Outlook Scenario peak load forecast and the range corresponding to the highest

Growth Economy and lowest Distributed Marketplace scenarios (see Section 2.4). Under the Current Outlook Scenario, TVA requires 2,500 MW of additional capacity and 14,000 GWh of additional energy by 2020, growing to 11,600 MW and 51,000 GWh by 2033.

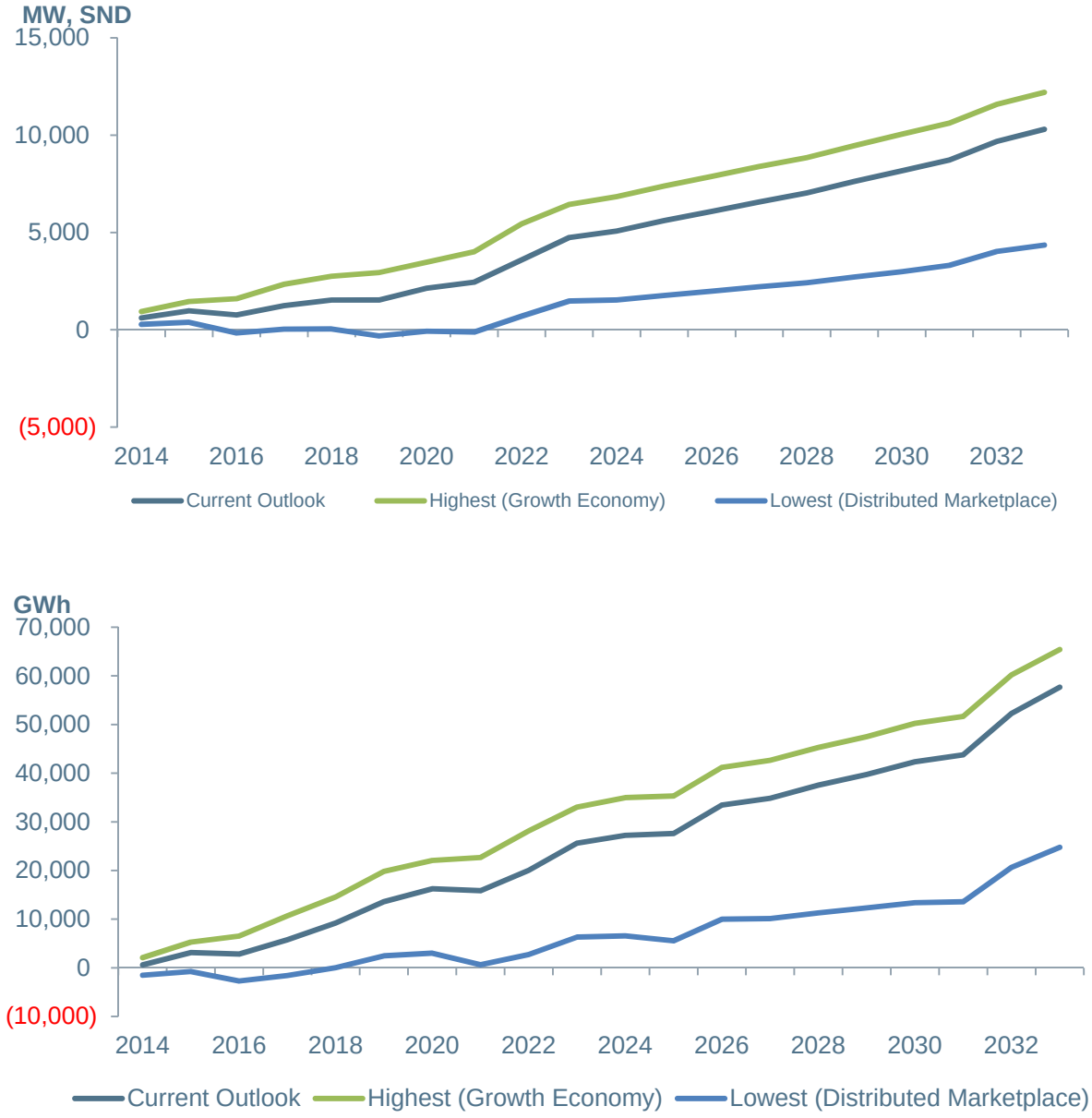

Figure 2-4 Capacity (top) and energy (bottom) gaps for the baseline Current Outlook Scenario and lowest and highest scenarios.

2.2 Scenario Development

TVA employed a scenario planning approach in the development of the IRP. The goal of this approach, which is commonly used in the utility industry, is to develop a "least regrets" strategy that is relatively insensitive to changing future conditions. In other words, once strategic decisions are made, the strategy will perform well regardless of how the future unfolds. Scenarios are sets of potential future conditions, typically organized around different themes or narratives. They provide a foundation to consider various supply and demand options in selecting a low-risk, adaptable 20-year resource plan. The major steps in development of the scenarios are listed below and are described in more detail in IRP Chapter 6:

- Identify the key uncertainties.
- Develop the scenarios.
- Determine the range of scenario uncertainty values.

The key uncertainties used to define the scenarios are:

- TVA sales – The customer energy requirements, in GWh, for the TVA service territory, including transmission losses; the load to be served by TVA.
- Natural gas prices – The price, in $/MMBtu (million Btu), of natural gas delivered to TVA.
- Wholesale electricity prices for TVA – The hourly price of energy, in $/MWh, at the boundary of the TVA service area. This is used as a proxy for the market price of power.
- Coal prices – The price, in $/MMBtu, of coal delivered to TVA.
- Regulations – All regulatory and legislative actions, including applicable codes and standards, that impact the operation of electric utilities except for regulations on greenhouse gas (GHG) emissions.
- CO_2 regulation/price – The cost of compliance with possible regulation of GHG emissions (including CO_2) and/or the price of related cap-and-trade legislation, expressed in $/ton of CO_2.
- Distributed generation penetration – National trends of distributed generation resources and related regional activity by customers and non-TVA developers.
- National energy efficiency adoption – An estimate of the adoption of energy efficiency (EE) measures by customers nationally, used to measure the interest and commitment of customers in general to adopt EE measures while recognizing the impacts of both EE technology affordability and electricity price.
- Economic outlook – All aspects of the regional and national economy, including general inflation, financing considerations, population growth, gross domestic product and other factors.

A broad range of scenarios were originally developed with various combinations of the above uncertainties. The scenarios were refined to ensure the following characteristics:

- Represent a plausible, meaningful future world.
- Are unique.
- Reflect a future that TVA could find itself in during the IRP planning period.

- Place sufficient stress on the resource selection process.
- Provide a foundation for analyzing the robustness, flexibility and adaptability of each combination of supply- and demand-side energy resources.
- Capture relevant stakeholder interests.

Five scenarios were developed (Table 2-1).

Table 2-1 Attributes of the five scenarios.

Scenario	Description and Attributes
1 – Current Outlook	TVA's current forecasts: • Power demand grows around 1.0 percent/year as described above in Section 2.2.3 • Steady moderate increase in gas price • Steady slow increase in coal price, similar to other scenarios. • CO_2 price imposed ca. 2022, gradually increasing
2 – Stagnant Economy	Flat to slightly negative economic growth, delaying the need for capacity expansion: • Power demand less than Current Outlook • Steady increase in gas price, somewhat lower than Current Outlook • Lowest CO_2 price, not imposed until 2029
3 – Growth Economy	Highest economic growth with highest forecast energy sales and need for capacity expansion: • Power demand grows 1.1–1.5 percent/year • Gas price increases rapidly ca. 2017–2020, then remains flat • CO_2 price imposed ca. 2022, somewhat higher than for Current Outlook and gradually increasing
4 – De-Carbonized Future	Increasing climate-driven effects create strong federal push to curb GHG emissions with new legislated caps, penalties on utility industry CO_2 emissions and incentives for non-emitting energy resources: • Fairly rapid decrease in energy demand following GHG emission constraints, then steady growth at rates comparable to Current Outlook • Sharp increase in gas price ca. 2020, then levels off • Highest CO_2 cost imposed ca. 2020, then gradually increasing
5 – Distributed Marketplace	Rapid advances in energy technologies and increased customer awareness resulting in high and rapid adoption of distributed generation and energy efficiency: • Gradually decreasing growth in energy demand through ca. 2023, then slow growth, no significant overall demand growth • Gas price slightly lower than Current Outlook • CO_2 cost same as Current Outlook

2.3 Planning Strategies

Planning strategies are designed to test various business decisions and energy resource portfolio choices that TVA can control. The issue of TVA control is important to differentiate between strategies and scenarios; the attributes of scenarios are largely outside of TVA's control and the attributes of strategies are within TVA's control. Each strategy is defined by a unique combination of attributes; these attributes are described in Table 2-2.

Table 2-2 Attributes of planning strategies.

Attribute	Description
Existing Nuclear Generation	Watts Bar 2 completed in 2015 and existing units assumed to generate through end of planning period.
New Nuclear Generation	Limitations on the types and timing of nuclear capacity expansion.
Existing Coal Generation	Unit retirements occur as already scheduled through 2020; other units assumed to generate through end of planning period unless selected in portfolio for retirement; approved air emissions controls on Gallatin and Shawnee units completed as scheduled.
New Coal Generation	Limitations on the types and timing of coal capacity expansion.
Renewable Generation	Limitations on types and timing of utility-scale renewable capacity expansion; considers options pursued by TVA through power purchase agreements.
Energy Efficiency / Demand Response	Considers EE and DR programs offered by TVA and LPCs, but excludes impacts from naturally occurring efficiency and conservation.
Power Purchase Agreements	Amount varies across strategies; no limits on the type of energy resource.
Energy Storage	Limitations on the types and timing of new energy storage facilities.

Five strategies were developed based on these attributes (Table 2-3). In addition to these strategies, a Baseline Case was defined based on the current 2011 IRP, using traditional least cost optimization with energy efficiency and demand response (EEDR) and renewable generation expansions as scheduled inputs. Following the release of the Draft SEIS and IRP for public review, the parameters of Strategy C were altered as described below in Section 6.1.4.

Table 2-3 Key characteristics of the planning strategies.

A – The Reference Plan	Traditional least cost (least regrets) optimization, with optimized EEDR and renewable expansions. No special resource targets.
B – Meet an Emission Target	Resources selected to create lower emitting portfolio based on a CO_2 emission rate target or level.
C – Focus on Long-Term, Market Supplied Resources	Most new capacity needs met using longer-term PPAs or other bilateral arrangements. TVA makes a minimal investment in owned assets.
D – Maximize Energy Efficiency	Majority of capacity needs are met by setting an annual energy target for EE priority resource to fill the energy gap. Other resources selected to serve remaining need.
E – Maximize Renewables	Renewable resources required to be selected to meet near-term and long-term renewable energy targets; targets met with lowest cost combination of renewables. Hydro is included as a renewable option, along with biomass, wind and solar.

Based on the characteristics of each strategy listed in Table 2-3, specific values and descriptions of each attribute were assigned to each strategy (Table 2-4). Under all strategies, Watts Bar Nuclear Plant Unit 2 is assumed to be completed, and the scheduled coal unit/plant retirements will occur (see Section 3.3). Similarly, the energy efficiency and demand response capacity increases that TVA has committed to under the Clean Air Act Settlement Agreements will be implemented and existing power purchase agreements are assumed to expire as scheduled under all strategies. The current program of upgrades to the transmission system, primarily to 161-kV lines and required by the scheduled coal unit/plant retirements, will also continue under all strategies.

Table 2-4 Attributes of the alternative strategies.

Attributes	Planning Strategy					
	Baseline Case – No Action Alternative	A – The Reference Plan	B – Meet an Emission Target	C – Focus on Long-Term, Market-Supplied Resources	D – Maximize Energy Efficiency	E – Maximize Renewables
Existing Nuclear	Operate existing units through end of period	Same as Baseline	Same as Baseline	Same as Baseline	Same as Baseline	Same as Baseline

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Attributes	Planning Strategy					
	Baseline Case – No Action Alternative	A – The Reference Plan	B – Meet an Emission Target	C – Focus on Long-Term, Market-Supplied Resources	D – Maximize Energy Efficiency	E – Maximize Renewables
New Nuclear	Browns Ferry EPUs and new nuclear selectable	Same as Baseline	Same as Baseline	Browns Ferry EPUs selectable; no new TVA-build nuclear; nuclear selectable as PPA	Browns Ferry EPUs selectable; no other new nuclear	Same as D
Existing Coal	Based on current fleet strategy; all coal units selectable for idling and additional air emissions controls selectable for 7 Shawnee units	Same as Baseline	Same as Baseline	Same as Baseline	Same as Baseline	Same as Baseline
New Coal	Expansion allowed	Expansion allowed	Expansion allowed	Only coal PPA selectable	No expansion	No expansion
New Gas	Expansion allowed	Same as Baseline	Same as Baseline	No TVA gas expansion	Same as Baseline	Same as Baseline
EE/DR	Scheduled inputs per 2011 IRP and 2015 power supply plan	EE and DR available for resource selection	Same as A	Same as A	EE required to be selected first	Same as A
Utility Scale Renewables	Expansion under current programs	Expansion under current programs and new selectable renewable options	Same as A	Same as A	Same as A	Aggressive renewable energy target enforced to promote growth in renewable resources first through current programs or new selectable options

Attributes	Planning Strategy					
	Baseline Case – No Action Alternative	A – The Reference Plan	B – Meet an Emission Target	C – Focus on Long-Term, Market-Supplied Resources	D – Maximize Energy Efficiency	E – Maximize Renewables
New Energy Storage	Selectable expansion options	Same as Baseline	Same as Baseline	Same as Baseline	Same as Baseline	Same as Baseline
Hydroelectric	Hydro PPA selectable	Hydro PPA and expansion options selectable	Same as A	Same as A	Same as A	Same as A

2.4 Portfolio Development

The next step in the resource planning process is the development of the 20-year capacity expansion plans, also known as resource portfolios. A major input to the portfolio development is the definition of the supply-side and demand-side energy resource options that can become components of the portfolios. These options include existing and potential future TVA generating facilities and existing and potential future PPAs. The options are described in Chapter 5, along with their fuel requirements, operational characteristics and other attributes. This resource option information and the forecast power demands are then used by the capacity planning model to develop a portfolio for each combination of a planning strategy and scenario, along with the Baseline Case, for a total of 26 resource portfolios.

The capacity planning model (System Optimizer produced by Ventyx, Inc.) solves for the "optimum" combination of resource options to meet projected demand/energy requirements over the 20-year planning period. An optimized portfolio has the lowest net Present Value of Revenue Requirements (PVRR) subject to the constraints of energy balance, reserve margin, generation limits, fuel purchase and utilization limits, and environmental compliance requirements, as well as the attributes of each scenario and strategy. PVRR represents the cumulative present value of the total expected future revenue requirements associated with a particular resource portfolio based on an 8 percent discount rate. The capacity planning modeling process is described in more detail in IRP Section 6.2. For Strategies A–E, energy efficiency was included as a selectable resource with defined attributes that considered uncertainty in their future design and in their delivery. See IRP Appendix C for a more detailed discussion of energy efficiency.

Each of the 26 portfolios was then evaluated using an hourly production costing program with stochastics (the consideration of uncertainty using probability distributions). This second step computed detailed plan costs, financial indicators, environmental profiles, and other information. This analysis was accomplished using the Strategic Planning (MIDAS) software produced by Ventyx; its operation is described in more detail in IRP Section 6.2.

2.5 Portfolio and Strategy Evaluation Metrics

The portfolios and strategies are evaluated with a trade-off analysis that focuses on cost, financial risk, other risks, environmental impacts and other aspects of TVA's overall mission. A

strategy scorecard consisting of several scoring metrics supplemented as need by reporting metrics is used to facilitate this trade-off analysis. The metrics were developed with stakeholder feedback to evaluate the performance of the strategies in relation to the TVA strategic imperatives of cost, financial risk, stewardship, Valley economics and flexibility. The metrics are defined in Tables 2-5 and 2-6 and described in more detail in IRP Section 6.3.

Table 2-5 Scoring metrics for portfolio and strategy evaluation.

Cost Metrics	
Expected Value PVRR 20 years ($billion)	Total plan cost expressed as present value of revenue requirements over 20-year planning period.
System Average Cost 2014-2023 ($/MWh)	Average system cost for first 10 years, computed as levelized annual system average cost: $\frac{\text{NPV Rev Reqs}_{(2014\text{-}2023)}}{\text{NPV Sales}_{(2014\text{-}2023)}}$
Risk Metrics	
Risk/Benefit Ratio	Area under plan cost distribution curve (produced by stochastic modeling) between 95th and 5th percentile expected values divided by area between expected value and 5th percentile value: $\frac{95^{th}_{(PVRR)} - \text{Expected}_{(PVRR)}}{\text{Expected}_{(PVRR)} - 5^{th}_{(PVRR)}}$
Risk Exposure ($billion)	Point on plan cost distribution curve below which the likely plan costs will occur 95 percent of the time: $95^{th}\ \text{Percentile}_{(PVRR)}$
Environmental Stewardship Metrics	
CO_2 Emissions (million tons)	Annual average CO_2 emissions during the planning period
Water Consumption (million gallons)	Annual average water consumption during the planning period
Waste Production (million tons)	Annual average quantity of coal combustion residuals (ash, scrubber residue, slag) generated during the planning period
Flexibility Metric	
System Regulating Capability	A measure of the ability of the system to respond to rapid increases in demand: $\frac{\sum(\text{regulating reserve + demand response + quick start})}{\text{Peak Load}}$
Valley Economics Metric	
Per Capita Income	Percent difference in per capita personal income compared to Strategy A (for each scenario)

Table 2-6 Reporting metrics for portfolio and strategy evaluation.

Cost Metric	
System Average Cost 2024-2033 ($/MWh)	Average system cost for second 10 years, computed as levelized annual system average cost: $\frac{\text{NPV Rev Reqs}_{(2024\text{-}2033)}}{\text{NPV Sales}_{(2024\text{-}2033)}}$
Risk Metrics	
Cost Uncertainty	Predicted variation in plan cost determined by the difference in the tails of the stochastic analysis distribution curve: $95^{th}_{(PVRR)} - 5^{th}_{(PVRR)}$
Risk Ratio	A measure of risk of plan cost exceeding the expected value: $\frac{95^{th}_{(PVRR)} - \text{Expected}_{(PVRR)}}{\text{Expected}_{(PVRR)}}$
Environmental Stewardship Metrics	
CO2 Intensity (Tons/GWh)	CO2 emissions rate: $\frac{\text{Tons } CO_{2\,(2014\text{-}2033)}}{\text{GWh Generated}_{(2014\text{-}2033)}}$
Spent Nuclear Fuel Index (Tons)	Quantity of spent nuclear fuel generated
Flexibility Metrics	
Variable Energy Resource Penetration	A measure of the level of exposure to potential system flexibility challenges: $\frac{(\text{Variable Resource Capacity})_{(2033)}}{\text{Peak Load}_{(2033)}}$
Flexibility Turn Down Factor	A measure of the ability of the system to respond to rapid decreases in demand: $\frac{\text{“Must run” + Non-dispatchable(wind/solar/nuclear)}_{(2033)}}{\text{Sales}_{(2033)}}$
Valley Economics Metric	
Employment	Difference in change in TVA region employment compared to Strategy A

3.0 The TVA Power System

3.1 Introduction

This chapter describes TVA's existing power system, including power sales and purchases, generating facilities, energy efficiency and demand response programs, and the transmission system.

As of September 30, 2014, TVA's power system had a summer net generating capability of 37,347 MW. Approximately 33,236 MW of the total capability was provided by TVA facilities and the remainder was provided by non-TVA facilities under long-term power purchase agreements (PPAs). TVA operates a network of approximately 16,200 miles of transmission lines and 511 substations, switching stations and switchyards. This system transmits power from TVA and non-TVA generating facilities to 1,278 customer connection points. TVA's power system is described in more detail in the remainder of this chapter. Unless stated otherwise, the capacity of energy resources described in this EIS is the net summer dependable capacity.

3.2 TVA Customers, Sales, and Power Exchanges

TVA is primarily a wholesaler of power. In fiscal year 2014, it sold 161 billion kilowatt-hours (KWh) of electricity; total revenue from these sales was $11.0 billion. Wholesale power is delivered to 155 LPCs that, in turn, distribute electricity to residential, commercial and industrial customers within their service areas. These non-profit, publicly owned LPCs are diverse and include municipal systems and rural electric cooperatives. The largest, Memphis Light, Gas and Water Division, serves approximately 421,000 electric customers and accounted for 9 percent of TVA's 2014 operating revenues. Some of the smallest LPCs serve less than 1,500 customers. Many only provide electrical service while others provide water, wastewater, telecommunications and/or natural gas service. Sales to LPCs comprised 87 percent of TVA 2014 power sales and 91 percent of power sale revenues.

In addition to the LPCs, TVA sells power directly to 52 large industries and seven Federal installations. The directly served industries include chemical, metal, paper, textile, and automotive manufacturers. The proportion of total power sales to directly served industries has recently decreased due to the closure of the U.S. Enrichment Corporation facility in Kentucky, which was previously the largest industrial customer. The Federal installations include the Department of Energy Oak Ridge Operations in Tennessee and military bases. Sales to directly served industries and Federal installations comprised 13 percent of 2014 power sales and 8.5 percent of power sale revenues.

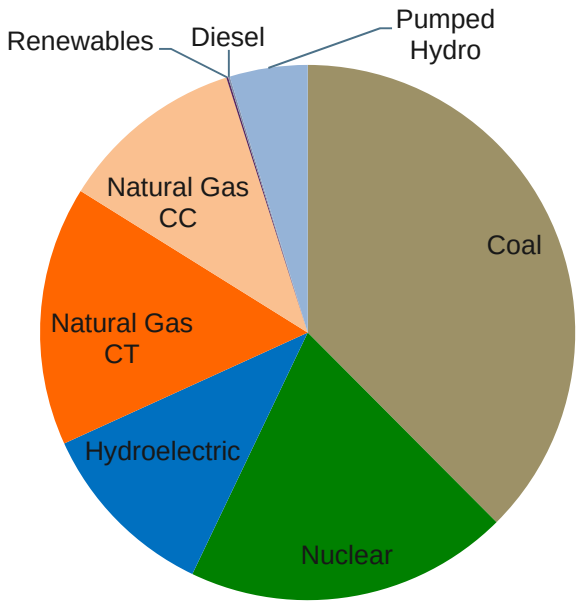
The TVA service area (Figure 1-1) is defined by the TVA Act. The TVA Act restricts TVA from entering into contracts that would make TVA or its LPCs a source of power outside the area for which TVA or its LPCs were the primary source of power on July 1, 1957. The Federal Power Act prevents the Federal Energy Regulatory Commission (FERC) from ordering TVA to deliver power generated by other entities to customers within the TVA service area.

The TVA Act authorizes TVA to exchange, buy or sell power with 14 neighboring electric utilities. This arrangement gives TVA the ability to purchase power when its generating capacity cannot meet demand or when purchasing power from a neighboring utility is more economical for TVA than generating it. It also allows TVA to sell power to neighboring utilities when its

generation exceeds demand. TVA conducts these exchanges through 64 transmission system interconnections. To the extent allowed by Federal law, TVA offers transmission services to others to transmit or "wheel" power through the TVA service area.

3.3 TVA-Owned Generating Facilities

TVA owns 33,236 MW of generating capability (Figure 3-1). These facilities generated about 142,200 million kWh in FY 2014, a decrease from the average of the preceding four years (Table 3-1).



Type of Generation	Capability (MW)	Percent
Coal	11,933	35
Nuclear	6,724	18
Natural Gas: Combustion Turbine	5,388	15
Combined Cycle	3,854	11
Hydroelectric: Conventional	3,802	10
Pumped-Storage	1,616	4
Diesel	9	<1
Renewables*	0.4	<1
Total	33,236	100

*Other than hydroelectric

Figure 3-1 Fiscal year 2014 TVA-owned summer generating capability by type of generation. Source: FY2014 TVA 10-K Report.

Chapter 3 – The TVA Power System

Table 3-1 Fiscal year 2010–2014 TVA-owned generation by type.

Type of generation	Kilowatt Hours (millions)		Percent	
	FY 2010–2013 Average	FY2014	FY 2010–2013 Average	FY 2014
Coal	67,569	62,525	47	44
Nuclear	52,561	53,788	36	38
Hydroelectric	14,429	13,228	10	9
Natural Gas	10,509	12,615	7	9
Renewables	14	5	<1	<1
TOTAL	145,082	142,151	100	100

Source: FY2010 – FY2014 TVA 10-K Reports

Coal-Fired Generation

As of January 2015, TVA had 48 coal-fired generating units at 10 plant sites with a total summer net dependable capability of approximately 12,603 MW (Figure 1-1, Table 3-2). The coal-fired units range in size from 70 MW (Johnsonville Units 1-4) to 1,200 MW (Cumberland Units 1 and 2). The oldest unit was placed in service in 1951 at Johnsonville, and the newest is Cumberland Unit 2, which began operation in 1973.

TVA's coal generating capacity is expected to decrease in the next few years as TVA retires at least 13 currently operating and mothballed units. Mothballed units are unavailable for service but can be returned to service following maintenance which could require weeks or months. The installation of additional pollution control equipment on a few operating units will also slightly lower their capacity. TVA coal-fired units are equipped with mechanical precipitators, electrostatic precipitators, scrubbers or baghouses to control emissions of particulate matter and sulfur dioxide. Other controls for reducing emissions of nitrogen oxides are listed in Table 3-2. Some units also use boiler optimization to limit nitrogen oxide emissions.

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Table 3-2 Characteristics of TVA coal-fired generating facilities. "Total units" includes currently operating units and mothballed units (see explanation in text). It excludes plants and units that have been retired.

Facility	Total Units	Operating Units	2014 Summer Net Dependable Capacity (MW)	Commercial Operation Date (First and Last Unit)	Boiler Type*	Emissions Controls**
Allen	3	3	711	1959	CF	LSC, SCR
Bull Run	1	1	865	1967	SCPC	FGD, SCR
Colbert	5	4	1,111	1955, 1965	PC	LSC, LNB
Cumberland	2	2	2,400	1973	SCPC	FGD, LNB, SCR
Gallatin	4	4	962	1956, 1959	PC	LSC, LNB
Johnsonville	10	4	1,206	1951, 1959	PC	LSC, SNCR
Kingston	9	9	1,361	1954, 1955	PC	LNB (4 units), SCR, FGD
Paradise	3	3	1,982	1963, 1970	CF, SCPC	FGD, SCR
Shawnee	9	9	1,206	1953, 1955	PC	LSC, LNB, SNCR
Widows Creek	2	1	833	1965	PC	FGD, SCR
Total Coal	48	40	12,546			

*CF – cyclone furnace; PC – pulverized coal; SCPC – supercritical pulverized coal
**FGD – Flue gas desulfurization ("scrubber"); LNB – low-NOx burner; LSC – low sulfur coal, may be blended with high sulfur coal; SCR – selective catalytic reduction; SNCR – selective non-catalytic reduction.

Since 2010, TVA has retired the 4-unit, 704-MW John Sevier Fossil Plant, 6 units totaling 666 MW at Widows Creek and a 126-MW unit at Shawnee. An additional 8 coal-fired units are mothballed: the 412-MW Widows Creek Unit 8, Johnsonville Units 5–10 with a total capacity of 926 MW, and the 431-MW Colbert Unit 5. The Johnsonville units will be retired by December 31, 2015. Widows Creek Units 7 and 8 will be retired by October 2015.

In April 2011, TVA entered into two agreements to resolve litigation over Clean Air Act (CAA) New Source Review requirements for its maintenance and repair of its coal-fired units. The first agreement is a Federal Facilities Compliance Agreement with the Environmental Protection Agency (EPA). The second agreement is with Alabama, Kentucky, North Carolina, Tennessee, the Sierra Club, National Parks Conservation Association and Our Children's Earth Foundation. Under the terms of these agreements (collectively the "CAA Environmental Agreements"), TVA

agreed to retire 18 coal-fired units by December 2017. With the exception of Johnsonville Units 1-4, which are scheduled to be retired by December 2017, all of these units have been retired or are mothballed. The CAA Environmental Agreements also require TVA to take additional actions at several of its coal plants. Those actions affecting the future of currently operating units and mothballed units include the following:

Allen – TVA must install FGD systems or retire the three units by December 31, 2018. The TVA Board has approved the construction of an adjacent combined cycle (CC) plant and committed to retiring the coal units.

Colbert – TVA must install FGD and SCR systems on Units 1-4, convert them to burn renewable biomass, or retire them by June 30, 2019. TVA must install an FGD system or retire Unit 5 by December 31, 2018. TVA has placed Unit 5 in inactive reserve and committed to retire all five units by their respective compliance dates.

Gallatin – TVA must install FGD and SCR systems, convert to burn renewable biomass, or retire the four units by December 31, 2017. TVA has committed to installing and operating FGD and SCR systems which are currently under construction. Once complete, the summer net dependable capacity of the plant will be reduced to 922 MW.

Shawnee – TVA must install FGD and SCR systems on Units 1 and 4, convert them to burn renewable biomass, or retire them by December 31, 2017. TVA has committed to installing and operating FGD and SCR systems on the two units. Construction is expected to begin in 2015 and to be completed in 2017.

Paradise –After evaluating how to comply with the CAA Mercury and Air Toxics Standards, TVA decided to retire Paradise Units 1 and 2 (with a combined capacity of 1,176 MW) upon completion of adjacent CC plant currently under construction. This is scheduled to occur in 2017 and is not associated with the CAA Settlement Agreements.

Once all of the announced coal plant/unit retirements occur and FGD/SCR installations are completed, which are anticipated by 2020, the operating coal units will have a total capacity of approximately 7,980 MW.

Fuel Procurement – TVA is a large consumer of coal and consumed a total of 31 million tons of coal in FY 2014. During the previous four years, TVA's coal consumption ranged from 29 to 36 million tons (Figure 3-2). In 2013, the most recent year for which detailed U.S. production data is available (EIA 2015), TVA consumed 3.2 percent of eastern U.S. coal production and 3.2 percent of western U.S. coal production. In recent years, TVA has obtained coal from the Northern Appalachian, Central Appalachian and Illinois Basin regions in the eastern U.S. and from the Powder River Basin and Uinta Basin regions in the western U.S.

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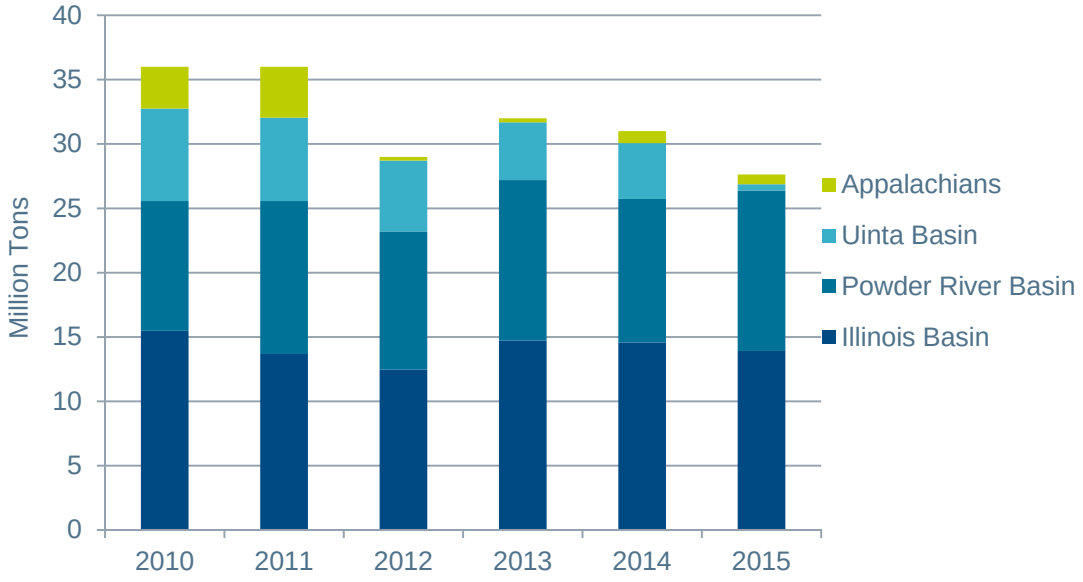

Figure 3-2 Fiscal year 2010–2014 coal purchases and contracted fiscal year 2015 coal purchases by mining region.

For FY 2015, TVA has contracted to purchase approximately 27.4 million tons of coal (Figure 3-2, Table 3-3). The largest sourcing area is the Illinois Basin, which will provide about 51 percent of the coal, a slight increase over recent years. Fifty-seven percent of the coal will be from surface mines, mostly in the Powder River Basin; this proportion has increased in recent years. None of the coal is projected to be from Appalachian mountaintop removal surface mines. In recent years, coal from these mines has comprised less than 2 percent of TVA's coal purchases.

Table 3-3 TVA coal purchase contracts for 2015, in millions of tons, by mining region and mining method.

	Mining Method			
Region	Underground	Surface - Open Pit/Area	Surface - Contour/ Highwall	Totals
Illinois Basin	10.6	3.2	0	13.9 (51%)
Powder River Basin	0	12.5	0	12.5 (45%)
Uinta Basin	0.5	0	0	0.5 (2%)
Central Appalachians	0	0	0.2	0.2 (1%)
Totals	11.5 (42%)	15.7 (57%)	0.2 (1%)	27.4

TVA purchases coal under both short-term (one year or less) and long-term (more than one year) contracts; 91 percent of 2014 purchases were with long-term contracts. During 2014, 23 percent of TVA's coal supply was delivered by rail, 16 percent was delivered by barge, and 54 percent was delivered by a combination of barge and rail. The remaining 7 percent was

delivered by truck. These percentages vary from year to year depending on the coal sourcing areas and other factors.

TVA uses large quantities of limestone to operate the FGD systems at five of its coal plants. This limestone is acquired from quarries in the vicinity of the plants and transported to the plants primarily by truck.

Nuclear Generation

TVA operates six nuclear units at three sites with a total net summer dependable capacity of 6,708 MW (Figure 1-1, Table 3-4). In 2007, TVA resumed construction of Watts Bar Unit 2, which had been halted in the mid-1980s. Once complete in 2015, this unit will provide an additional 1,151 MW of net summer dependable capacity. The completion of Watts Bar Unit 2 is incorporated into the forecast of the capacity of existing generating resources used in determining the future need for power.

TVA submitted the license renewal applications for Sequoyah Units 1 and 2 to the NRC in January 2013. If approved, the operating licenses for these units would be extended an additional 20 years beyond the expiration dates shown in Table 3-4.

Fuel Procurement - TVA's six nuclear units use a total of about 4 million pounds of enriched uranium (U_{238}) per year. This uranium comes from uranium producing areas around the world. In the past, TVA has relied on the now-closed Paducah, Kentucky gaseous diffusion enrichment plant for some of its enrichment services. TVA currently has sufficient enriched uranium in inventory or under contract to provide all of its requirements through 2019. TVA has agreements with the U.S. Department of Energy (DOE) and nuclear fuel contractors to mix surplus DOE highly enriched uranium from dismantled nuclear weapons with other uranium to fabricate fuel suitable for use in nuclear power plants. TVA began using this blended nuclear fuel at Browns Ferry in 2005 and expects this use to continue through at least 2016. TVA has used this blended nuclear fuel at Sequoyah but does not expect to use it there in the future.

Table 3-4 Characteristics of TVA nuclear generating units.

Facility	Units	2014 Net Summer Capacity (MW)	Type	Commercial Operation Date (First and Last Unit)	Operating License Expiration
Browns Ferry	3	3,299	Boiling Water	1974, 1977	2033, 2034, 2036
Sequoyah	2	2,287	Pressurized Water	1981, 1982	2020, 2021
Watts Bar	1	1,122	Pressurized Water	1996	2035
Total Nuclear	6	6,708			

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Natural Gas-Fired Generation

TVA has 87 natural gas-fueled simple-cycle combustion turbine (CT) units at 9 sites (Figure 1-1, Table 3-5). The oldest CTs were completed in 1971 and the newest in 2002. Fifty-six CTs are co-located at four coal-fired plant sites and 31 CTs are located at five stand-alone plant sites. TVA also has 16 natural-gas fueled combined cycle (CC) combustion turbine units at six stand-alone plant sites. The three-unit Caledonia plant is leased by TVA and the other CC plants are owned by TVA. Most of the CT units are capable of using fuel oil and 76 are capable of quick start-up by reaching full generation capability in about 10 minutes. The total net summer dependable capacities are 5,272 MW for the combustion turbine units and 4,520 MW for the combined cycle units.

In 2014, TVA initiated construction activities (e.g., site clearing) for a 1,002-MW three-unit natural gas fueled CC plant on the Paradise Fossil Plant reservation. This plant is scheduled to be completed in 2017. In FY 2016, TVA will begin construction of a 995-MW two-unit natural gas fueled CC plant adjacent to Allen Fossil Plant. This plant is scheduled to be completed in 2018. TVA also is committed to refurbishing the Gleason CT plant. When complete in 2016, the plant will have a summer net dependable capacity of 528 MW. In April 2015, TVA completed the acquisition of the 700-MW Ackerman CC Plant in Choctaw County, Mississippi from Quantum Choctaw Power. TVA had been purchasing power generated by this plant for several years.

Fuel Procurement - In 2014, TVA used about 56 billion cubic feet of natural gas to fuel its CT and CC plants and to fuel generating facilities at some non-TVA plants that sell power to TVA under terms of a PPA. TVA purchases natural gas from a variety of suppliers under contracts with terms of up to two years. Due in part to the design of the gas pipeline network serving the TVA region, most of the gas purchased by TVA is sourced from eastern Texas, southern Louisiana, and southern Mississippi, including adjacent offshore areas. TVA contracts with its suppliers to store natural gas at facilities in Mississippi and Texas.

Most of the fuel oil is purchased on the spot market for immediate delivery to the plants. TVA maintains an inventory of fuel oil at its plants with oil fueling capability to provide a short-term backup supply in the event the gas supply is disrupted.

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Table 3-5 Characteristics of TVA natural gas-fueled plants.

Facility	Units	2014 Summer Net Capacity (MW)	Commercial Operation Date (First and Last Unit)	Oil Fueling Capability
Simple Cycle				
Allen	20	424	1971, 1972	Yes
Brownsville	4	484	1999	No
Colbert	8	360	1972	Yes
Gallatin	8	624	1975, 2000	Yes
Gleason[1]	3	220	2007	No
Johnsonville	20	1,212	1965, 2000	Yes
Kemper	4	336	2001	Yes
Lagoon Creek	12	1004	2002	Yes
Marshall County	8	608	2002	Yes
Subtotal	87	5,272		
Combined Cycle				
Ackerman	2	700	2004	No
Caledonia	3	765	2003	No
John Sevier	3	870	2012	No
Lagoon Creek	2	516	2010	No
Magnolia	3	895	2003	No
Southaven	3	774	2003	No
Subtotal	16	4,520		
Total Gas-Fueled	103	9,792		

[1]The Gleason plant has 3 units but one unit is removed from service. The capacity figure is for the two operating units.

Diesel-Fired Generation

TVA owns one diesel generating facility with a total net summer capacity of 9 MW. This plant, located in Meridian, Mississippi, consists of 5 units completed in 1998. Diesel fuel is purchased on the spot market.

Hydroelectric Generation

The TVA hydroelectric generating system consists of 29 hydroelectric dams with 109 conventional hydroelectric generating units. Twenty-eight of these dams are on the Tennessee River and its tributaries and one dam (Great Falls) is on a Cumberland River tributary (Figure 1-1). TVA also operates the four-unit Raccoon Mountain pumped storage hydroelectric facility near Chattanooga.

The total net summer capability of the TVA hydroelectric system is 5,418 MW; this includes 3,802 MW of conventional hydroelectric generation and 1,616 MW from Raccoon Mountain. Conventional hydroelectric plants range in size from the 4-unit, 11-MW Wilbur plant to the 21-unit, 675-MW Wilson plant. The oldest of the conventional plants, Ocoee No. 1, was completed in 1911 and the newest, Tims Ford, was completed in 1970. Since 1994, TVA has been replacing outdated turbines and other equipment in the hydroelectric plants. At the end of FY 2014, these modernization efforts had been completed on 56 conventional hydroelectric units and the four pumped hydroelectric units. These efforts resulted in a 427-MW increase in generating capacity of the conventional units and an average efficiency gain of 5 percent. TVA plans to update additional units in the future. Details about the hydroelectric plants and the operation of the hydroelectric system are available in the *Reservoir Operations Study* (TVA 2004).

The four Raccoon Mountain units were taken out of service in 2012 for maintenance overhauls to correct rotor cracking and other problems. Three of the units have subsequently been returned to service and the fourth unit is scheduled to be returned to service in the third quarter of 2015.

Non-Hydro Renewable Generation

TVA owns 16 small photovoltaic (PV) installations with a total capacity of about 400 kW (Figure 1-1). TVA also co-fires methane from a nearby sewage treatment plant in a boiler at Allen Fossil Plant and co-fires wood waste in a boiler at Colbert Fossil Plant. The combined capacity of these two co-firing projects is approximately 15 MW. Electricity generated by the PV facilities and the methane co-firing is marketed through TVA's Green Power Switch program (see Section 3-5).

3.4 Purchased Power

For the 2010 through 2014 fiscal years, purchased power comprised 11 to 16 percent of TVA's total power supply. In FY 2014, TVA purchased 18,740 million kWh, 11.6 percent of its total power supply. This total includes the generation from the leased Caledonia CC plant.

TVA has power purchase agreements (PPAs) for about 3,300 MW of generating capacity; the major PPA contracts/facilities are listed in Table 3-6. The hydroelectric generation is from eight U.S. Army Corps of Engineers dams on the Cumberland River and its tributaries, purchased through a long-term contract with the Southeastern Power Administration (SEPA), a Federal power marketing agency. The power generated by the Buffalo Mountain wind farm, completed in 2004, is marketed through the Green Power Switch program (see Section 3-5).

Two of the facilities listed in Table 3-7 are qualifying facilities as defined by the Public Utility Regulatory Policies Act (PURPA). Qualifying facilities are cogeneration or small power production facilities that meet certain ownership, operating, and efficiency criteria. Cogeneration (also known as combined heat and power) facilities produce electricity and another form of useful thermal energy (heat or steam) for industrial or other uses. Small power production facilities typically have a capacity of 80 MW or less whose primary energy source is renewable (hydro, wind or solar), biomass, waste, or geothermal resources. Utilities are required to purchase energy from qualifying facilities at the utility's avoided cost of self-generating or purchasing the energy from another source.

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In December 2008, TVA issued a request for proposals (RFP) for up to 2,000 MW of electricity from renewable and/or clean sources to be delivered by 2011. Qualifying sources include solar, wind, hydropower, ocean, tidal, geothermal, biomass and other biologically derived fuels, combined heat and power, waste heat recovery and other low-carbon emitting resources. TVA has subsequently signed contracts for purchasing power from eight wind farms with a combined nameplate capacity of 1,542 MW. Two of these wind farms, the Streator-Cayuga Ridge wind farm in Illinois and the Pioneer Prairie wind farm in Iowa, began delivering power in 2010 (Table 3-6). The other six wind farms were delivering power by late 2012.

Table 3-6 Major power purchase agreement contracts/facilities.

Facility	Owner/Marketer	Location	Capacity (MW)[1]	Contract End Date
Natural Gas – Combined Cycle				
Decatur Energy Center	LS Power	Decatur, Al	720	2023
Lignite Coal				
Red Hills Power Plant[2]	Southern Company	Chester, MS	432	2032
Diesel	various	various	total of 112	various
Wind				
Buffalo Mountain	Invenergy	Oliver Springs, TN	27	
Streator-Cayuga Ridge Wind Power Project	Iberdrola Renewables	Livingston County, IL	300	2030
Lost Lakes Wind Farm	EDP Renewables North America	Dickinson County, IA	101	2030
Pioneer Prairie I Wind Farm	EDP Renewables North America	Howard, Mitchell Counties, IA	198	2031
White Oak Energy Center	NextEra Energy Resources	McClean County, IL	150	2032
Bishop Hill Wind Energy Center	Invenergy	Henry County, IL	200	2032
Cimarron Wind Energy Center	NextEra Energy Resources	Gray County, KS	165	2032
Caney River Wind Project	ENEL Green Power	Elk County, KS	201	2032
California Ridge Wind Energy Center	Invenergy	Champaign County, IL	200	2032

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Facility	Owner/Marketer	Location	Capacity (MW)[1]	Contract End Date
Solar				
West Tennessee Solar Farm	University of Tennessee	Haywood County, TN	4.5	2032
Biomass				
Landfill Gas	Republic Services	Rutherford County, TN	5.4	
Landfill Gas	WM Renewable Energy	Heiskel, TN	3.2[3]	
Landfill Gas	Cogeneration Technologies	Chattanooga, TN	2[3]	
Hydroelectric				
Cumberland River Hydroelectric Dams	US Army Corps of Engineers/SEPA	TN, KY	405	n/a

[1]Contracted capacity.
[2]Coal supplied by adjacent surface mine.
[3]Qualifying facility as defined by PURPA.

Renewable Power Purchase Programs

In October 2010, TVA issued the Renewable Standard Offer (RSO) to promote the development of renewable energy in the TVA service area. RSO offers set prices to developers of small to mid-size renewable projects under long-term contracts of up to 20 years. The generating facilities must be between 50 KW and 20 MW in size and located within the TVA region. Qualifying fuel sources include solar photovoltaic, wind, and biomass from wood waste, agricultural crops or waste, animal and other organic waste, energy crops, and landfill gas and wastewater methane. Additional information on the RSO is available at http://www.tva.com/renewablestandardoffer/. The available capacity under the RSO program has been 120 MW in recent years, with 20MW reserved for the Solar Solutions Initiative (SSI) in 2015. As of December 2014, the RSO program had about 78 MW of operating generation and about 190 MW in the application and approval process or under construction. About 87 percent of the total capacity of operating facilities and facilities under development is solar. Thirteen percent is biomass, with 7 percent from landfill gas and the remainder from wood and other organic wastes.

In February 2012, TVA initiated the SSI, a targeted incentive program that aims to support the existing TVA-region solar industry and to recruit new industry to the region. SSI provides incentive payments for solar projects in the RSO program greater than 50 kw and less than or equal to 1 MW that use local certified solar installers. As of December 2014, the program had about 4 MW of operating generation and numerous projects under development.

TVA also purchases renewable power through its Green Power Providers program (formerly known as the Generation Partners program). Power from qualifying small-scale renewable generating systems is resold through the Green Power Switch program. The Green Power Providers program is described in more detail in Section 3-5.

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3.5 Demand-Side Management Programs

TVA has had a portfolio of demand-side management programs focusing on energy efficiency and demand response for many years. Energy efficiency programs are designed to reduce the use of energy while still providing reliable electric service service. Demand response programs are designed to temporarily reduce a customer's use of electricity, typically during peak periods when demand is highest. Because the energy use is typically shifted to off-peak times, demand response typically has little effect on total energy use. The TVA energy efficiency and demand response (EEDR) portfolio is a combination of fully deployed mature programs, recently initiated programs and programs under development.

In 2008 TVA set a goal of reducing the growth in peak demand by up to 1,400 MW by the end of 2012. The 2011 IRP identified goals of cumulative EEDR savings, including those realized before 2011, of 3,600–5,100 MW and 11,400–14,400 GWh by 2020. TVA realized 521 GWh and 553 GWh of energy efficiency savings in 2013 and 2014, respectively.

TVA EEDR programs are targeted at residential, commercial and industrial customers, and include a variety of energy-saving tools and incentives that help save energy and reduce power costs while providing peak reduction benefits for the power system. Unlike integrated power systems where the utility generates and distributes electricity to end users, most of the electricity TVA generates is distributed to end users by the 155 LPCs. This complicates the development and implementation of many types of EEDR programs because they are delivered through partnerships with the LPCs and not all LPCs participate in all programs. The TVA EEDR portfolio is described in more detail below; information about many programs is also available at http://www.energyright.com/.

Residential Energy Efficiency Programs

Self Audit Program – Homeowners complete an online home energy survey. The homeowners then receive a personalized report that breaks down their annual and monthly energy usage by category and makes recommendations for increasing energy efficiency. Participants also receive a free energy efficiency kit that may include items such as compact fluorescent light bulbs and gaskets for wall outlet and light switches. From the program's inception in 2008 through 2014, over 170,000 homeowners completed the audit; 10,264 were in 2014.

In-Home Energy Evaluation – Under this program, a trained evaluator conducts a comprehensive in-home energy assessment of a participant's home. The homeowner receives a detailed listing of potential energy-efficiency improvements and available cash incentives and financing options. The homeowner pays for the evaluation, but TVA rebates the evaluation cost to homeowners who make at least $150 in improvements and have post-installation inspections. From the introduction of the program in 2009 through 2014, over 85,000 evaluations were performed and over 60,000 homeowners made improvements. This program was replaced with the eScore program in late 2014.

eScore Program – The eScore Program offers homeowners a simple path to make their homes as efficient as possible. Under this program, a certified energy advisor inspects a participant's home, rates its energy efficiency, and recommends measures to increase its energy efficiency. Through rebates on eligible improvements performed by a Quality Contractor Network (QCN) member, eScore allows homeowners to work at their own pace toward their home's goal of a 10, re-engaging with the program as many times as needed to achieve their home's best

possible energy performance. eScore is part of the EPA Whole Home Energy Efficiency Upgrades Project.

Heat Pump Program – Under this program, TVA promotes the installation of high-efficiency heat pumps in homes and small businesses by providing low-interest, fixed-rate financing for up to 10 years through a third-party lender, with repayment through the consumer's electric bill. Installation, performance and weatherization standards ensure the comfort of the customer and the proper operation of the system. TVA has established the Quality Contractor Network of installers to maintain high installation standards. TVA reimburses LPCs for inspection and loan processing/collection. During 2014, 12,149 heat pumps were installed through the program. This program is part of the EPA Whole Home Energy Efficiency Upgrades Project.

Volume Heat Pump Program for Manufactured Homes – The Volume Heat Pump Program is an upstream program that promotes the installation of electric heat pumps in qualified manufactured homes. It features include a network of HVAC wholesalers, incentives and an on-site validation of 10 percent of randomly-selected installations. The program installed 2,168 heat pumps in 2014.

Energy Star Pilot Program for Manufactured Homes – The ENERGY STAR Pilot Program for Manufactured Homes is an upstream program administered by Systems Building Research Alliance. The rebate is paid to manufactured homes producers to encourage them to build ENERGY STAR homes to be sited in the Tennessee Valley. The program yielded 1,731 manufactured homes in 2014.

New Homes Program – This program promotes energy-efficient new homes by offering Market Value Payments for new homes built in the Tennessee Valley. There are three incentive tiers available: an Energy Right® or entry-level home, platinum home, and platinum-certified home (RESNET or ENERGY STAR Certification required). The program had 2,051 participants in 2014.

EPA Smart Communities Program – Smart Communities is an EPA project which is made up of two components: Smart Energy Technologies and Extreme Energy Makeovers. Smart Energy Technologies is a project that tests the integration of ultra-efficient homes with smart grid technologies, and the human interaction with such technologies. Extreme Energy Makeovers is a project that performs whole-home, deep energy retrofits for 20-year-old homes or older in lower income communities.

Water Heating Program – The Water Heater Program promotes the installation of electric water heaters in homes and small businesses. A principle program feature is a Market Value Payment from TVA to the LPC for each electric water heater installation.

Business Energy Efficiency Programs

EnergyRight Solutions for Business saved 152 GWh in 2014, while providing incentives of $11.6 million. The main program components are described below.

Small Business Direct Install Pilot Program – Small Business Direct Install is a turnkey program that provides an opportunity to reach small commercial customers who are unlikely to participate in other types of efficiency offers.

Standard Rebate Program for Commercial – The Commercial Standard Rebate program provides pre-determined incentives for qualified energy efficient measures allowing commercial customers to simplify their decision-making process regarding cost effectiveness.

Custom Solutions Program for Commercial – The Commercial Custom Solutions Program provides unbiased, reliable technical assistance and information to help identify custom facility and process electric savings opportunities at commercial/institutional facilities. Incentives under the program help minimize upfront costs to encourage business owners to follow through on energy efficiency upgrades.

Industry Energy Efficiency Programs

EnergyRight Solutions for Industry saved 269 GWh in 2014, while providing incentives of $24 million. The main program components are described below.

Standard Rebate Program for Industry – The Industrial Standard Rebate program provides pre-determined incentives for qualified energy efficient measures allowing industrial customers to simplify their decision-making process regarding cost effectiveness.

Tailored Solutions Program for Industry – This program provides a highly customized delivery of site-specific technical assistance and incentives tailored to the needs of industrial customers.

Custom Solutions Program for Industry – The Industrial Custom Solutions Program provides unbiased, reliable technical assistance and information to help identify custom facility and process electric savings opportunities at industrial facilities. Incentives under the program help minimize upfront costs to encourage business owners to follow through on energy efficiency upgrades.

Education and Outreach

EnergyRight Solutions for Youth – This is a new energy education program for schools, parents and community organizations serving youth. Developed jointly by LPCs, TVA, and the Tennessee Valley Public Power Association (TVPPA), the program aligns with state learning standards and is designed to help children ages 8–11 learn about the environment and how to use energy wisely. The program includes detailed lesson plans that cover three categories: Energy Fundamentals, Forms of Energy, and Energy Use and Delivery.

TVA Facilities

Internal Energy Management Program – This TVA program, created in 1978, is responsible for the planning, coordination of regulatory reviews, performance analysis and reporting, oversight of energy related audits and sustainable design for TVA facilities. The program coordinates TVA compliance with energy efficiency goals and objectives for Federal agencies established by the National Energy Conservation Policy Act, the subsequent Energy Policy Acts of 1992 and 2005, and several Executive Orders including the 2009 EO 13514, Federal Leadership in Environmental, Energy, and Economic Performance. This program has resulted in significant reductions in energy use; for example, between 2003 and 2012, energy intensity in TVA facilities was reduced by 21.2 percent. Savings in 2014 totaled 32 GWh. See http://www.tva.gov/abouttva/energy_management/ for more information and annual reports of accomplishments.

Demand Response Programs

Direct Load Control (EnerNOC) Program – The Commercial and Industrial Direct Load Control Program (DLC) targets commercial and industrial customers that can provide dispatchable peak load reduction for up to 40 hours per year for economic calls and allows for unlimited reliability calls.

Aggregated Demand Response Proof of Concept Pilot – This program enables LPCs to aggregate and provide dispatchable peak load reduction to TVA in a manner similar to the Commercial and Industrial DLC program.

Direct Load Control – The Residential Direct Load Control Program is a part of a 10-year smart grid technology demonstration project in which previously qualified LPCs utilize DLC switches or devices to reduce peak demand from their end use customers.

EPA Conservation Regulation Program – The Conservation Voltage Regulation (CVR) Program is part of the Voltage Optimization Project undertaken by TVA under the 2011 Federal Facilities Compliance Agreement with EPA. It uses conservation voltage regulation technologies with TVA customers to achieve energy savings by optimizing voltage levels along electric system distribution feeders in an “always-on” basis.

Dispatchable Voltage Regulation Program – The Dispatchable Voltage Regulation (DVR) Program is part of the Voltage Optimization Project and began as a smart grid technology demonstration project in which qualified LPCs can provide dispatchable peak load reduction by optimizing distribution-level voltage.

Water Heating Project – The Water Heating Project is intended to replace the legacy Cycle and Save program. The new program will be a more innovative water heater control that intelligently manages residential electric water heaters to add load during off-peak hours to “Fill the Valley” of the TVA daily load shape.

Green Power Providers

This end-use generation program was begun in 2003 as the Generation Partners pilot program. TVA purchases renewable energy generated by facilities installed by residential, commercial and industrial customers, and then resells this energy through the Green Power Switch program. TVA purchases this power by paying the retail rate, any fuel cost adjustment, and a premium rate. New participants also receive a $1,000 incentive from TVA to help defray their start-up costs. Payment is in the form of a credit on the participant’s monthly bill from their LPC that shows the energy they used, which is billed at the standard rate, and the energy they generated, for which they receive credit. Power bills are reconciled either monthly or annually at the discretion of the participating LPC. The participant is guaranteed premium rate payments for 10 years from the time the LPC accepts their system. By 2012, the program had 1,186 generating systems with a total combined capacity of about 67 MW (DC).

In 2012, the Generation Partners pilot program was replaced with the Green Power Providers program, which operates similarly to its predecessor. The 2015 premium rate is $0.2/kWh and the maximum facility size is 50 kW. Qualifying generating systems include solar photovoltaic panels, wind turbines, low-impact hydropower, and systems using several types of biomass fuels. For calendar year 2015, the Green Power Providers program capacity for new applicants is capped at 11.33 MW, with 4 MW available for residential projects and 7.33 MW available for

non-residential projects. The maximum capacity of individual systems has varied from a high of 1 MW to the current 50 kW. Through late 2014, the combined Generation Partners and Green Power Providers program had 2,176 generating system installations with a total nameplate capacity of 88 MW (DC). Solar PV facilities comprised 87.2 percent of this capacity. Biomass (landfill gas, wastewater methane and wood waste and chips) comprised 12.4 percent of capacity. Wind generation provided 121 kW and small hydroelectric systems provided 3 kW. An additional 283 projects, mostly solar, with a total capacity of 5.7 MW have been approved by TVA and are in various states of construction. Additional information on the Green Power Providers program is available at http://www.tva.com/greenpowerswitch/providers/index.htm.

3.6 Transmission System

TVA operates one of the largest transmission systems in the U.S. It serves an area of 80,000 square miles through a network of approximately 16,200 miles of transmission line; 513 substations, switchyards and switching stations; and 1,278 individual customer connection points. The system connects to switchyards at generating facilities and transmits power from them at either 161 kV or 500 kV to LPCs and directly served customers. Substations at delivery points reduce the voltage for delivery through LPC distribution lines serving end users.

The TVA transmission system operates at a range of voltages:

- 500-kV lines – 2,471 miles
- 345- and 230-kV lines – 150 miles
- 161-kV lines – 1,512 miles
- 138- and 115-kV lines – 202 miles
- 69-kV lines – 1,153 miles
- 46-kV lines – 681 miles
- 26- and 13-kV lines – 15 miles

The TVA transmission system has 69 interconnections with 12 neighboring utilities at interconnection voltages ranging from 69-kV to 500-kV. These interconnections allow TVA and its neighboring utilities to buy and sell power from each other and to wheel power through their systems to other utilities. To the extent that Federal law requires access to the TVA transmission system, the TVA transmission organization offers transmission services to others to transmit power at wholesale in a manner that is comparable to TVA's own use of the transmission system. TVA has also adopted and operates in accordance with the Standards of Conduct for Transmission Providers (FERC 2008) and appropriately separates its transmission functions from its marketing functions.

In recent years, TVA has built an average of about 150 miles of new transmission lines and several new substations and switching stations to serve new customer connection points and/or to increase the capacity and reliability of the transmission system. The majority of these new lines are 161-kV. In 2008, TVA completed a 39-mile 500-kV transmission line in Tennessee which was the first major TVA 500-kV line built since the 1980s. TVA also completed a 27-mile 500-kV transmission line in Tennessee in 2010. TVA has also upgraded many existing transmission lines in recent years to increase their capacity and reliability by re-tensioning or replacing conductors, installing lightning arrestors and other measures. In FY 2014, TVA spent $301 million on transmission system construction and over the past 15 years the system has operated with 99.999 percent reliability.

Chapter 3 – The TVA Power System

A major focus of recent transmission system upgrades has been to maintain reliability when coal units are retired. Between 2011 and 2014, TVA spent $215 million on these upgrades and anticipates spending $230 on coal-retirement related transmission system upgrades between 2015 and 2020. The upgrades include modifications of existing lines and substations and new installations as necessary to provide adequate power transmission capacity, maintain voltage support and ensure generating plant and transmission system stability.

Chapter 4 – Affected Environment

4.0 Affected Environment

4.1 Introduction

This chapter describes the natural and socioeconomic resources that could be affected by the alternative strategies and portfolios developed in the integrated resource planning process. These resources are described at a regional scale rather than a site-specific scale.

The primary study area, hereinafter called the TVA region, is the combined TVA power service area (PSA) and the Tennessee River watershed (Figure 4-1), comprising 202 counties and approximately 59 million acres. All but one of TVA's hydroelectric plants, as well as all of its nuclear plants, are located in the Tennessee River watershed. Its coal fired plants are located in the Tennessee River watershed and along the Cumberland, Mississippi, Green and Ohio Rivers. Its other generating plants, as well as some of the generating plants from which TVA purchases power, are located throughout the combined TVA PSA and Tennessee River watershed (Figure 1-1). Eight of the nine windfarms from which TVA purchases power (see Section 3-4) are outside this area. For some resources such as air quality, climate change, and renewable energy resources, the assessment area extends beyond the TVA region. For most socioeconomic resources, the primary study area consists of the 170 counties where TVA is a major provider of electric power and Muhlenberg County, Kentucky, where the TVA Paradise Fossil Plant is located. The economic model used to compare the effects of the alternative strategies on general economic conditions in the TVA region includes surrounding areas to address some of TVA's major fuel sourcing areas and inter-regional trade patterns.

4.2 Climate and Greenhouse Gases

The TVA region spans the transition between a humid continental climate to the north and a humid subtropical climate to the south. This provides the region with generally mild temperatures (i.e., a limited number of days with temperature extremes), ample rainfall for agriculture and water resources, vegetation-killing freezes from mid-autumn through early spring, occasional severe thunderstorms, infrequent snow and infrequent impacts—primarily in the form of heavy rainfall—from tropical storms. The seasonal climate variation induces a dual-peak in annual power demand, one for winter heating and a second for summer cooling. Rainfall does not fall evenly throughout the year, but tends to peak in late winter/early spring and again in mid-summer. Winds over the region are generally strongest during winter and early spring and lightest in late summer and early autumn. Solar radiation (insolation) varies seasonally with the maximum sun elevation above the horizon and longest day length in summer. However, insolation is moderated by frequent periods of cloud cover typical of a humid climate.

Chapter 4 – Affected Environment

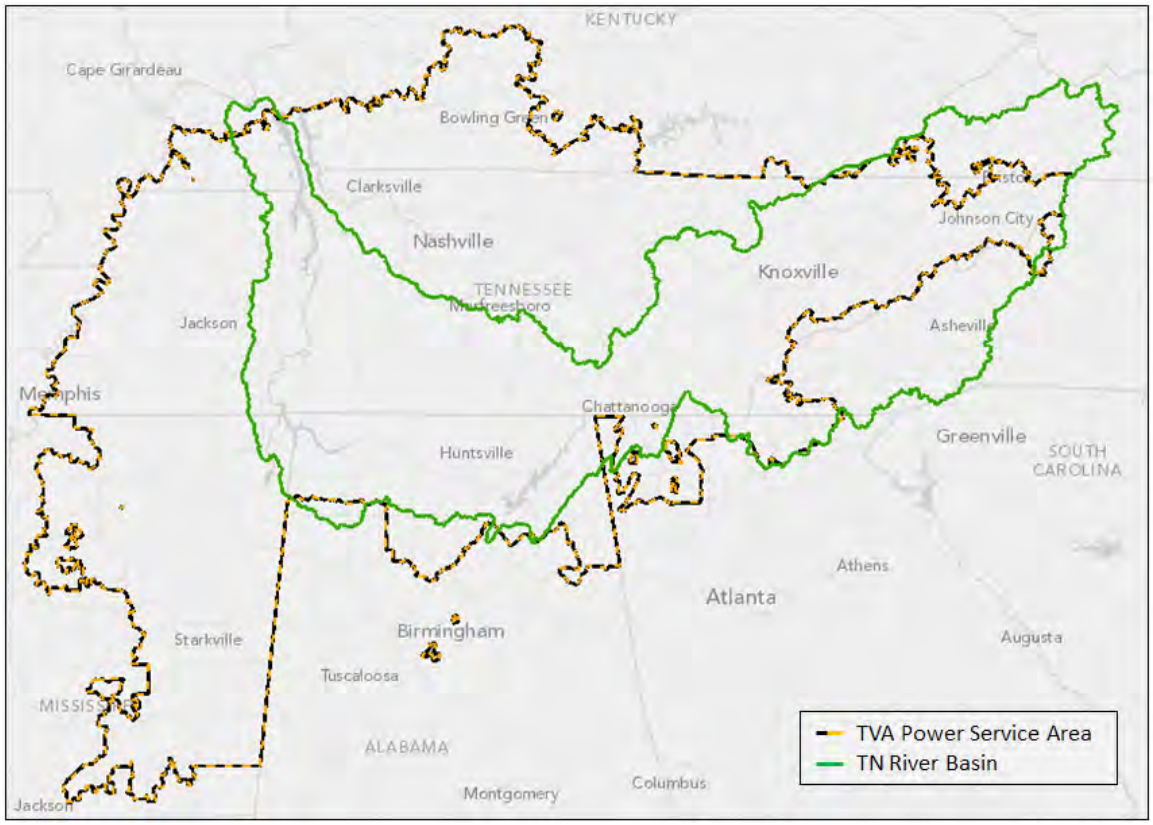

Figure 4-1 TVA power service area and Tennessee River watershed.

The remainder of this section describes the current climate and recent climate trends of the TVA region in more detail. It describes emissions of greenhouse gases (GHGs), widely considered to be a major source of climate change (NAS and RS 2014). It also describes projected changes in climate during this century, based on the National Climate Assessment (NCA; Melilo et al. 2014) and related sources. Identifying recent trends in regional climate parameters such as temperature and precipitation is a complex problem because year-to-year variation may be larger than the multi-decadal change in a climate variable. Climate is frequently described in terms of the climate "normal," the 30-year average for a climate parameter (NCDC 2011). The climate normals described in the following sections are for the 1981–2010 period. Earlier and more recent data are also presented, where available. The primary sources of these data are National Weather Service (NWS) records and records from the rain gauge network maintained by TVA in support of its reservoir operations. NWS records, unless stated otherwise, are for Memphis, Nashville, Chattanooga, Knoxville the Tri-Cities area in Tennessee and Huntsville, Alabama.

2014 National Climate Assessment Scenarios

Scenarios as used in the 2014 NCA provide ways to help understand what future conditions might be. As with the five distinct scenarios used in the IRP process, each NCA scenario used provides climate modelers with a consistent set of assumptions. NCA scenarios are not intended to be predictions or forecasts. The NCA uses three types of scenarios to frame climate modeling analysis in a consistent way: emissions scenarios, climate scenarios and sea level

rise scenarios. Emissions and climate scenarios are briefly described below as adapted from the 2014 NCA (Melilo et al. 2014).

NCA Emissions Scenarios – The NCA uses emissions scenarios to quantitatively illustrate how the atmospheric release of different amounts of GHGs and particles produces different future climate conditions. Since 1990, the Intergovernmental Panel on Climate Change (IPCC) has released three different sets of scenarios. Two global emission scenarios, A1 and B2, were used as foundation scenarios by the 2014 NCA. The A2 scenario represents a world with high population growth, low economic growth, relatively slow technological improvement and diffusion, and other factors that contribute to high emissions and lower adaptive capacity. The B1 scenario represents a world with lower population growth, higher economic development, a shift to low-emitting efficient energy technologies that are diffused rapidly around the world through free trade, and other conditions that reduce the rate and magnitude of climate change as well as increase capacity for adaptation.

Models and Sources of Uncertainty – There are many well-documented sources of uncertainty in climate model simulations. Some uncertainties can be reduced with improved models. Some may never be completely eliminated. The climate system is complex, including natural variability on a range of time scales. Building models that accurately represent the physics of multiple interacting processes is inherently difficult. As with all modeling, there is an important distinction between a “prediction” of what will happen and a “projection” of what future conditions are likely given a particular set of scenario assumptions (Melilo et al. 2014 Appendix 5; Kunkel et al. 2013a).

Temperature

1981–2010 Climate Normals and Recent Trends – Observed average monthly temperatures for the TVA region during 1981–2010 ranged from 39.1ºF in January to 79.3ºF in July (Table 4-1). These data show considerable year-to-year variability with an overall warming trend of 0.4–0.5ºF (0.2–0.3ºC) per decade for 1981–2010 (Figure 4-2). This is greater than the global average trend reported by the U.S. Climate Change Science Program (Lanzante et al. 2006), which shows an increase in global surface temperature of about 0.16ºC per decade between 1979 and 2004. Longer term TVA temperature data since the 1930s shows a slight cooling in the TVA region.

Table 4-1 Monthly, seasonal and annual temperature averages for six NWS stations in the TVA region for 1981–2010.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ºF	39.1	43.1	51.1	59.7	68.1	76.0	79.3	78.6	71.9	60.8	50.5	41.5
ºC	3.9	6.2	10.6	15.4	20.1	24.4	26.3	25.9	22.1	16.0	10.3	5.3

	Winter	Spring	Summer	Fall	Annual
ºF	41.2	59.7	78.0	61.1	60.0
ºC	5.1	15.4	25.5	16.1	15.5

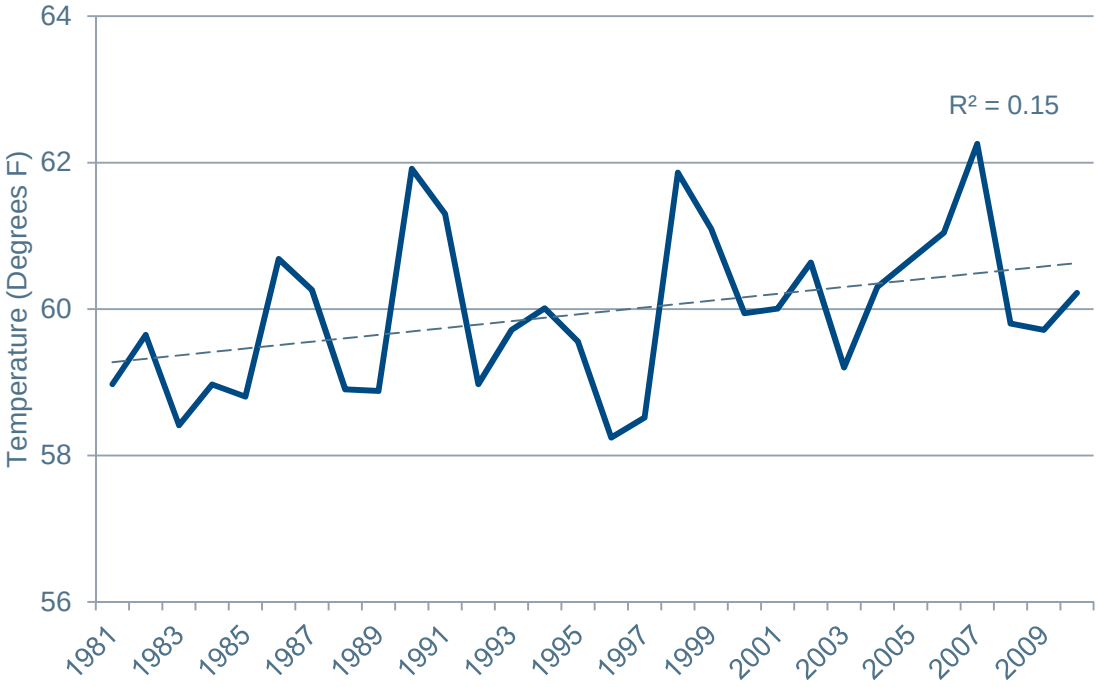

Figure 4-2 1981–2010 TVA region annual average temperature (°F) based on data from six NWS stations. The dashed line is the trend based on least squares regression analysis.

Projected Trends in Temperature **–** Based on climate models, temperatures across the Southeast and Caribbean are expected to increase during this century, with shorter-term fluctuations over time (year-to-year and decade-to-decade) due to natural climate variability (Carter et al. 2014; Walsh et al. 2014a). Although projected temperature increases for some parts of the Southeast region by the year 2100 are generally smaller than for other regions of the U.S., projected increases for Southeast interior areas are larger than for Southeast coastal areas by 1°F to 2°F. Regional average increases are in the range of 4°F to 8°F (combined 25th to 75th percentile range for A2 and B1 emissions scenarios) (Carter et al. 2014; Kunkel et al. 2013b). Figure 4-3 shows historic and projected temperature trends for the Southeast for the A2 and B1 scenarios. The figure also shows that generally historic temperatures have been less than modeled projected temperatures. Under both emissions scenarios, the number of days over 95°F is projected to increase, and the number of days below 32°F is projected to decrease in the TVA region (Carter et al. 2014).

Chapter 4 – Affected Environment

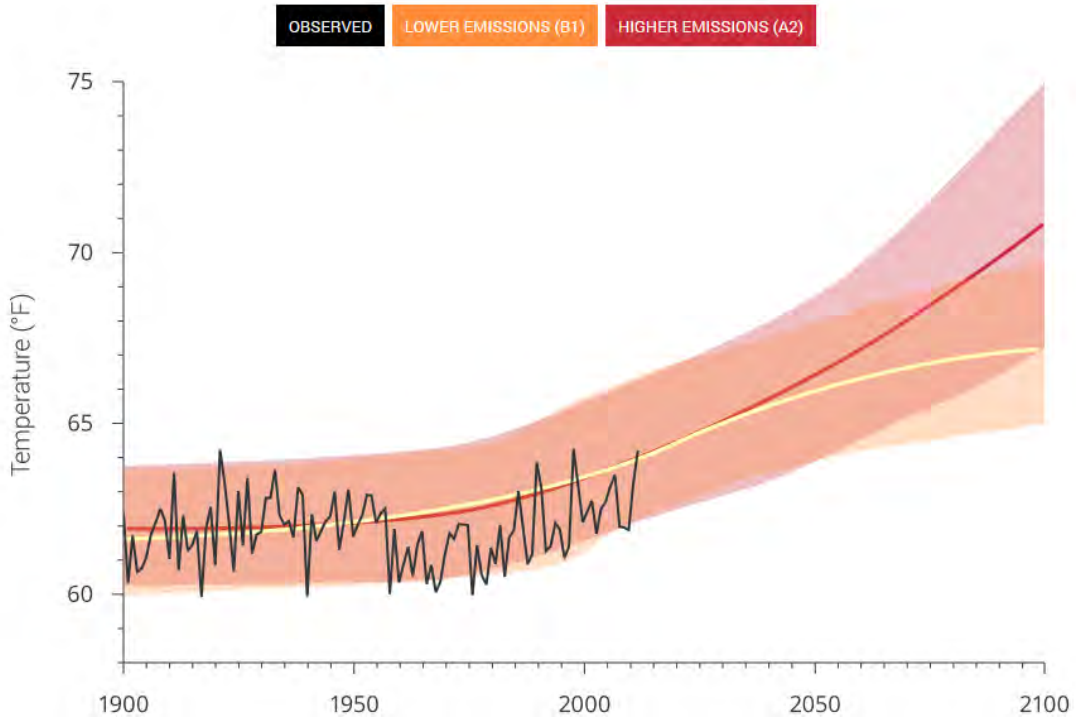

Figure 4-3 Observed and projected temperature trends, based on the SRES B1 and A2 scenarios, for the Southeast US. The scenario trend lines represent central estimates and the adjacent shaded areas represent the 5th to 95th percentile estimates. Source: Kunkel et al. (2013b).

Precipitation

1981–2010 Climate Normals and Recent Trends – The observed average annual precipitation in the Tennessee River watershed during 1981–2010 was 49.92 inches; monthly averages ranged from 2.86 inches in October to 4.73 inches in December (Table 4-2). There is significant year-to-year variability in precipitation (Figure 4-4) with no significant increasing or decreasing trend during the 30-year period.

Average annual mean total precipitation across the TVA region is 52 inches, an amount well above the national average of 30 inches annually (TVA 2004). Precipitation totals vary considerably across the region. The wettest locations in the TVA region, as well as in the larger Southeast Climate Region, occur in southwestern North Carolina (Ingram et al. 2013). The annual average of snowfall across most of the TVA region ranges from five to 25 inches, except in the higher elevations of the southern Appalachians in North Carolina and Tennessee. These locations can receive up to 100 inches of snowfall (Walsh et al. 2014a).

Table 4-2 Monthly, season, and annual precipitation averages in the Tennessee River watershed for 1981–2010. Source: TVA rain gage network data.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inches	4.22	4.23	4.26	3.79	4.23	3.64	3.89	3.23	3.42	2.86	4.01	4.73
Centimeters	10.7	10.8	10.8	9.6	10.8	9.2	9.9	8.2	8.7	7.3	10.2	12.0

	Winter	Spring	Summer	Fall	Annual
Inches	13.18	12.28	10.76	10.29	46.51
Centimeters	33.5	31.2	27.3	26.1	118.1

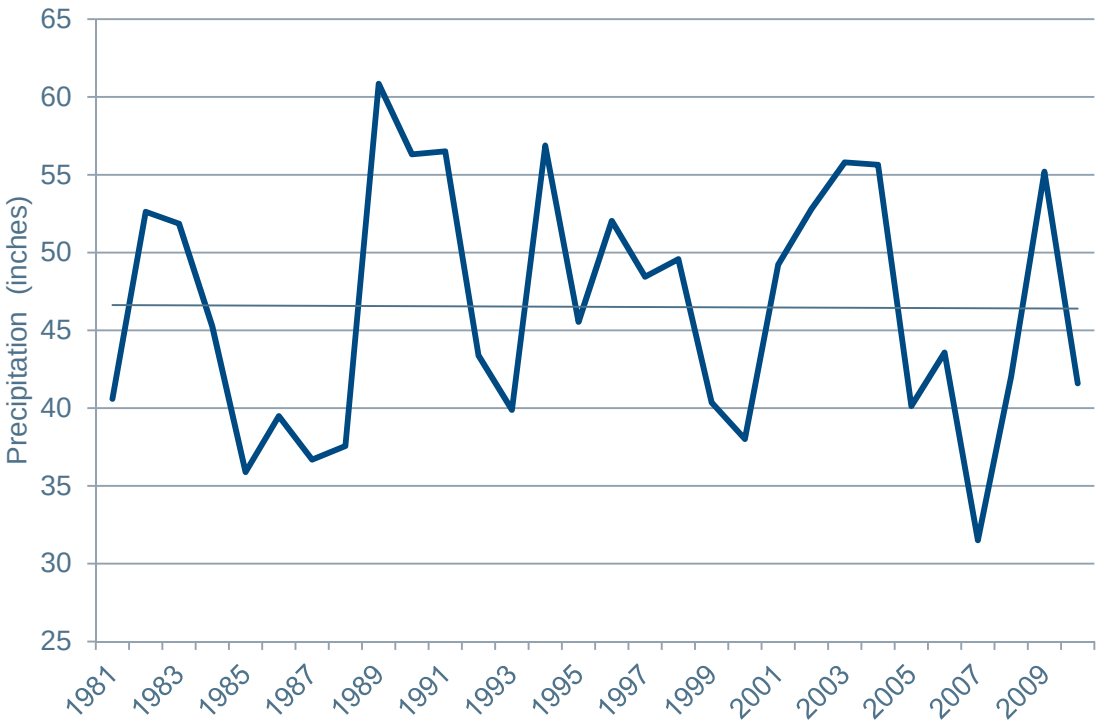

Figure 4-4 Annual average precipitation (inches) for the Tennessee River basin, 1981–2010. The straight line indicates there is no increasing or decreasing trend in annual precipitation for the period. Source: TVA rain gauge network data.

The 2014 NCA noted that while significant trends in average precipitation have been observed, the fraction of these trends attributable to human activity is difficult to quantify at regional scales because the range of natural variability in precipitation is large (Melilo et al. 2014).

The contiguous U.S. straddles the transition zone between drier conditions in the south and wetter conditions at higher latitudes in the north. Because the precise location of this zone varies somewhat among models, projected changes in precipitation in central areas of the U.S.

range from small increases to small decreases. A clear direction of change in precipitation only occurs in Alaska and the far north of the contiguous U.S. where increases are projected, and in the far Southwest where decreases are projected (Melilo et al. 2014).

Both nationwide and for most regions of the U.S., including the Southeast, the amount of precipitation falling in very heavy events (the heaviest 1 percent of all daily precipitation events) has increased since the 1950s (Walsh et al. 2014a). The increase has been greatest in the Northeast and Midwest.

Projected Trends in Precipitation – Projections of future precipitation patterns are more uncertain than temperature projections (Ingram et al. 2013). For the high (SRES A2) emissions scenario, average changes in annual precipitation range from nearly 10 percent reduction in the far southern and western portions of the Southeast region—with most of that reduction in the summer—to about 5 percent increases in the northeastern part of the region by late this century (Walsh et al. 2014a).

While significant trends in average precipitation have been detected, the fraction of these trends attributable to human activity is difficult to quantify at regional scales because the range of natural variability in precipitation is large. The northern U.S. is projected to experience more precipitation in the winter and spring (except for the Northwest in spring), while the Southwest is projected to experience less precipitation, particularly in spring. The wet areas will get wetter and the dry areas will get drier (Melilo et al. 2014).

Although future changes in overall precipitation are uncertain in many U.S. areas, there is a high degree of certainty that the heaviest precipitation events will increase everywhere and by large amounts (Figure 4-16) (Groisman et al. 2012). This consistent model projection is well understood and is a direct outcome of the increase in atmospheric moisture caused by warming. There is more certainty regarding dry spells. The annual maximum number of consecutive dry days is projected to increase in most areas, especially in the southern and northwestern portions of the contiguous U.S. Thus, both extreme wetness and extreme dryness are projected to increase in many areas.

The observed and model-stimulated mean precipitation changes for the Southeast are illustrated in Figure 4-5 for annual values, and Figure 4-6 for seasonal values. The observed variability tends to be somewhat higher than the model simulations, although the decadal values are within the range of the model simulations for annual, spring and summer. The overall trend is within the range of model simulations for all seasons except fall. However, for the fall, the observed upward trend is not simulated by any model and many decadal values are outside the range of the model simulations. The 21st Century portions of the time series show increased variability among the model simulations. The majority of the models simulate an overall increase in precipitation for winter, spring and fall (Kunkel et al. 2013b).

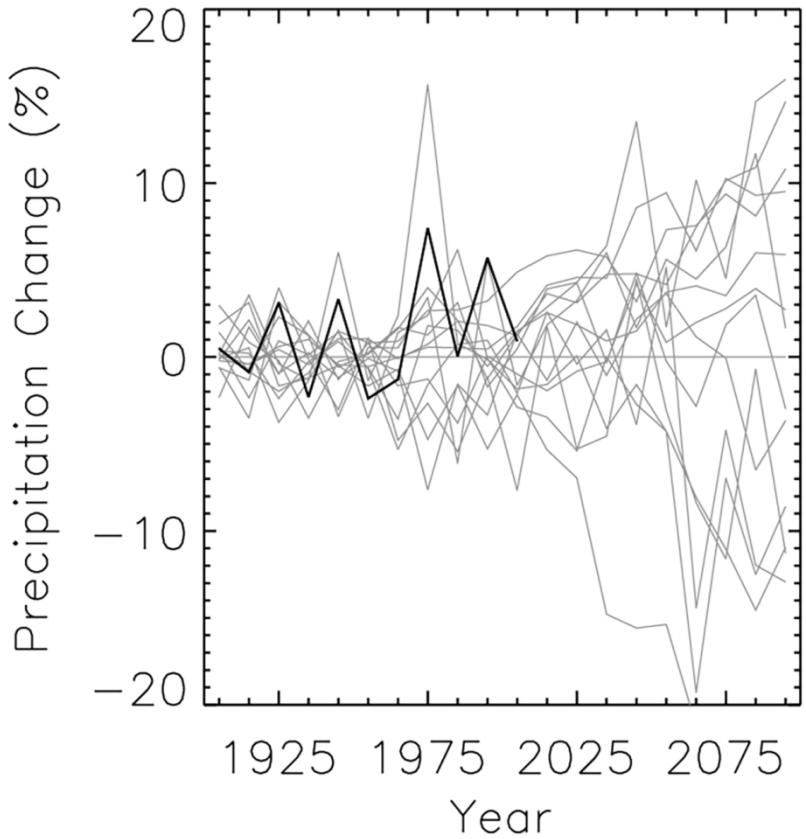

Figure 4-5 Observed and predicted decadal mean annual precipitation change (percent deviations from the 1901–1960 average) for the Southeast U.S. Light gray lines indicate the 20th and 21st Century simulations from 15 CMIP3 models for the high (SRES A2) emissions scenario. Observed precipitation (dark gray line) is within the range of model simulations. Source: Kunkel et al. (2013b).

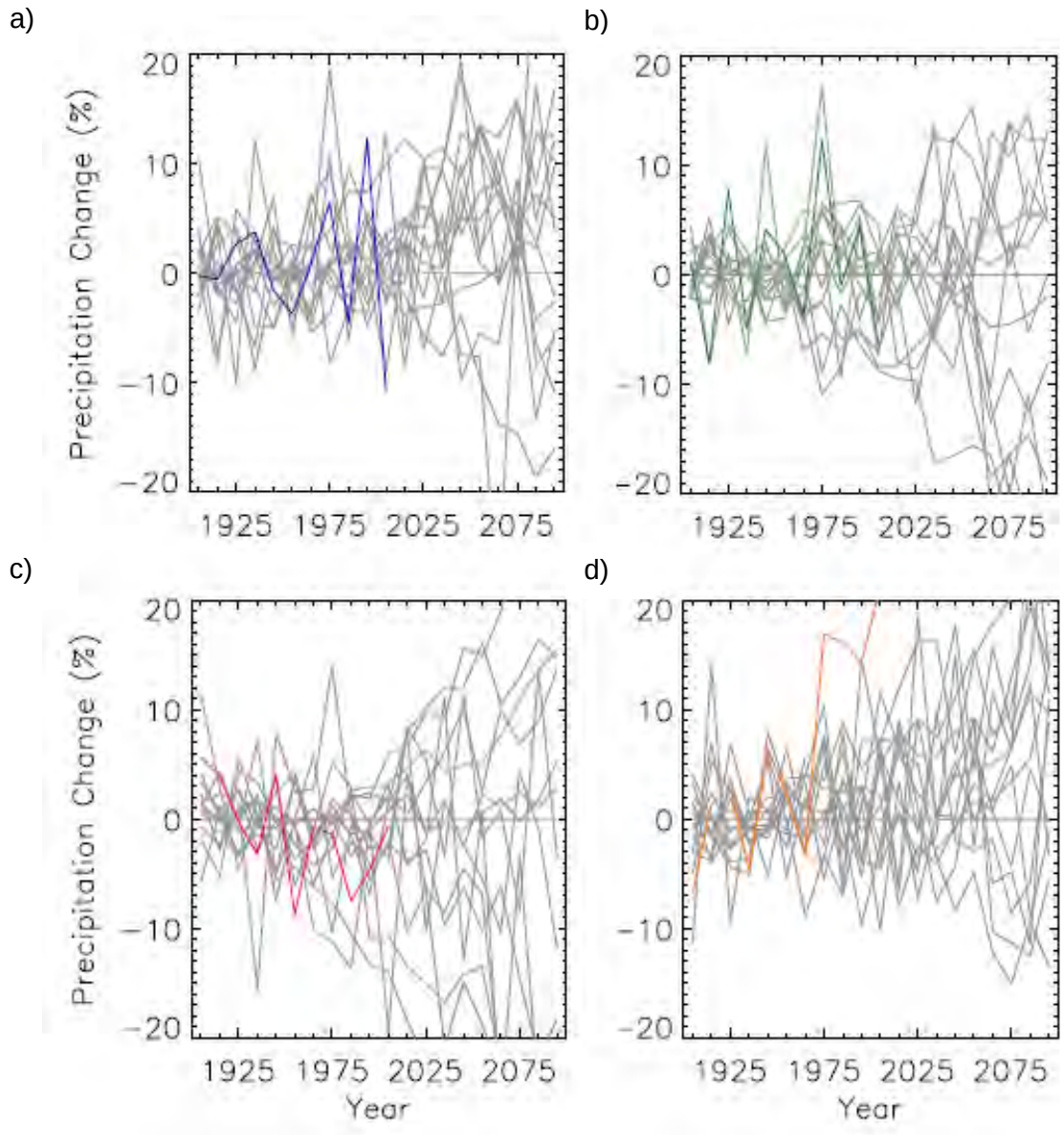

Figure 4-6 Observed and predicted decadal mean precipitation changes (percent deviations from the 1901–1960 average) for the Southeast in a) winter, b) spring, c) summer, and d) fall. Gray lines indicate 20th and 21st Century simulations from 15 CMIP3 models for the high (A2) emissions scenario. Observed 20th Century precipitation variations are within the range of model simulations in winter and spring, but deviate from model simulations in summer and fall. Source: Kunkel et al. (2013b)

Wind

1981–2010 Climate Normals and Recent Trends – Wind speed and direction are important indicators of weather patterns and dispersion of air pollutants. Wind speed is also a factor in determining the potential of an area for wind energy development. Average surface wind speeds (measured 33 feet (10 m) above the ground) for nine NWS stations in the TVA region for 1981–

2010 are relatively light, with higher speeds in winter and spring and lower speeds in summer and fall (Table 4-3). The highest monthly wind speed occurred in March and the lowest monthly wind speed occurred in August. In general, wind speeds at higher elevations are greater than those shown in the table.

Table 4-3 Monthly, seasonal and annual wind speed averages for nine sites* in the TVA region for 1981–2010.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Miles/Hour	7.7	7.8	8.1	7.7	6.6	5.6	5.3	4.9	5.4	5.7	6.6	7.2
Meters/second	3.4	3.5	3.6	3.4	2.9	2.5	2.4	2.2	2.4	2.5	3.0	3.2

	Winter	Spring	Summer	Fall	Annual
Miles/Hour	7.6	7.5	5.3	5.9	6.5
Meters/Second	3.4	3.3	2.4	2.6	2.9

*Asheville, NC; Tri-Cities, Knoxville, Chattanooga, Nashville and Memphis, TN; Huntsville, AL; Tupelo, MS; Paducah, KY

Surface wind directions are sensitive to area terrain and other factors and tend to be fairly stable over time. Prevailing winds are from the north and south sectors at Memphis, Tupelo, Paducah, Nashville, Chattanooga and Asheville. Prevailing wind directions at Knoxville and Tri-Cities are from northeast and/or southwest sectors, which reflect down-valley and up-valley flow patterns. Wind directions at Huntsville are more variable than at the other sites.

Pryor et al. (2009) analyzed surface wind speed trends over the continental U.S. for the 1973–2005 period. They found the median wind speeds significantly decreased at over 75 percent of the sample sites and increased at about 5 percent of the sample sites. Sites in the TVA region had either small decreases or no change in median wind speeds. The decrease in wind speed is most prevalent at eastern U.S. sites and shows no seasonality (i.e., variation across seasons).

Data from the nine sites used to describe the wind speed normals were analyzed to quantify trends in wind speed in the TVA region (Figure 4-7). Wind speeds increased slightly from 1984 to 1988, then decreased after 1989. The overall trend in the region has been a significant decrease ($p < 0.05$), which is consistent with the trend identified for the continental U.S. by Pryor et al. (2009).

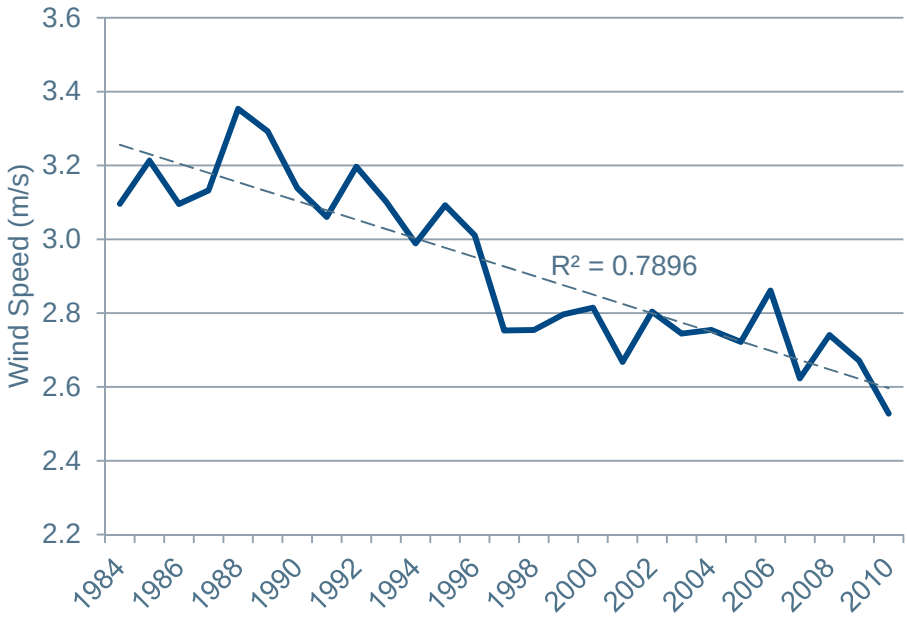

Figure 4-7 Annual median wind surface wind speeds for the TVA region, 1984–2010. The dashed line is the trend based on least squares regression analysis.

Greenhouse Gas Emissions

The sun is the primary source of energy for the Earth's climate. About 30 percent of the sun's energy that reaches Earth is reflected back to space by clouds, gases and small particles in the atmosphere. The remainder is absorbed by the atmosphere and the surface. Earth's temperature depends on the balance between the energy entering and leaving the planet's system. When energy is absorbed by the Earth's system, global temperatures increase. Conversely, when the sun's energy is reflected back into space, global temperatures decrease (Walsh et al. 2014b).

In nature, CO_2 is exchanged continually between the atmosphere, plants and animals through processes of photosynthesis, respiration and decomposition, and between the atmosphere and oceans through gas exchange. Billions of tons of carbon in the form of CO_2 are annually absorbed by oceans and living biomass (i.e., sinks) and are annually emitted to the atmosphere through natural and man-made processes (i.e., sources). When in equilibrium, carbon fluxes among these various global reservoirs are roughly balanced (Galloway et al. 2014).

Greenhouse Effect – Similar to the glass in a greenhouse, certain gases, primarily CO_2, nitrous oxide (N_2O), methane (CH_4), hydroflurocarbons (HFCs), perflourocarbons (PFCs) and sulfur hexafluoride (SF_6), absorb heat that is radiated from the surface of the Earth. Increases in the atmospheric concentrations of these gases cause the Earth to warm by trapping more heat. The common term for this phenomenon is the "greenhouse effect," and these gases are typically referred to as "greenhouse gases" (GHGs). Atmospheric levels of CO_2 are currently increasing at a rate of 0.5 percent per year. Atmospheric levels measured at Mauna Loa in Hawai'i and at other sites around the world reached 400 parts per million in 2013, higher than the Earth has experienced in over a million years (Walsh et al. 2014b).

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While water vapor is the most abundant GHG in the atmosphere, it is not included in the above list of GHGs because changes in the atmospheric concentration of water vapor are generally considered to be the result of climate feedbacks related to the warming of the atmosphere, rather than a direct result of human activity. That said, the impact of water vapor is critically important to projecting future climate change, and quantifying the effect of feedback loops on global and regional climate is the subject of ongoing data collection and active research (Walsh et al. 2014b).

The size of the warming depends largely on the amount of GHG accumulating in the atmosphere (Walsh et al. 2014a). GHGs can remain in the atmosphere for different amounts of time, ranging from a few years to thousands of years (NAS and RS 2014). GHGs are assigned global warming potentials, a measure of the relative amount of infrared radiation they absorb, their absorbing wavelengths and their persistence in the atmosphere (Table 4-4). All of these gases remain in the atmosphere long enough to become well mixed, meaning the amount that is measured in the atmosphere is roughly the same all over the world, regardless of the source of the emissions.

Table 4-4 The major man-made greenhouse gases and their global warming potentials. Source: Forster et al. (2007).

Gas	Global warming potential
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous oxide (N_2O)	310
Hydroflourocarbons (HFCs)	140 – 11,700
Perfluorocarbons (PFCs)	6,500 – 9,200
Sulfur hexaflouride (SF_6)	23,900

Electric Utility Greenhouse Gas Emissions – The primary GHG emitted by electric utilities is CO_2 produced by the combustion of coal, natural gas and other fossil fuels. HFC-containing refrigeration equipment is widely used in industry and these gases are emitted to the atmosphere in small amounts, primarily through equipment leaks. Small amounts of SF_6, which has a very high global warming potential, are released due to its use in high-voltage circuit breakers, switchgears and other electrical equipment. CH_4 is emitted during coal mining and from natural gas wells and delivery systems.

In 2013, worldwide man-made annual CO_2 emissions were estimated at 36 billion tons, with sources within the U.S. responsible for 14 percent of this total (Le Quere et al. 2014). U.S. electric utilities, in turn, emitted 2.039 billion tons in 2012, roughly 32 percent of the U.S. total (USEPA 2014c). Figures 4-8 and 4-9 illustrate the recent and projected trends in TVA CO_2 emissions from the generation of power by both TVA and non-TVA facilities and marketed by TVA. The projections in these figures are based on the continued implementation of the 2011 IRP and subsequent TVA decisions on coal plant retirements, gas plant additions and related actions. CO_2 emissions from TVA-owned generating facilities were 81,248,765 tons in 2012 and 72,154,380 tons in 2013; these accounted for about 4 percent of annual U.S. electric utility emissions.

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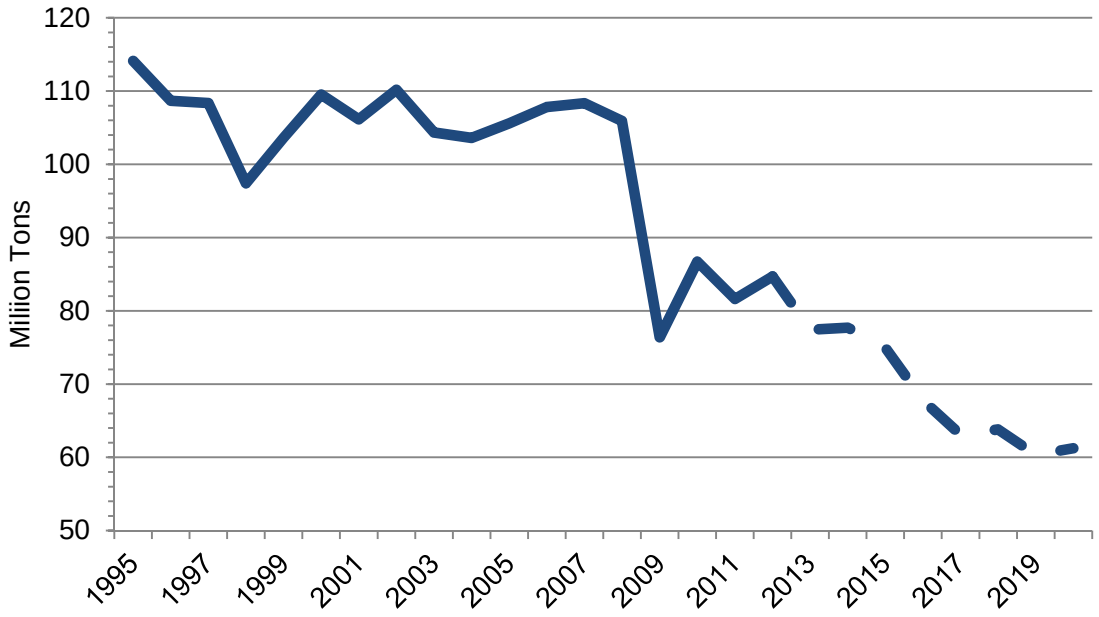

Figure 4-8 Historical and projected TVA CO_2 emissions (million tons) from generation of power marketed by TVA.

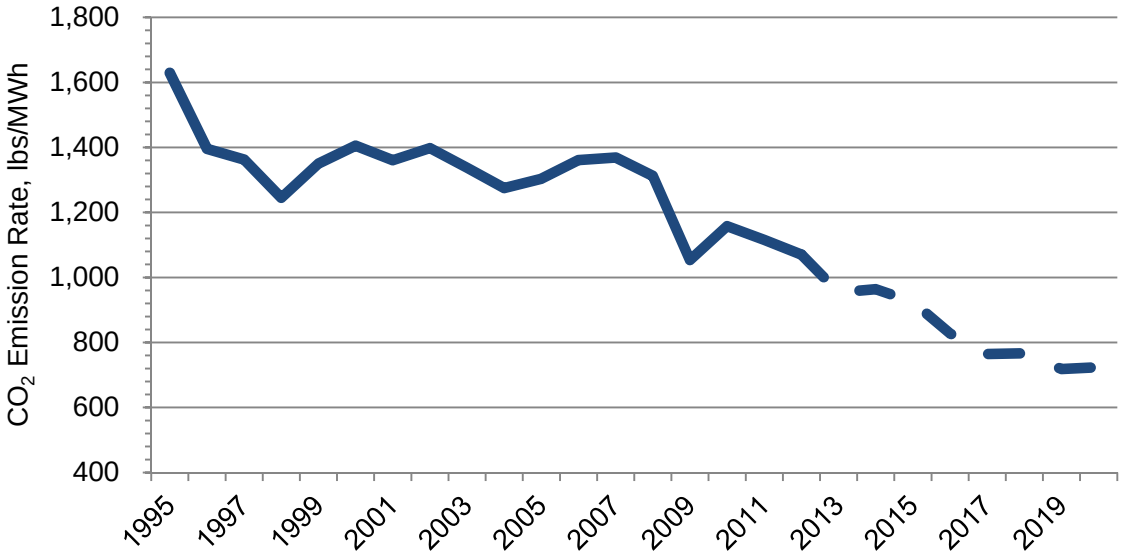

Figure 4-9 TVA historical and projected CO_2 emissions rate (lbs/MWh) rate from generation of power marketed by TVA.

In 2013, TVA began providing specific CO_2 content rates to large industrial, Federal installation and LPC customers. TVA provides as-delivered CO_2 emission rates in a manner consistent with generally accepted carbon accounting standards, such as The Climate Registry's *Electric Power Sector (EPS) Protocol for the Voluntary Reporting Program* and the World Resources Institute

and World Business Council for Sustainable Development's *Greenhouse Gas Reporting Protocol Corporate Standard*. Consistent with these widely-used standards, TVA CO_2 power delivery metrics include owned and purchased power, and are reported in CO_2 terms in order to allow customers to compile their GHG emissions by gas. The rates do not include emissions of other GHGs such as methane and nitrous oxide.

Consistent with the EPS, the LPC 2013 as-delivered CO_2 emission rate was 1,048.77 lbs CO_2/MWh. A single rate is calculated collectively for LPCs and rates for large industrial and Federal customers are calculated individually according to their electricity usage. CO_2 lbs/MWh rate disclosure is made to large industrial and Federal customers individually to ensure double-counting does not inadvertently occur between these customers. TVA's Scope 2 CO_2 lbs/MWh rates include an adjustment for the 2013 retirement of renewable energy credits that resulted in an additional 4.35% Scope 2 CO_2 lbs/MWh rate reduction. TVA's as-delivered CO_2 emission rates are lower than the current EPA eGRID (Year 2010) national CO_2 lbs/MWh rate of 1,232.35 and regional CO_2 rate of 1,389.20.

Climate Adaptation

TVA has, in accordance with the requirements of Executive Orders (E.O.) 13514 – Federal Leadership in Environmental, Energy, and Economic Performance and 13653 – Preparing the United States for the Impacts of Climate Change, adopted a climate adaptation plan that establishes adaptation planning goals and describes the challenges and opportunities a challenging climate may present to its mission and operations (TVA 2014g). The goal of TVA's adaptation planning process is to ensure that the Agency continues to achieve its mission and program goals and to operate in a secure, effective and efficient manner in a changing climate.

TVA manages the effects of climate change on its mission, programs and operations within its environmental management processes. TVA's Environmental Policy (TVA 2008a) provides objectives for an integrated approach related to providing cleaner, reliable and affordable energy, supporting sustainable economic growth and engaging in proactive environmental stewardship. The policy includes the specific objective of stopping the growth in volume of emissions and reducing the rate of carbon emissions by 2020 by supporting a full slate of reliable, affordable, lower-CO_2 energy-supply opportunities and energy efficiency. TVA's Adaptation Plan (TVA 2014g) specifies that each TVA major planning process shall identify any significant climate change risks. Significant climate change risks are those with the potential to substantially impair, obstruct or prevent the success of agency mission activities, both in the near term and particularly in the long term, using the best available science and information.

4.3 Air Quality

Air quality is a vital resource that impacts us in many ways. Poor air quality can affect our health, ecosystem health, forest and crop productivity, economic development and our enjoyment of scenic views. This section summarizes current conditions and trends over the past 35 years for key air quality issues, including criteria pollutants, hazardous air pollutants, mercury, acid deposition and visibility impairment. Air quality within the TVA region has steadily improved over the past 35 years.

Regulatory Framework for Air Quality

The Clean Air Act is the comprehensive law that affects air quality by regulating emissions of air pollutants from stationary sources (such as power plants) and mobile sources (such as automobiles). It requires EPA to establish National Ambient Air Quality Standards (NAAQS) and

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directs the states to develop State Implementation Plans to achieve these standards. This is primarily accomplished through permitting programs that establish limits for emissions of air pollutants. The act also requires EPA to set standards for emissions of hazardous air pollutants.

Criteria Air Pollutants

EPA has established NAAQS for the six criteria air pollutants: carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter and sulfur dioxide (Table 4-5). There are two different standards for particulate matter, one for particles less than 10 microns in size (PM_{10}), and one for particles less than 2.5 microns in size ($PM_{2.5}$). Primary standards protect public health, while secondary standards protect public welfare (e.g., visibility, crops, forests, soils and materials).

Table 4-5 National Ambient Air Quality Standards. Source: USEPA (2014a).

Pollutant		Primary/ Secondary	Averaging Time	Level	Form	Final rule
Carbon Monoxide (CO)		Primary	8-hour	9 ppm	Not to be exceeded more than once per year	76 FR 54294, (Aug. 31, 2011)
			1-hour	35 ppm		
Lead		Primary and secondary	Rolling 3 month average	0.15 µg/m^3 (1)	Not to be exceeded	73 FR 66964, (Nov. 12, 2008)
Nitrogen Dioxide (NO_2)		Primary	1-hour	100 ppb	98th Percentile, averaged over 3 years	75 FR 6474, (Feb. 9, 2010)
		Primary and secondary	Annual	53 ppb (2)	Annual mean	61 FR 52852, (Oct. 8, 1996)
Ozone		Primary and secondary	8-hour	75 ppb (3)	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years	73 FR 16436, (Mar. 27, 2008)
Particulate Matter	$PM_{2.5}$	Primary and secondary	Annual	15 µg/m^3	Annual mean, averaged over 3 years	71 FR 61144, (Oct. 17, 2006)
			24-hour	35 µg/m^3	98th Percentile, averaged over 3 years	
	PM_{10}	Primary and secondary	24-hour	150 µg/m^3	Not to be exceeded more than once per year on average over 3 years	
Sulfur Dioxide (SO_2)		Primary	1-hour	75 ppb (4)	99th Percentile of 1-hour daily maximum concentrations, averaged over 3 years	75 FR 35520, (Jun. 22, 2010)
		Secondary	3-hour	0.5 ppm	Not to be exceeded more than once per year on average over 3 years	38 FR 25678, (Sept. 14, 1973)

FR = Federal Register; µg/m^3 = micrograms per cubic meter; PM = particulate matter; ppb = parts per billion; ppm = parts per million.

(1) The 1978 lead standard (1.5 micrograms per cubic meter [µg/m^3] as a quarterly average) remains in effect until one year after an area is designated for the 2008 standard, except that in areas designated nonattainment for the 1978 standard, the 1978 standard remains in effect until implementation plans to attain or maintain the 2008 standard are approved.

(2) The official level of the annual NO_2 standard is 0.053 parts per million (ppm), equal to 53 parts per billion (ppb), which is shown here for the purpose of clearer comparison to the 1-hour standard.

(3) The 1997 ozone standard (0.08 ppm, annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years) and related implementation rules remain in place. In 1997, the USEPA revoked the 1-hour ozone standard (0.12 ppm, not to be exceeded more than once per year) in all areas, although some areas have continued obligations under that standard ("anti-backsliding"). The one-hour ozone standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is less than or equal to 1.

(4) The 1971 annual and 24-hour SO_2 standards were revoked in this rulemaking. However, they remain in effect until one year after an area is designated for the 2010 standard, except in areas designated nonattainment for the 1971 standards, where the 1971 standards remain in effect until implementation plans to attain or maintain the 2010 standard are approved.

Ambient air monitors measure concentrations of these pollutants to determine attainment with these standards. Areas where these measurements exceed the standards are designated as non-attainment areas.

Sulfur Dioxide

Sulfur dioxide (SO_2) is a colorless gas with a sharp odor that can cause respiratory problems at high concentrations. SO_2 also combines with other elements to form sulfate, a secondary pollutant that contributes to acid deposition, regional haze and fine particle concentrations.

Most SO_2 is produced from the burning of fossil fuels (coal and oil), as well as petroleum refining, cement manufacturing and metals processing. In addition, geothermic activity, such as volcanoes and hot springs, can be a significant natural source of SO_2 emissions. In 2012, TVA emitted 65 percent of the human-produced SO_2 emissions in the TVA region (Figure 4-10). While TVA emits roughly two-thirds of the SO_2 emissions in the region, TVA's SO_2 emissions have decreased by 94 percent since 1974 (Figure 4-11). This reduction is largely the result of TVA's installation of FGD systems on coal plants and recent coal plant retirements. TVA has retired 11 coal units since 2010 and announced plans to retire 14 coal units, most of which do not have FGD systems (see Section 3-3).

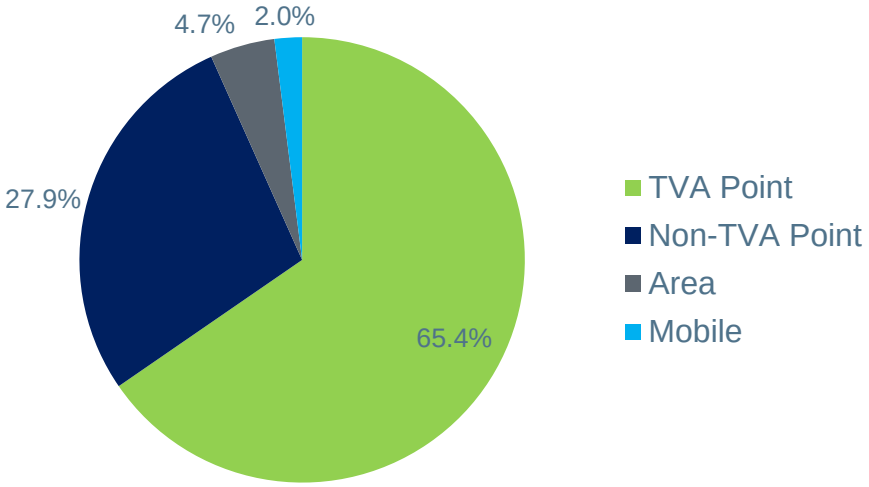

Figure 4-10 Percent contribution of human-made sulfur dioxide (SO_2) emissions by major source group in the TVA region in 2012. Source: TVA data.

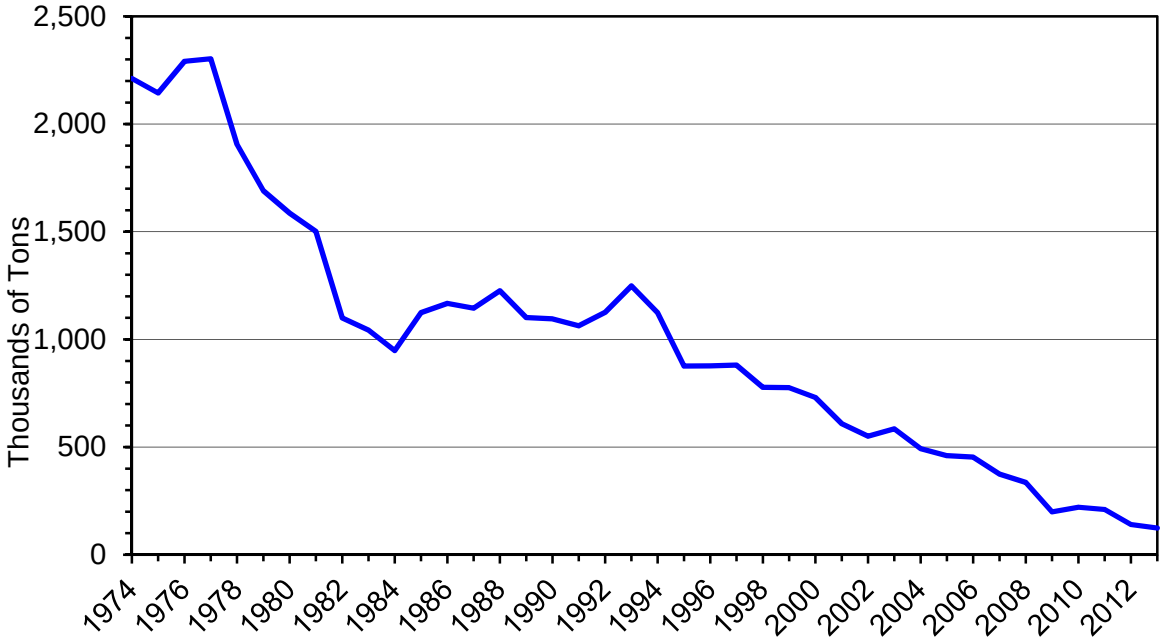

Figure 4-11 TVA sulfur dioxide (SO_2) emissions, 1974–2013. Source: TVA data.

There are two air quality standards for SO_2: a one-hour primary standard and a three-hour secondary standard. Average three-hour concentrations of SO_2 in the TVA region have been reduced by 87 percent from 1979 to 2013 and concentrations are well below the NAAQS standard (Figure 4-12). In 2013, average three-hour SO_2 concentrations were just 7 percent of the standard, and there were no exceedances of the three-hour SO_2 standard in the TVA region. In 2010, EPA finalized a new one-hour SO_2 NAAQS which is much more stringent than the three-hour NAAQS. Initial non-attainment areas have been designated based on available monitoring data and include part of Sullivan County in northeast Tennessee. However, other non-attainment areas are expected to be designated in the future after additional monitors are installed.

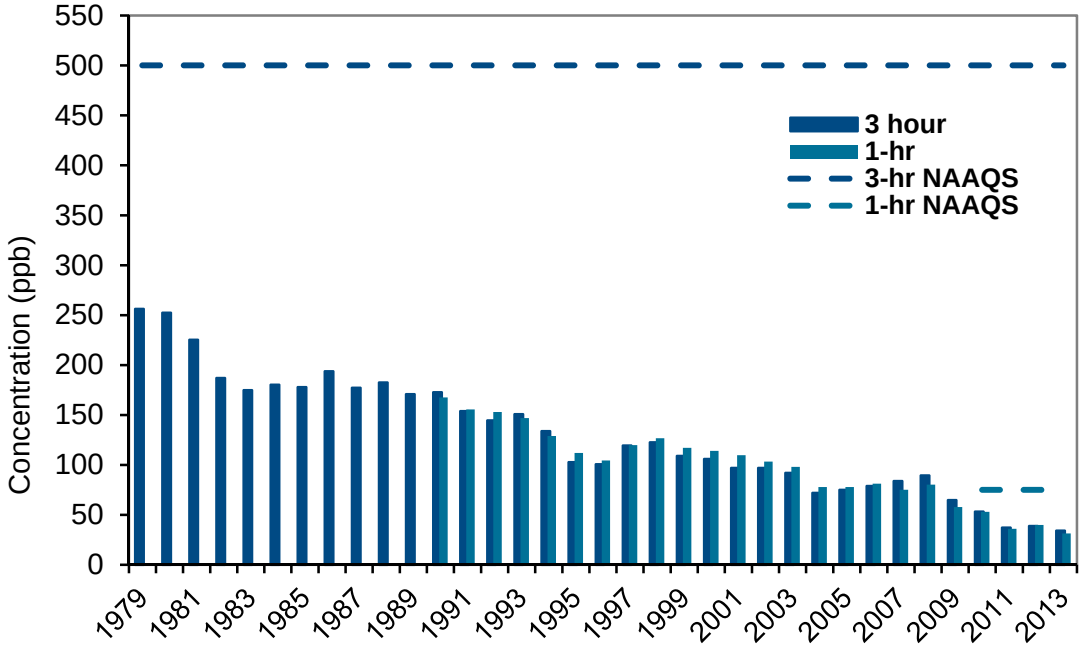

Figure 4-12 Regional average sulfur dioxide (SO_2) concentrations, 1979–2013. Source: EPA AQS Database.

Nitrogen Oxides

Nitrogen oxides (NOx) are a group of highly reactive gases, including nitrogen dioxide (NO_2), containing varying amounts of nitrogen and oxygen. NOx emissions contribute to a variety of environmental impacts, including ground-level ozone, fine particulate matter, regional haze, acid deposition and nitrogen saturation. Natural sources of NOx include lightning, forest fires and microbial activity; major sources of human-produced NOx emissions include motor vehicles, electric utilities, industrial boilers, nitrogen fertilizers and agricultural burning. Within the TVA region, two-thirds of the human-produced NOx emissions come from mobile sources (Figure 4-13). Between the peak in 1995 and 2013 (Figure 4-14), TVA reduced its NOx emissions by 91 percent and currently emits 11 percent of the human-produced NOx emissions in the TVA region. These emissions reductions have been the result of an aggressive emissions control program that included the installation of selective catalytic reduction (SCR) systems on 21 coal units and five combined cycle combustion turbines. TVA is currently installing SCR systems on the four units at the Gallatin plant and has committed to installing SCR systems on two units at the Shawnee plant (see Section 3-3). Most of the coal-fired units that TVA has retired or announced plans to retire do not have SCR systems.

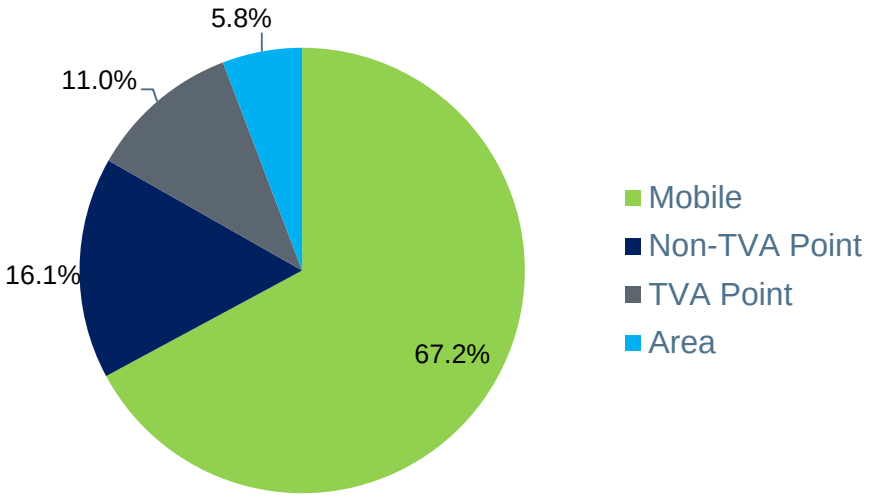

Figure 4-13 Percent contribution of nitrogen oxides (NOx) emissions in the TVA region by major source group. Source: TVA data.

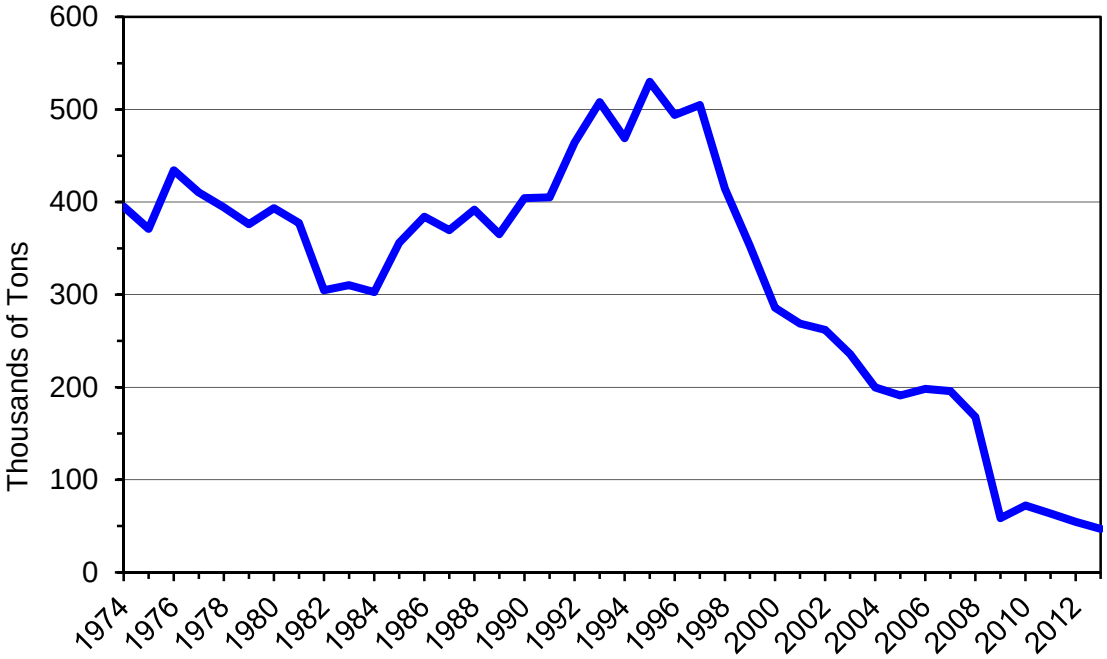

Figure 4-14 Trends in TVA nitrogen oxides (NOx) emissions, 1974–2013. Source: TVA data.

Regional annual NO_2 concentrations declined by 52 percent between 1979 and 2013 and by 63 percent since the peak concentration in 1988 (Figure 4-15). Average regional concentrations are well below the NO_2 annual NAAQS standard; the 2013 average concentration was 14 percent of the annual NAAQS. In 2010, EPA set a new, more stringent one-hour NO_2 standard; the regional average one-hour concentration was 38 percent of the one-hour NAAQS.

Based on the NO_2 concentrations recorded by the network of monitors, TVA does not expect any non-attainment areas for one-hour NO_2 in the TVA region, although additional monitors will be required in larger cities.

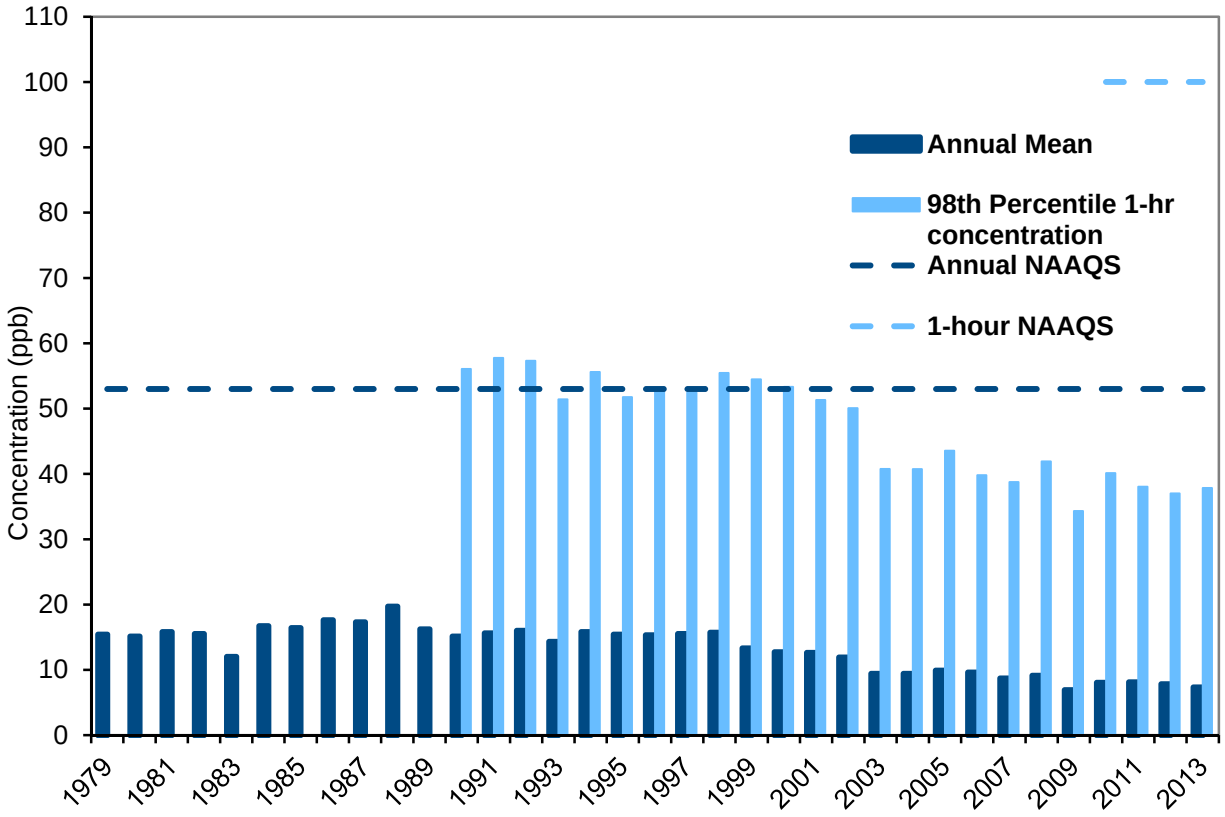

Figure 4-15 Regional average nitrogen dioxide (NO_2) concentrations, 1979–2013. Source: EPA AQS Database.

Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are compounds that have a high vapor pressure (i.e., readily evaporate at ambient temperatures) and low solubility in water. The most common sources of man-made VOCs are petrochemical storage and transport, chemical processing, motor vehicles, paints and solvents. Natural sources of VOCs include vegetation, biological decay and forest fires. In many areas of the Southeast, natural sources contribute up to 90 percent of total VOCs. TVA does not emit a significant amount of VOC emissions. While VOCs are not a criteria pollutant, they are important because they are a precursor to ground-level ozone.

Ozone

Ozone is a gas that occurs both in the stratosphere (10 to 30 miles above the Earth's surface) and at ground level where it is the main ingredient of smog. While stratospheric ozone is beneficial due to its role in absorbing ultraviolet radiation, ground-level ozone is an air pollutant that can damage lung tissue and harms vegetation at sufficiently high concentrations. The ozone NAAQS applies to ground-level ozone. Ozone is a secondary pollutant which is not directly emitted by any source; it is formed by a chemical reaction between NOx and VOCs in

the presence of sunlight. Because ozone formation depends on sunlight, ozone concentrations are highest during the summer and greater in areas with hot summers, such as the southeastern U.S.

In 2008, EPA lowered the eight-hour ozone standard from 80 ppb to 75 ppb. In Tennessee, Knox County, part of Anderson County, and Shelby County are currently designated as non-attainment areas for this standard. Blount County, Tennessee is designated as marginal attainment, as is DeSoto County, Mississippi, which, although outside the TVA service area, is immediately south of Memphis and Shelty County, Tennessee. The remainder of the TVA service area is in attainment. In November 2014, EPA proposed revised primary and secondary ozone standards of between 60 and 65 ppb; this revision would likely cause additional areas in the TVA region to be designated non-attainment for ozone standards.

Ozone concentrations are strongly impacted by meteorological conditions with higher ozone concentrations during hot, stagnant years and lower concentrations in wet, milder years. This causes a great deal of variability in ozone trends. Despite this variability, average ozone concentrations have decreased about 38 percent from the peak in 1988–2013 (Figure 4-16).

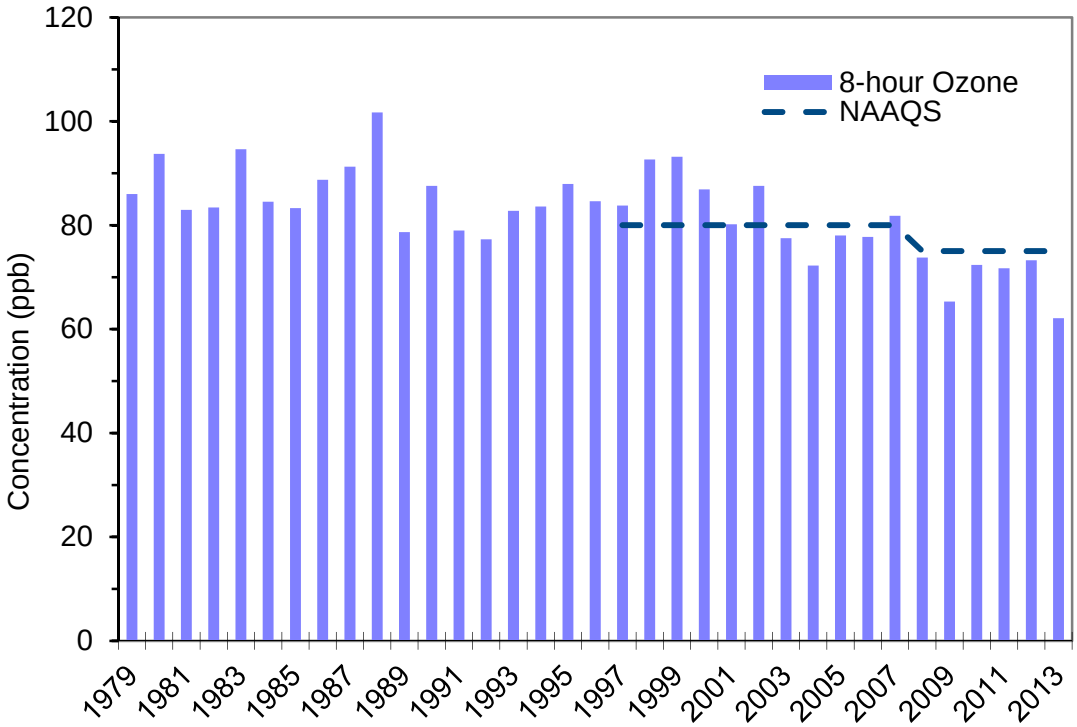

Figure 4-16 Regional average ozone concentrations, 1979–2013. Source: EPA AQS Database.

Particulate Matter

Particulate matter consists of small solid “dust” particles or liquid droplets; some are just large enough to be seen with the naked eye, while others are too small to be seen without the aid of a microscope. The composition and shape of these particles varies greatly, as do their many sources. Particles emitted directly from a pollution source are called primary particles, whereas those formed after emission—by the chemical and physical conversion of gaseous pollutants—

are called secondary particles. Generally speaking, primary particles tend to be larger and heavier and are deposited close to their source, while smaller, lighter secondary particles may remain in the air for several days and can be transported long distances. Primary particle emissions are generally considered a local air quality issue, while secondary particles are a regional concern.

When inhaled by humans, large particles are filtered by the nose and throat, while fine particles can be drawn deeper into the lungs. Consequently, fine particles have more adverse health impacts (USEPA 2009). Exposure to high levels of fine particles can impact the respiratory and cardiovascular systems, particularly in elderly people and those with respiratory or cardiovascular disease. In addition to potential health effects, fine particles also contribute to acid deposition, visibility impairment and hazardous air pollutants.

Particulate matter has many natural and human-made sources. Natural sources include wind-blown dust, forest fires, volcanoes, and ocean spray, while human-made sources include motor vehicles, fossil-fuel combustion, industrial processes, mining, agricultural activities, waste incineration and construction.

Particulate matter is regulated by size class: particulate matter less than 10 micrometers in diameter (PM_{10}), and particulate matter less than 2.5 micrometers in diameter ($PM_{2.5}$). Particulate matter regulations have evolved over the past 40 years to become more stringent and to place more importance on fine particles. The first NAAQS for particulate matter established in 1971 was based on total suspended particulates (TSP). The standards have changes everal times since then. In 1987, the PM_{10} NAAQS was added and in 1997 the $PM_{2.5}$ NAAQS was added and the TSP NAAQS was dropped. In 2006 the 24-hour $PM_{2.5}$ NAAQS was lowered from 65 to 35 µg/m^3 and in 2012 the $PM_{2.5}$ NAAQS was lowered from 15 to 12 µg/m^3.

There are no non-attainment areas for PM_{10} in the TVA region. There are two $PM_{2.5}$ non-attainment areas in the region based on the previous annual NAAQS of 15 µg/m^3 which include counties in the vicinity of Chattanooga and Knoxville. The counties in the vicinity of Knoxville are also non-attainment for the 24-hour $PM_{2.5}$ NAAQS. EPA issued final designations for the 2012 PM2.5 NAAQS in December 2014. The entire state of Illinois, St. Louis, MO and Louisville, KY were designated as “Unclassifiable;” the entire state of Tennessee, except Hamilton, Marion, Sequatchie Counties (Chattanooga area), and the greater Atlanta area were deferred. The Chattanooga area and the remainder of the TVA service area were designated “Unclassifiable/Attainment.”

Ambient particulate levels have decreased in recent decades. Since 1986, 24-hour PM_{10} levels have decreased 57 percent (Figure 4-17) to a 2013 regional average level of 26 percent of the NAAQS. Annual average $PM_{2.5}$ levels decreased by 46 percent and 24-hour $PM_{2.5}$ decreased 50 percent between 1999 and 2013 (Figure 4-18). In 2013, regional average annual $PM_{2.5}$ levels were 78 percent of the new lower annual NAAQS and regional average 24-hour $PM_{2.5}$ levels were 55 percent of the 24-hour NAAQS. Particulate levels are strongly influenced by weather patterns causing considerable fluctuation from year to year, but the trend of declining particulate levels is still apparent.

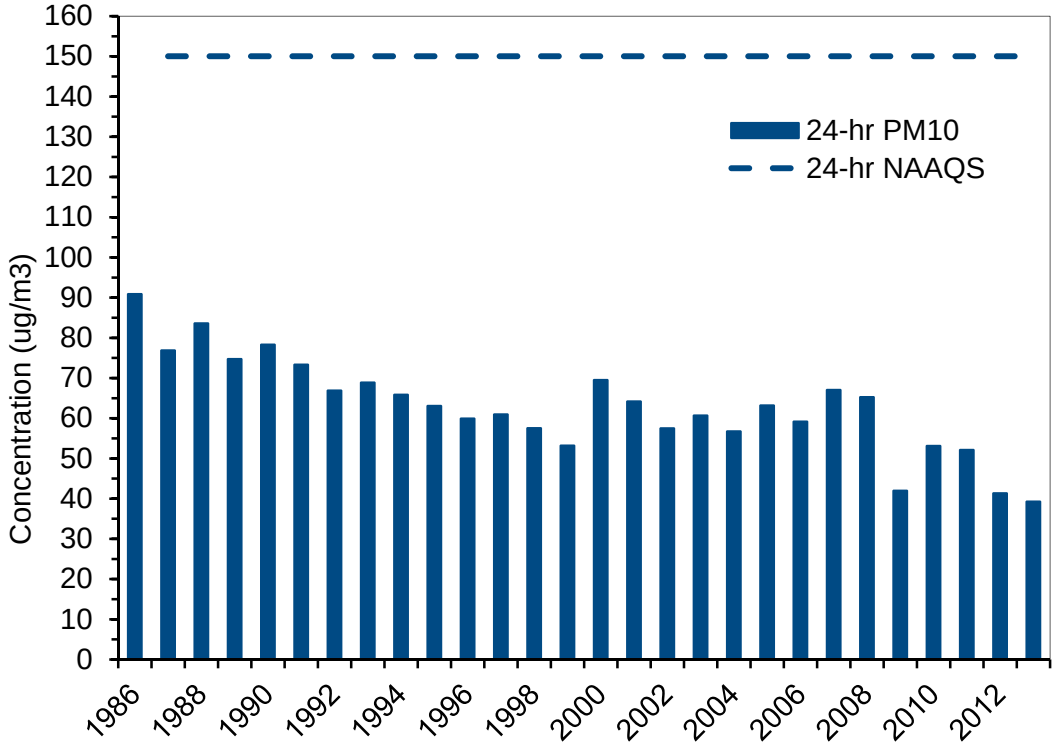

Figure 4-17 Regional average PM_{10} concentrations, 1986–2013. Source: EPA AQS Database.

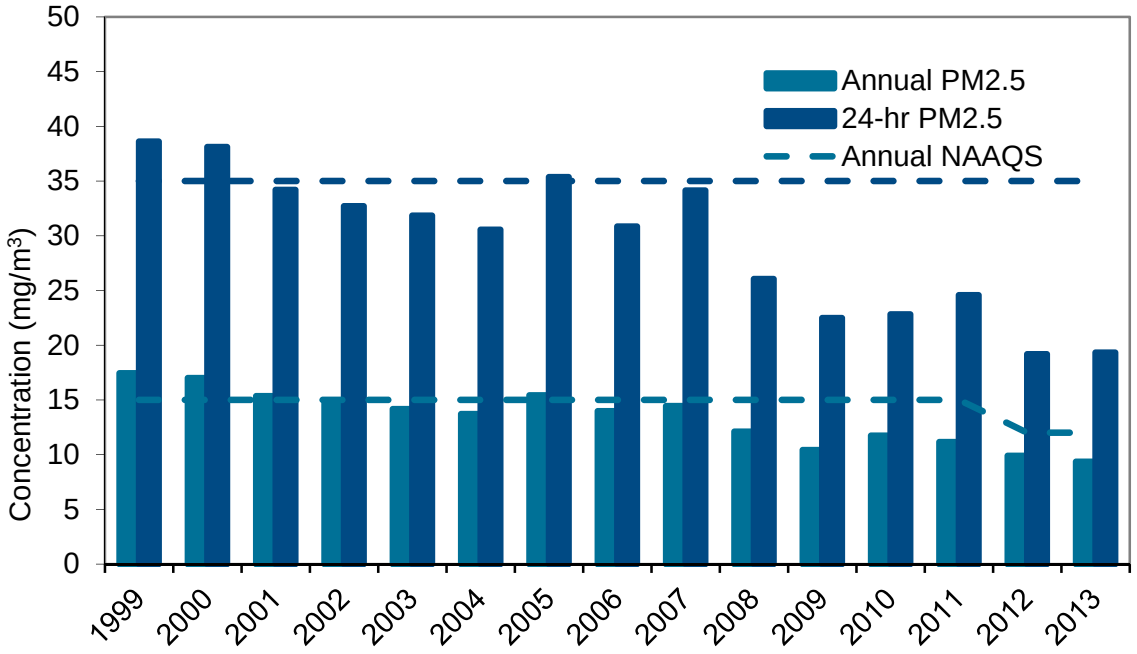

Figure 4-18 Regional average $PM_{2.5}$ concentrations, 1999–2013. Source: EPA AQS Database.

Carbon Monoxide
Carbon monoxide (CO) is a colorless and odorless gas formed when carbon in fuel is not burned completely. At high concentrations, CO can aggravate heart disease and even cause death. Major CO sources include motor vehicles, off-road sources (i.e., construction equipment, airplanes and trains), metals processing and chemical manufacturing. The primary natural source of CO is wildfires. Electric utilities are not a major source of CO emissions and account for 1 percent of the total CO emissions in the United States.

There are two CO air quality standards: one-hour and eight-hour. From 1979 to 2013, regional average one-hour concentrations decreased by 86 percent, and eight-hour concentrations decreased by 85 percent (Figure 4-19). Regional average concentrations are less than 20 percent of the standards and there are no CO non-attainment areas in the TVA region.

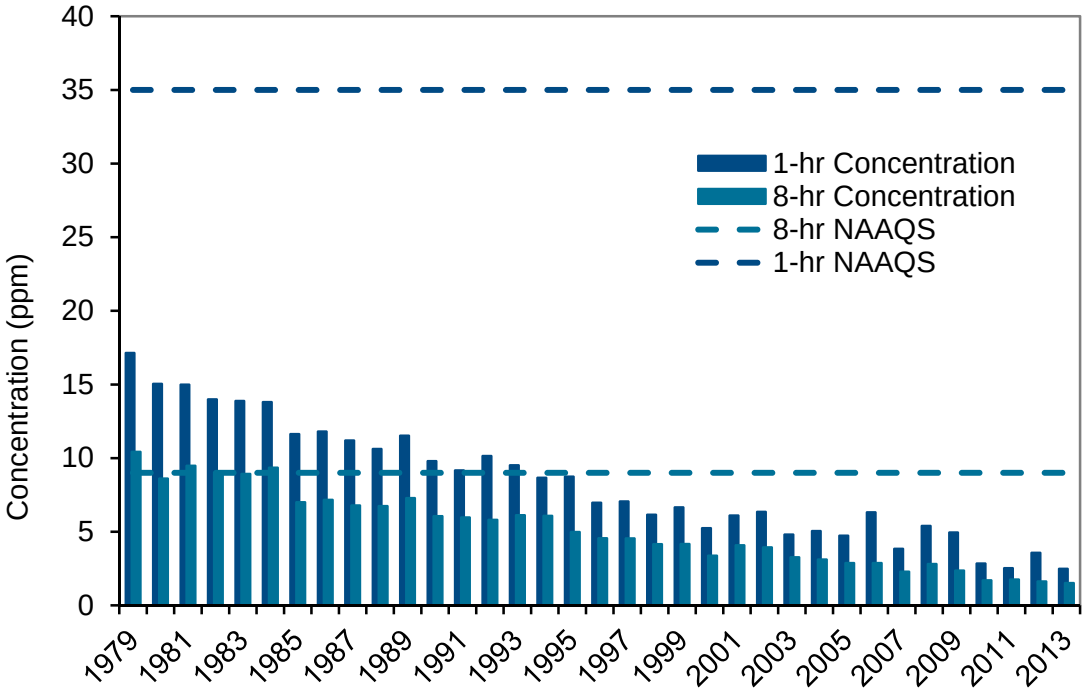

Figure 4-19 Regional average carbon monoxide concentrations, 1979–2013. Source: EPA AQS Database.

Lead
Lead is a naturally occurring metal. Exposure to lead can adversely affect the human nervous system, kidneys and cardiovascular system. There has been particular concern over neurological effects on children from exposure to lead-based paint in older homes. For many years, lead was added to gasoline to increase engine performance, and the primary source of human-made lead emissions was motor vehicles. Since lead in gasoline was phased out during the 1980s and early 1990s, lead concentrations have declined considerably. The largest current sources of lead emissions are ore and metals processing, waste incinerators and battery manufacturing. Coal contains small amounts of lead, so coal-burning utilities also have lead emissions. In 2013 TVA emitted about 3,300 pounds of lead; approximately two-thirds of which was emitted by Paradise Fossil Plant. TVA's lead emissions will significantly decrease following the pending retirement of Paradise Units 1 and 2.

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Ambient lead concentrations have dropped dramatically in the past 20 years and regional average concentrations have decreased 77 percent from 1990 to 2013 and 88 percent from the peak in 1993 to 2013 (Figure 4-20).

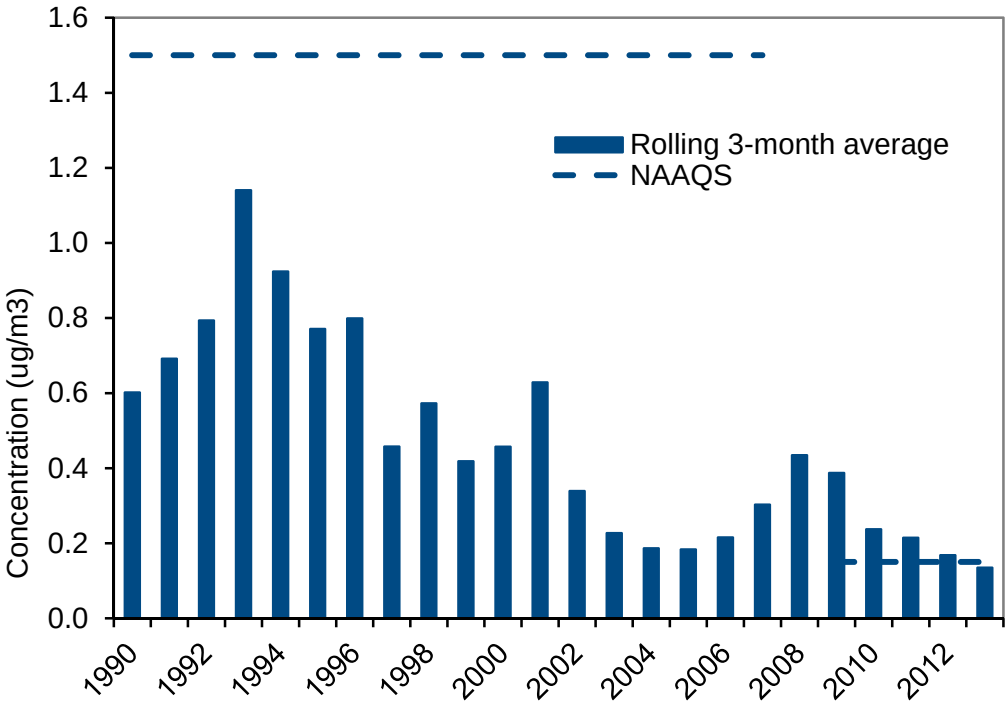

Figure 4-20 Regional average lead concentrations, 1990–2013. Source EPA AQS Database.

There are currently two non-attainment areas for lead in the vicinity of the TVA region. One, designated under an early lead standard, is associated with a lead smelting operation in Herculaneum, Missouri. Part of Sullivan County, Tennessee, was designated non-attainment in 2010 under the new, more stringent lead standard. An EPA analysis indicated that nationwide, approximately 40 percent of the counties with a lead monitor are likely to exceed the new lead NAAQS (USEPA 2008). There are very few lead monitors currently operating in the U.S., and the new NAAQS will require additional monitors in the vicinity of large lead sources and large urban areas. Therefore, additional non-attainment areas will likely be designated after data are available from the expanded monitoring network.

Hazardous Air Pollutants (HAPs)

Hazardous air pollutants (HAPs) are toxic air pollutants, which are known or suspected to cause cancer or other serious health effects or adverse environmental effects. The Clean Air Act identifies 187 pollutants as HAPs. Most HAPs are emitted by human activity, including motor vehicles, factories, refineries and power plants. There are also indoor sources of HAPs such as building materials and cleaning solvents. Some HAPs are emitted by natural sources, such as volcanic eruptions and forest fires. Exposure to HAPs can result from breathing air toxics, drinking water in which HAPs have deposited, or eating food exposed to HAPs deposition on soil or water. Exposure to high levels of HAPs can cause various chronic and acute harmful health effects, including cancer. The level of exposure which may result in adverse health impacts varies for each pollutant.

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EPA established the Toxic Release Inventory (TRI) under the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) and expanded it under the Pollution Prevention Act of 1990. TRI is a database containing information on toxic chemical releases and waste management activities for nearly 650 chemicals, including HAPs. In 2013, TVA emitted just over 10 million pounds of TRI pollutants to the air, mostly from coal plants. Acid gases (sulfuric acid, hydrochloric acid and hydrofluoric acid) accounted for the overwhelming majority of these emissions. The remaining portion was made up of heavy metals, such as arsenic, barium, chromium, copper, lead, manganese, mercury, nickel, vanadium and zinc, as well as very small amounts of organic compounds, such as benzoperylene, dioxin, naphthalene and polycyclic aromatic hydrocarbons. TVA reduced its TRI air emissions by 79 percent from 1999 to 2013 (Figure 4-21).

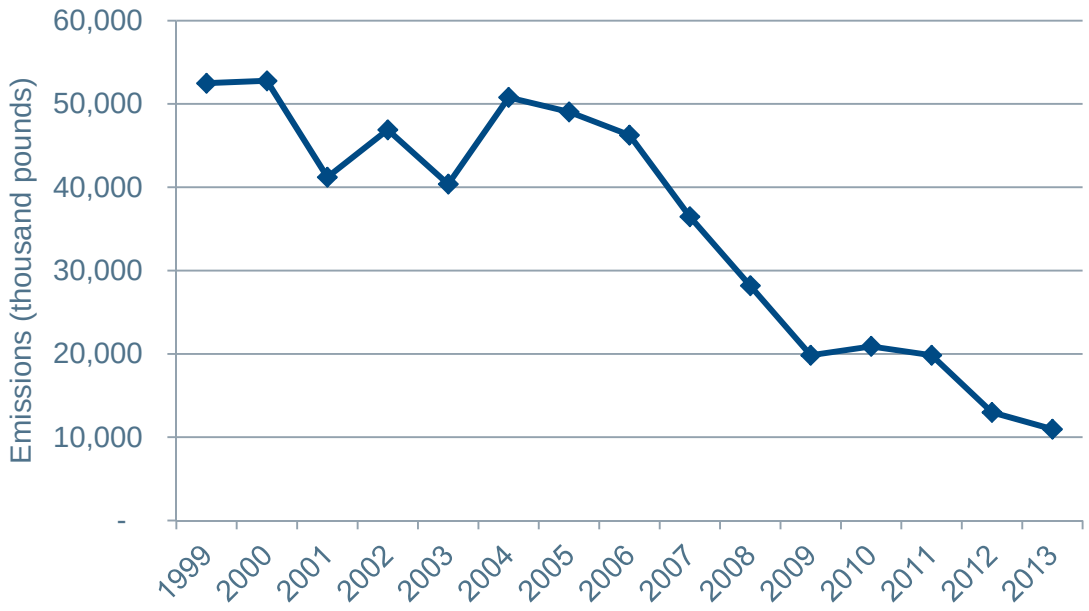

Figure 4-21 TVA Toxic Release Inventory (TRI) air emissions, 1999–2013. Source: TVA Form R Submittal to EPA TRI Database.

Mercury

Mercury is emitted to the air by human activities, such as burning coal or manufacturing, and from natural sources, such as volcanoes. Once it is in the environment, mercury cycles between air, water and soils, being re-emitted and re-deposited. Mercury is emitted in one of three forms: elemental mercury, particle-bound mercury and oxidized mercury. Elemental mercury can stay in the atmosphere for up to one year and travel long distances making it a global, rather than a local or regional, issue.

Once mercury is deposited in streams and lakes, it can be converted to methyl-mercury, the most toxic form of mercury, through microbial activity. Methyl-mercury accumulates in fish at levels that may cause harm to the fish and the animals that eat them. Some wildlife species with high exposures to methyl-mercury have shown increased mortality, reduced fertility, slower growth and development, and abnormal behavior that affects survival (Mercury Study Report to Congress). Studies have also shown impaired neurological development in fetuses, infants and children with high exposures to methyl-mercury. In June 2014, EPA and the FDA issued an

updated draft fish consumption advisory recommending that pregnant and breastfeeding women, those who may become pregnant, and young children avoid some marine fish and limit consumption of others. TVA region states have also issued advisories on fish consumption due to mercury for several rivers and reservoirs across the TVA region (see Section 4-6).

Globally, artisanal and small-scale gold mining is the largest source of anthropogenic mercury emissions, followed closely by coal combustion. Other large sources of emissions are non-ferrous metals production and cement production (UNEP 2013). However, U.S. anthropogenic mercury emissions are estimated to account for about 3 percent of the total global emissions and the U.S. power sector is estimated to account for just 1 percent of the total global emissions.

TVA mercury emissions have decreased 71 percent from 4,388 pounds in 2000 to 1,256 pounds in 2013 (Figure 4-22) and are expected to continue to decline as additional FGD and SCR systems are completed and more coal-fired units are retired. In 2011, EPA finalized the Mercury and Air Toxics Standards (MATS) rule to reduce mercury and other toxic air pollution from coal and oil-fired power plants. This rule will prevent about 90 percent of the mercury in coal burned in power plants from being emitted to the air. EPA estimates the rule to result in a 5 percent reduction in U.S. mercury deposition.

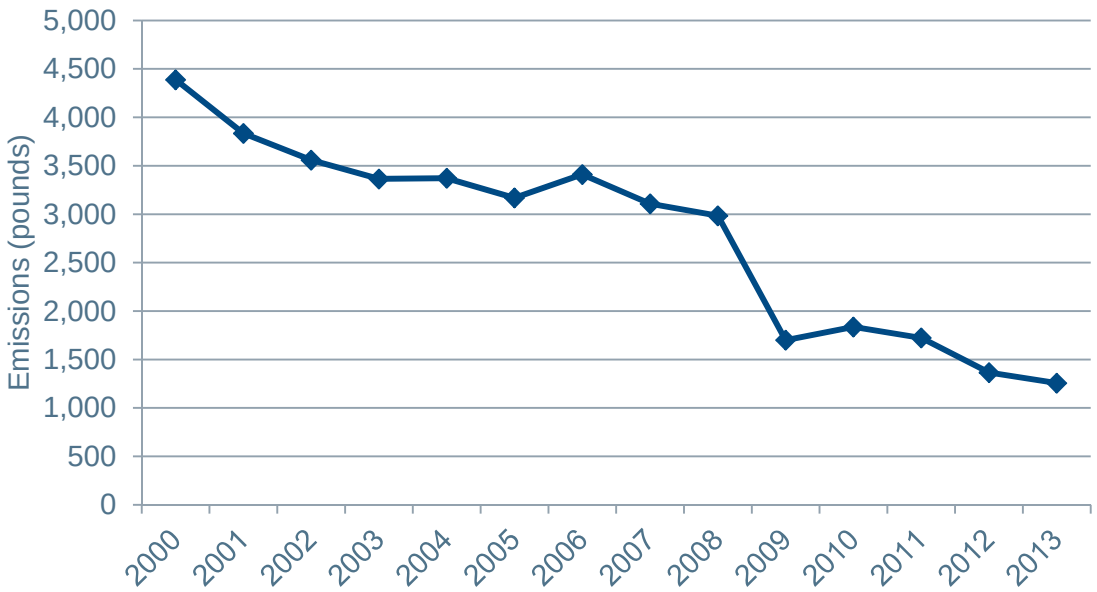

Figure 4-22 TVA mercury air emissions, 2000–2013. Source: TVA Form R Submittal to EPA TRI Database.

Deposition occurs in two forms: wet (dissolved in rain, snow or fog) and dry (solid and gaseous particles deposited on surfaces during periods without precipitation). Wet mercury deposition is measured at Mercury Deposition Network monitors operated by the National Atmospheric Deposition Program. The highest wet deposition of mercury in the U.S. occurs in Florida and along the Gulf Coast (Figure 4-23). Mercury deposition in the TVA region ranges from nine to 15 micrograms per square meter, in the medium-high range for North America.

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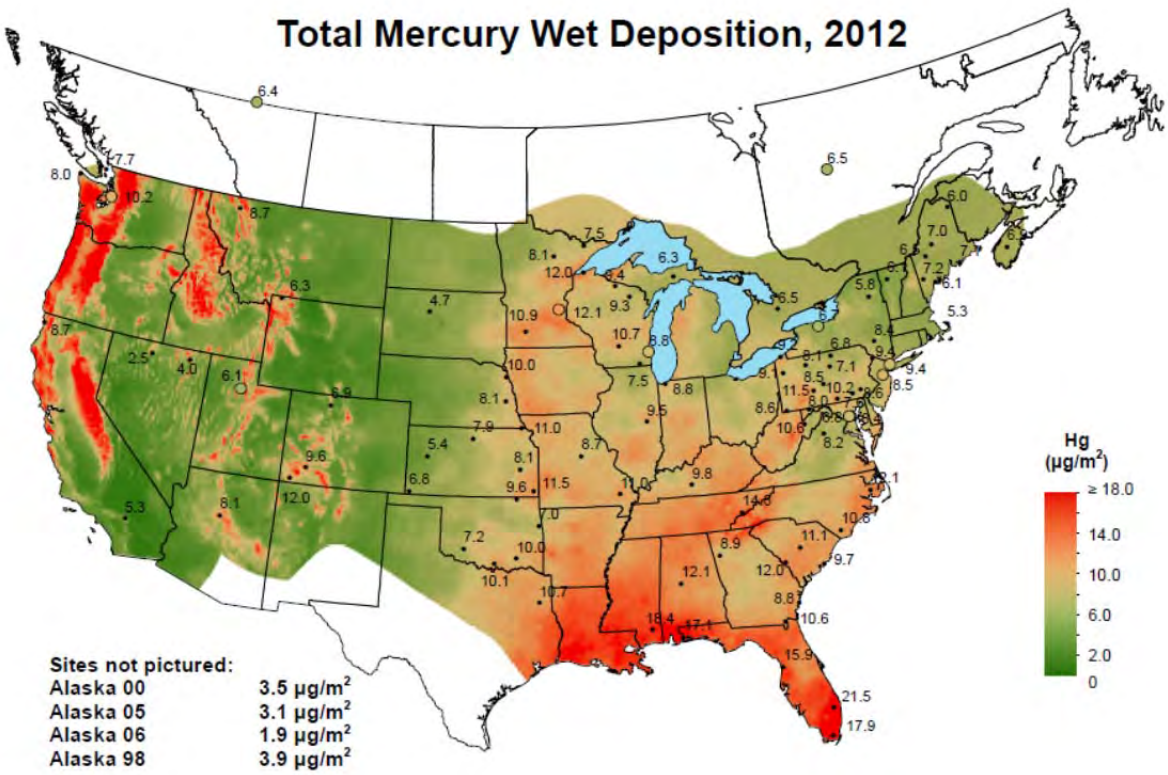

Figure 4-23 Total Mercury Wet Deposition in the United States in 2012. Source: National Atmospheric Deposition Program / Mercury Deposition Network.

Acid Deposition

Acid deposition, also called acid rain, is primarily caused by SO_2 and NOx emissions which are transformed into sulfate (SO_4) and nitrate (NO_3) aerosols, then deposited in precipitation (rain, snow, or fog). Acid deposition causes acidification of lakes and streams in sensitive ecosystems, which can adversely impact aquatic life. Acid deposition can also reduce agricultural and forest productivity. Some ecosystems, such as high elevation spruce-fir forests in the southern Appalachians, are quite sensitive to acidification, while other ecosystems with more buffering capacity are less sensitive to the effects of acid deposition. The acidity of precipitation is typically expressed on a logarithm scale called pH which ranges from zero to 14 with seven being neutral. pH values less than seven are considered acidic and values greater than seven are considered basic or alkaline. It is thought that the average pH of pre-industrial rainfall in the eastern United States was approximately 5.0 (Charlson and Rodhe 1982).

As previously shown in Figures 4-10 and 4-13, TVA currently emits 65 percent of the SO_2 emissions and 11 percent of the NOx emissions in the region. As shown in Figures 4-11 and 4-14, TVA has reduced its SO_2 emissions by 94 percent since 1974 and reduced its NOx emissions by 91 percent since 1995.

The 1990 Clean Air Act Amendments established the Acid Rain Program to reduce SO_2 and NOx emissions and the resulting acid deposition. Since this program was implemented in 1995, reductions in SO_2 and NOx emissions have contributed to significant reductions in acid deposition, concentrations of $PM_{2.5}$ and ground-level ozone, and regional haze. Figure 4-24

illustrates the dramatic decrease in sulfate deposition between 1992, prior to the implementation of the Acid Rain Program, and 2012. These figures show a reduction in both the magnitude of sulfate deposition and the size of the impacted area.

Visibility

Air pollution can impact visibility, which is a particularly important issue in national parks and wilderness areas where millions of visitors expect to be able to enjoy scenic views. Historically, "visibility" has been defined as the greatest distance at which an observer can see a black object viewed against the horizon sky. However, visibility is more than just a measurement of how far an object can be seen; it is a measurement of the conditions that allow appreciation of the inherent beauty of landscape features.

Visibility in the eastern United States is estimated to have declined by as much as 60 percent in the second half of the 20th Century (USEPA 2001). Visibility impairment is caused when sunlight is scattered or absorbed by fine particles of air pollution obscuring the view. Some haze-causing particles are emitted directly to the air, while others are formed when gases are transformed into particles. In the TVA region, the largest contributor to visibility impairment is ammonium sulfate particles formed from SO_2 emissions (primarily from coal-fired power plants). Other particles impacting visibility include nitrates (from motor vehicles, utilities, and industry), organic carbon (predominantly from motor vehicles), elemental carbon (from diesel exhaust and wood burning) and dust (from roads, construction, and agricultural activities). Visibility extinction is a measure of the ability of particles to scatter and absorb light and is expressed in units of inverse mega-meters (Mm^{-1}). The chemical composition of visibility extinction varies by season as well as degree of visibility impairment.

The Clean Air Act designated national parks greater than 6,000 acres and wilderness areas greater than 5,000 acres as Class I areas in order to protect their air quality under more stringent regulations. There are eight Class I areas in the vicinity of the TVA region: Great Smoky Mountains National Park, Mammoth Cave National Park and the Joyce Kilmer, Shining Rock, Linville Gorge, Cohutta, Sipsey, and Upper Buffalo Wilderness Areas (Figure 4-25). In 1999, EPA promulgated the Regional Haze Rule to improve visibility in Class I areas. This regulation requires states to develop long-term strategies to improve visibility with the ultimate goal of restoring natural background visibility conditions by 2064. Visibility trends are evaluated using the average of the 20 percent worst days and the 20 percent best days with the goal of improving conditions on the 20 percent worst days, while preserving visibility on the 20 percent best days. From 1990 to 2013, there was a 75 percent improvement in the visibility on the worst days and a 47 percent improvement on the best days in the Great Smoky Mountains National Park, the largest Class I area in the TVA region (Figure 4-26).

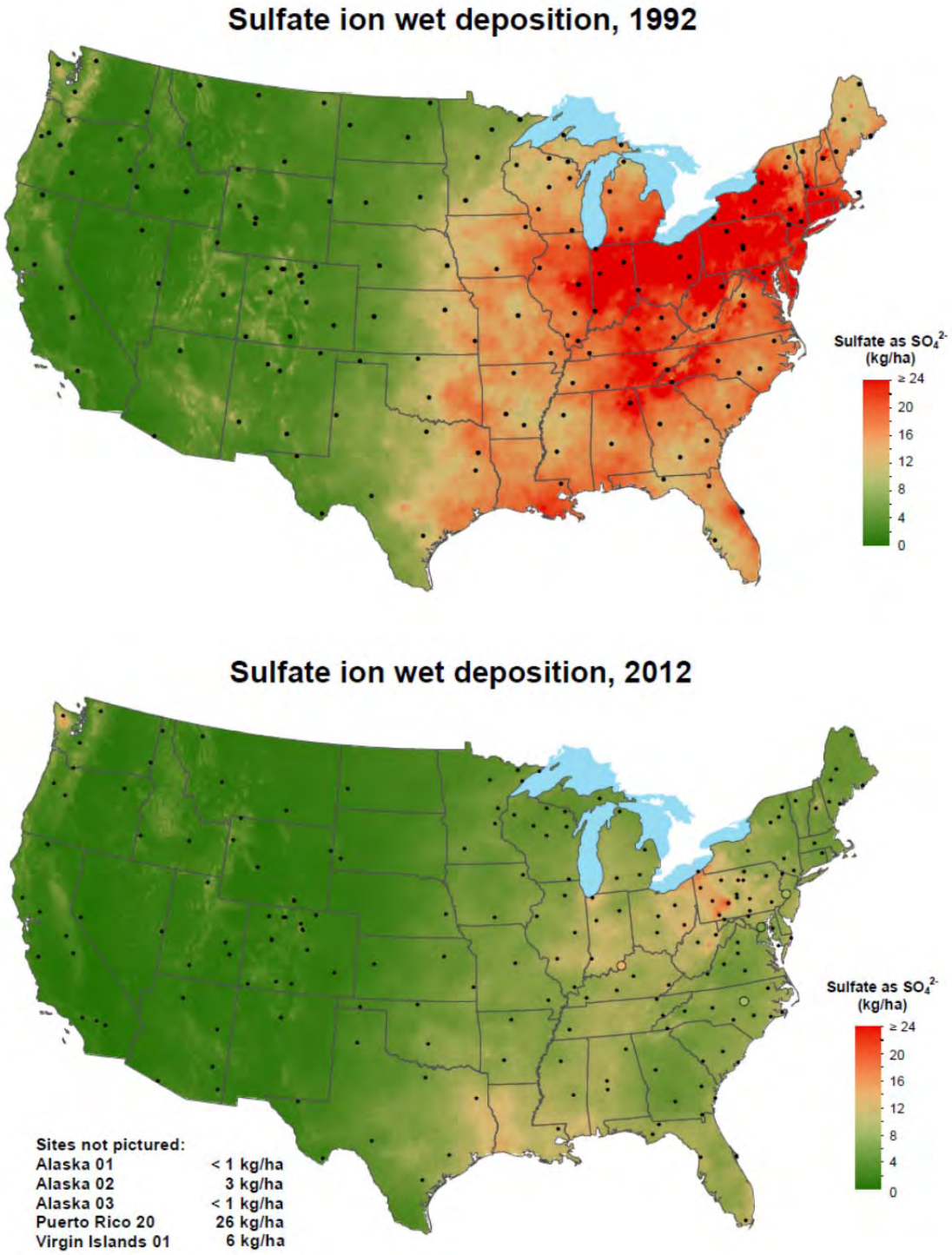

Figure 4-24 United States sulfate (SO_4) wet deposition in 1992 (top) and 2012 (bottom). Source: National Atmospheric Deposition Program / National Trends Network.

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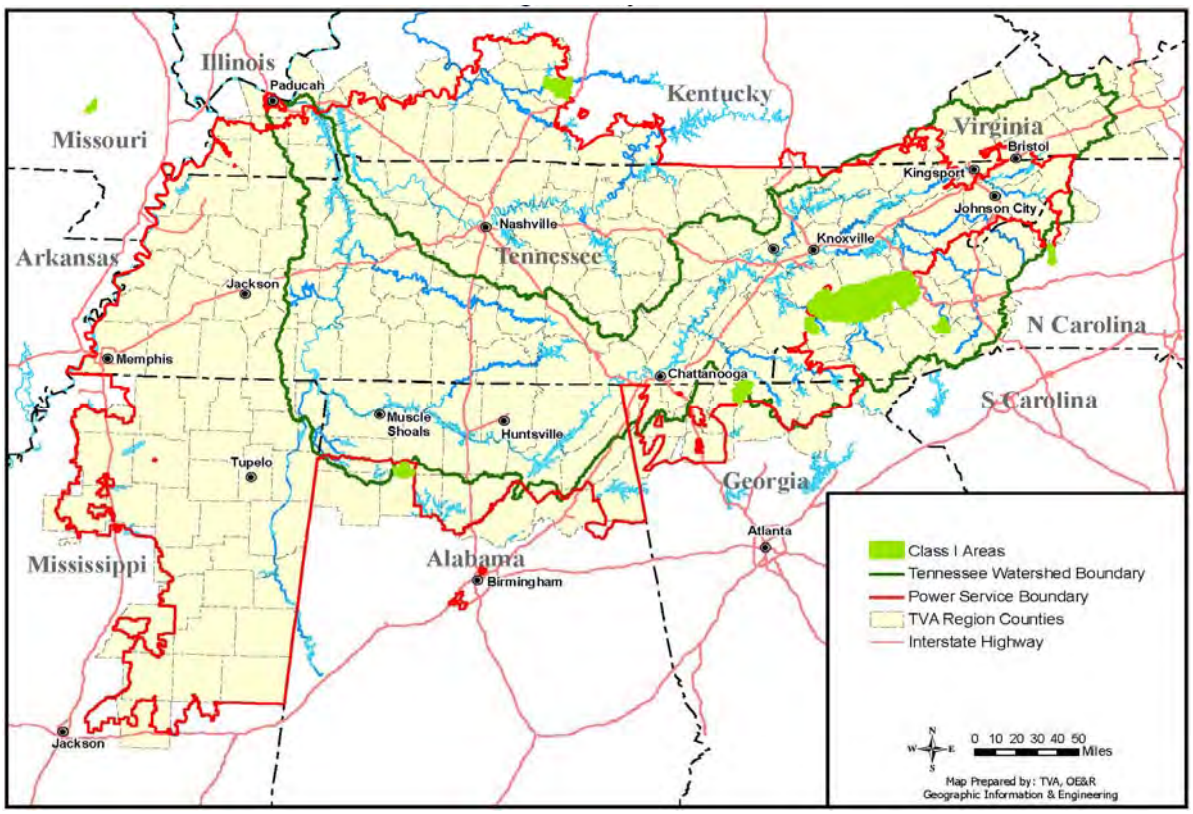

Figure 4-25 Class I areas in and near the TVA region.

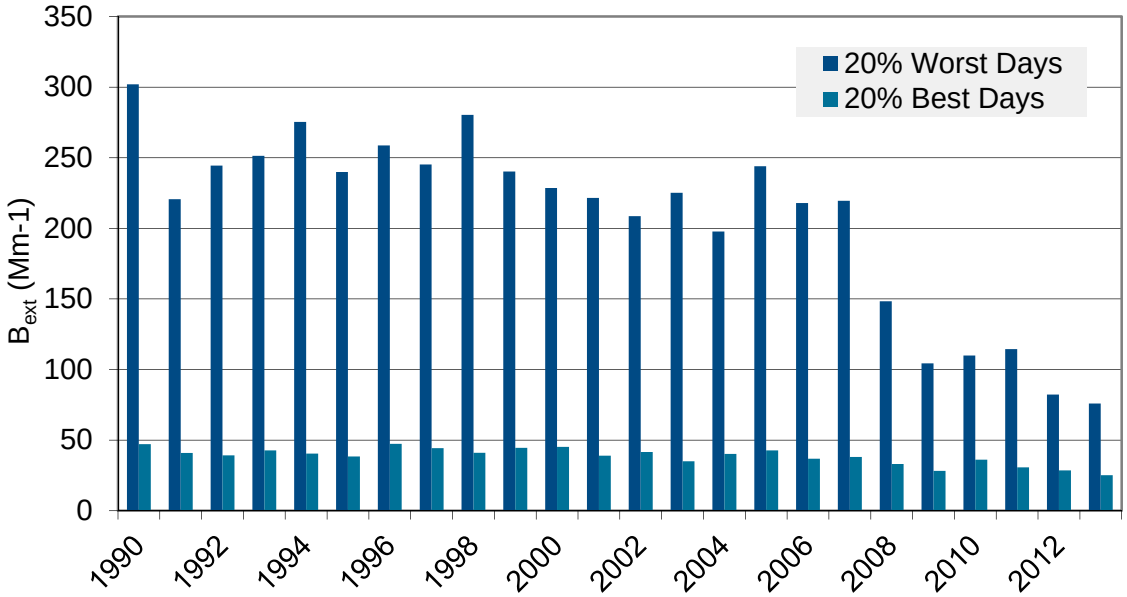

Figure 4-26 Visibility extinction in the Great Smoky Mountains National Park on the worst 20 percent days and best 20 percent days, 1990–2013. Source: IMPROVE Program.

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4.4 Regional Geology

The TVA region encompasses portions of five major physiographic provinces and six smaller physiographic sections (Figure 4-27) (Fenneman 1938, Miller 1974). Physiographic provinces and sections are areas of similar land surfaces resulting from similar geologic history.

The easternmost part of the region is in the Blue Ridge physiographic province, an area composed of the remnants of an ancient mountain chain. This province has the greatest variation in terrain in the TVA region. Terrain ranges from nearly level along floodplains at elevations of about 1,000 feet to rugged mountains that reach elevations of more than 6,000 feet. The rocks of the Blue Ridge have been subjected too much folding and faulting and are mostly shales, sandstones, conglomerates and slate (sedimentary and metamorphic rocks of Precambrian and Cambrian age from over a billion to about 500 million years ago).

Located west of the Blue Ridge and east of the Appalachian Plateaus, the Valley and Ridge Province has complex folds and faults with alternating valleys and ridges trending northeast to southwest. Ridges have elevations of up to 3,000 feet and are generally capped by dolomites and resistant sandstones, while valleys have developed in more soluble limestones and dolomites. The dominant soils in this province are residual clays and silts derived from in-situ weathering. Karst features such as sinkholes and springs are numerous in the Valley and Ridge. “Karst” refers to a type of topography that is formed when rocks with a high carbonate (CO_3) content, such as limestone and dolomite, are dissolved by groundwater to form sink holes, caves, springs and underground drainage systems.

The Appalachian Plateaus Province is an elevated area between the Valley and Ridge and Interior Low Plateaus provinces. It is comprised of two sections in the TVA region, the extensive Cumberland Plateau section and the smaller Cumberland Mountain section. The Cumberland Plateau rises about 1,000–1,500 feet above the adjacent provinces and is formed by layers of near horizontal Pennsylvanian sandstones, shales, conglomerates and coals, underlain by Mississippian and older shale and limestones. The sandstones are resistant to erosion and have produced a relatively flat landscape broken by stream valleys. Toward the northeast, the Cumberland Mountain section is more rugged due to extensive faulting and several peaks exceed 3,000 feet elevation. The province has a long history of coal mining and encompasses the Appalachian coal field (USGS 1996). Coal mining has historically occurred in much of the province. The most recent Appalachian coal mining within the TVA region has been from the southern end of the province in Alabama, the northern portion of the Cumberland Plateau section in Tennessee and the Cumberland Mountain section.

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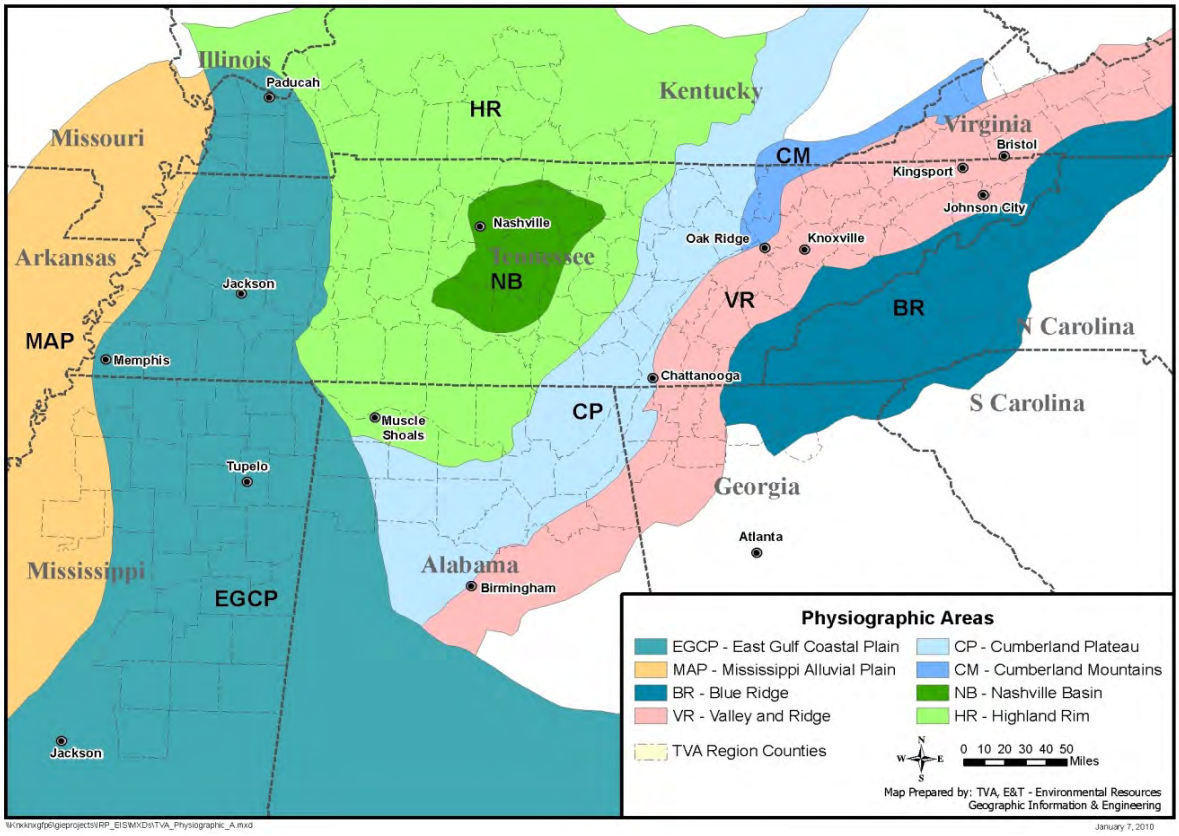

Figure 4-27 Physiographic areas of the TVA region. Adapted from Fenneman (1938).

Two sections of the Interior Low Plateaus Province occur in the TVA region. The Highland Rim section is a plateau that occupies much of central Tennessee and parts of Kentucky and northern Alabama. The bedrock of the Highland Rim is Mississippian limestones, chert, shale, and sandstone. The terrain varies from hilly to rolling to extensive relatively flat areas in the northwest and southeast. The southern end of the Illinois Basin coal region (USGS 1996) overlaps the Highland Rim in northwest Kentucky and includes part of the TVA region. The Nashville Basin (also known as the Central Basin) section is an oval area in middle Tennessee with an elevation about 200 feet below the surrounding Highland Rim. The bedrock is limestones that are generally flat-lying. Soil cover is usually thin and surface streams cut into bedrock. Karst is well-developed in parts of both the Highland Rim and the Nashville Basin.

The Coastal Plain Province encompasses much of the western and southwestern TVA region (Figure 4-27). Most of the Coastal Plain portion of the TVA region is in the extensive East Gulf Coastal Plain section. The underlying geology is a mix of poorly consolidated gravels, sands, silts and clays. Soils are primarily of windblown and alluvial (deposited by water) origin, low to moderate fertility and easily eroded. The terrain varies from hilly to flat in broad river bottoms. The Mississippi Alluvial Plain section occupies the western edge of the TVA region and much of the historic floodplain of the Mississippi River. Soils are deep and often poorly drained. The New Madrid Seismic Zone, an area of large prehistoric and historic earthquakes, is in the northern portion of the section.

Geologic Carbon Dioxide Sequestration Potential

The sequestration (i.e., capture and permanent storage) of CO_2 from large stationary point sources, such as coal-fired power plants, is potentially an important component of efforts to significantly reduce anthropogenic CO_2 emissions. Successful large-scale, economical, CO_2 sequestration (also referred to as carbon capture and storage (CCS)) would enable coal to continue to be used as an energy source with greatly reduced CO_2 emissions. Few power plant CCS projects are currently operating and the technology is in a relatively early stage of development.

Geologic CO_2 storage involves capturing and separating the CO_2 from the power plant exhaust, drying, purifying, and compressing the CO_2, and transporting it by pipeline to the storage site where it is pumped through wells into deep geological formations. When the CO_2 capacity of the formation has been reached or when the pressure of the formation or injection well has reached a pre-determined level, CO_2 injection is stopped and the wells are permanently sealed. The storage site would then be monitored for a period of time.

The suitability of a particular underground formation for CO_2 storage depends on its geology, as well as the geology of adjacent and overlying formations. In the central and southeastern U.S., deep saline formations, unmineable coal seams, and oil and gas fields are considered to have the best potential to store CO_2 from large point sources (NETL 2012). A brief description of each of these formations, as well as its storage potential in and near the TVA service area, is given below. In 2002, the Department of Energy's National Energy Technology Laboratory launched the Regional Carbon Sequestration Program to identify and evaluate carbon sequestration in different regions of the country. TVA, along with other agencies and utilities, has participated in the program's Southeast Regional Carbon Sequestration Partnership. The Midwest Geological Sequestration Consortium is conducting similar studies in the Illinois Basin area of Illinois, Indiana and Kentucky. Experimental CO_2 injection tests for enhanced coalbed methane recovery have been conducted in southwest Virginia and for enhanced oil recovery in southwest Kentucky (NETL 2012).

<u>Saline Formations</u> – Saline formations are layers of porous rock that are saturated with brine. They are more extensive than unmineable coal seams and oil and gas fields and have a high CO_2 storage potential. However, because they are less studied than the other two formations, less is known about their suitability and storage capacity. Potentially suitable saline formations are capped by one or more layers of non-porous rock, which would prevent the upward migration of injected CO_2. Saline formations also contain minerals that could react with injected CO_2 to form solid carbonates, further sequestering the CO_2.

Saline formations provide the greatest potential for CO_2 storage in the TVA region. Middle Tennessee and much of west-central Kentucky are underlain by the Mt. Simon and associated basal sandstone formations. These deep formations have a potential CO_2 storage capacity of up to about 9 billion metric tons. Recent research conducted by the Tennessee Geological Survey has shown that the shallower Knox-Stones River Groups underlying the Cumberland Plateau may be a viable storage reservoir. The extensive Tuscaloosa Group in Alabama and Mississippi south of the TVA region also has a high potential for CO_2 storage (NETL 2012).

<u>Unmineable Coal Seams</u> – Unmineable coal seams are typically too deep or too thin to be economically mined. When CO_2 is injected into them, it is adsorbed onto the surface of the coal. Although their storage potential is much lower than saline formations, they are attractive

because they are relatively shallow and because the injected CO_2 can be used to displace coalbed methane, which can be recovered in adjacent wells and used as a natural gas substitute. Coal seams within the TVA region in Tennessee and Alabama have little potential for CO_2 storage. Coal seams with greater potential near the TVA service area occur in southwest Virginia, in Alabama and Mississippi south of the TVA service area, and in the Illinois Basin of western Kentucky mostly north of the TVA service area (NETL 2012).

Natural gas-producing shales in the Illinois Basin also offer the potential for storing CO_2, including its use for enhanced gas recovery (NETL 2012). The occurrence of suitable unmineable coal seams and organic-rich shales in the TVA region is limited, but more extensive elsewhere in the Illinois Basin, as well as in southeast Kentucky/southwest Virginia, west-central Alabama, and southwest Mississippi.

Oil and Gas Fields – Mature oil and gas fields/reservoirs are considered good storage formations because they held crude oil and natural gas for millions of years. Their storage characteristics are also well known and some are currently used for storing natural gas. Like saline formations, they consist of layers of permeable rock with one or more layers of cap rock. Injected CO_2 can also enhance the recovery of oil or gas from mature fields. The potential for CO_2 storage in the oil and gas fields of Tennessee, southwest Virginia, and east-central Mississippi is limited (NETL 2012). Greater potential exists in oil and gas fields in central-southern Mississippi, where CO_2 from the Kemper County plant will be used for enhanced oil recovery (USDOE 2010a, NETL 2012). The potential for CO_2 storage is also high in the gas-rich New Albany Shale in northwest Kentucky and adjacent Illinois and Indiana (NETL 2012).

4.5 Groundwater

Regulatory Framework for Groundwater

The Safe Drinking Water Act of 1974 established the sole source aquifer protection program which regulates certain activities in areas where the aquifer (water-bearing geologic formations) provides at least half of the drinking water consumed in the overlying area. This act also established both the Wellhead Protection Program, a pollution prevention and management program used to protect underground sources of drinking water, and the Underground Injection Control Program to protect underground sources of drinking water from contamination by fluids injected into wells. Several other environmental laws contain provisions aimed at protecting groundwater, including the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act and the Federal Insecticide, Fungicide, and Rodenticide Act.

TVA Region Aquifers

Three basic types of aquifers occur in the TVA region: unconsolidated sedimentary sand, carbonate rocks, and fractured non-carbonate rocks. Unconsolidated sedimentary sand formations, composed primarily of sand with lesser amounts of gravel, clay and silt, constitute some of the most productive aquifers. Groundwater movement in sand aquifers occurs through the pore spaces between sediment particles. Carbonate rocks are another important class of aquifers. Carbonate rocks, such as limestone and dolomite, contain a high percentage of carbonate minerals (e.g., calcite) in the rock matrix. Carbonate rocks in some parts of the region readily transmit groundwater through enlarged fractures and cavities created by dissolution of carbonate minerals by acidic groundwater. Fractured non-carbonate rocks represent the third type of aquifer found in the region. These aquifers include sedimentary and metamorphic rocks, e.g., sandstone, conglomerate, and granite gneiss, which transmit groundwater through

fractures, joints, and beddings planes. Eight major aquifers occur in the TVA region (Table 4-6). These aquifers generally align with the major physiographic divisions of the region (Figure 4-27).

The aquifers include (in order of increasing geologic age): Quaternary age alluvium occupying the floodplains of major rivers, notably the Mississippi River; Tertiary and Cretaceous age sand aquifers of the Coastal Plain Province; Pennsylvanian sandstone units found mainly in the Cumberland Plateau section; carbonate rocks of Mississippian, Silurian and Devonian age of the Highland Rim section; Ordovician age carbonate rocks of the Nashville Basin section; Cambrian-Ordovician age carbonate rocks within the Valley and Ridge Province; and Cambrian-Precambrian metamorphic and igneous crystalline rocks of the Blue Ridge Province.

The largest withdrawals of groundwater for public water supply are from the Tertiary and Cretaceous sand aquifers in the Mississippi Alluvial Plain and Coastal Plain physiographic areas. These withdrawals account for about two-thirds of all groundwater withdrawals for public water supply in the TVA region. The Pennsylvanian sandstone and Orodovician carbonate aquifers have the lowest groundwater use (less than 1 percent of withdrawals) and lowest potential for groundwater use. Groundwater use is described in more detail in Section 4-7. The quality of groundwater in the TVA region largely depends on the chemical composition of the aquifer in which the water occurs (Table 4-6). Precipitation entering the aquifer is generally low in dissolved solids and slightly acidic. As it seeps through the aquifer it reacts with the aquifer matrix and the concentration of dissolved solids increases.

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Table 4-6 Aquifer, well, and water quality characteristics in the TVA region. Source: Webbers (2003).

Aquifer Description	Well Characteristics (common range, maximum)		Water Quality Characteristics
	Depth (feet)	Yield (gpm*)	
Quaternary alluvium: Sand, gravel, and clay. Unconfined.	10–75, 100	20–50, 1,500	High iron concentrations in some areas.
Tertiary sand: Multi-aquifer unit of sand, clay, silt and some gravel and lignite. Confined; unconfined in the outcrop area.	100–1,300, 1,500	200–1,000, 2,000	Problems with high iron concentrations in some places
Cretaceous sand: Multi-aquifer unit of interbedded sand, marl and gravel. Confined; unconfined in the outcrop area.	100–1,500, 2,500	50–500, 1,000	High iron concentrations in some areas.
Pennsylvanian sandstone: Multi-aquifer unit, primarily sandstone and conglomerate, interbedded shale and some coal. Unconfined near land surface; confined at depth.	100–200, 250	5–50, 200	High iron concentrations are a problem; high dissolved solids, sulfide or sulfate are problems in some areas.
Mississippian carbonate rock: Multi-aquifer unit of limestone, dolomite, and some shale. Water occurs in solution and bedding-plane openings. Unconfined or partly confined near land surface; may be confined at depth.	50–200, 250	5–50, 400	Generally hard; high iron, sulfide, or sulfate concentrations are a problem in some areas
Ordovician carbonate rock: Multi-aquifer unit of limestone, dolomite, and shale. Partly confined to unconfined near land surface; confined at depth.	50–150, 200	5–20, 300	Generally hard; some high sulfide or sulfate concentrations in places.
Cambrian-Ordovician carbonate rock: Highly faulted multi-aquifer unit of limestone, dolomite, sandstone, and shale; structurally complex. Unconfined; confined at depth.	100–300, 400	5–200, 2,000	Generally hard, brine below 3,000 feet
Cambrian-Precambrian crystalline rock: Multi-aquifer unit of dolomite, granite gneiss, phyllite, and metasedimentary rocks overlain by thick regolith. High yields occur in dolomite or deep colluvium and alluvium. Generally unconfined.	50–150, 200	5–50, 1,000	Low pH and high iron concentrations may be problems in some areas.

*gpm = gallons per minute

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Acidic precipitation percolating through carbonate aquifers tends to dissolve carbonate minerals present in limestone and dolomite, resulting in reduced groundwater acidity and elevated concentrations of calcium, magnesium and bicarbonate. Consequently, groundwater derived from carbonate rocks of the Valley and Ridge, Highland Rim and Nashville Basin is generally slightly alkaline and high in dissolved solids and hardness. Groundwater from mainly noncarbonated rocks of the Blue Ridge, Appalachian Plateaus and Coastal Plain typically exhibits lower concentrations of dissolved solids compared to carbonate rocks. However, sandstones interbedded with pyritic shales often produce acidic groundwater high in dissolved solids, iron and hydrogen sulfide. These conditions are commonly found on the Appalachian Plateaus and in some parts of the Highland Rim and Valley and Ridge (Zurawski 1978).

The chemical quality of most groundwater in the region is within health-based limits established by the EPA for drinking water. Pathogenic microorganisms are generally absent, except in areas underlain by shallow carbonate aquifers susceptible to contamination by direct recharge through open sinkholes (Zurawski 1978).

Historically, TVA has handled coal combustion residuals (CCR) at its coal plants by wet methods and stored them in large unlined impoundments. While several plants have had dry CCR operations for many years, the practice of wet ash disposal at some locations has resulted in the placement of coal ash in close proximity to shallow aquifers which increased the potential for groundwater to be impacted. Several of these unlined facilities are located very close to large rivers or reservoirs that receive groundwater flow without crossing privately owned land. TVA conducts extensive groundwater monitoring programs to help ensure permit compliance and to provide information about any potential adverse effects.

Following the dike failure and ash spill at its Kingston Fossil Plant in December 2008, TVA committed to converting its coal plants to dry CCR handling and disposal. This will result in the design, permitting, and construction of lined CCR disposal facilities at those plants slated for continuing operation. In accordance with existing state regulations, liners for these facilities must meet RCRA solid waste disposal site standards. In April 2015, EPA published its rule establishing minimum criteria for CCR management. While it is possible to manage CCRs in wet impoundments under the rule, it is likely to result in the closure of wet impoundments and shift CCR management to dry landfills. Pending Effluent Limitations Guidelines (ELGs) are expected to further mandate the dry disposal practice. As CCR management at TVA plants is converted to dry CCR disposal, and at the plant sites scheduled to cease operations, TVA anticipates dewatering and capping existing impoundments.

EPA reviewed groundwater data from CCR management units (impoundments and landfills) across the country, including TVA data, while drafting the CCR management rule. EPA also released numerous technical documents and responses to comments with the rule. EPA found widespread evidence of groundwater contamination from unlined CCR impoundments, but only limited evidence of proven damage to human health and the environment resulting from the migration of contamination off site.

Of the TVA CCR impoundments assessed by EPA, it found proven damage only at Kingston Fossil Plant in eastern Tennessee and that resulted from the structural failure that occurred in December 2008. The impacts of that spill have been remediated. The impacts of the spill and its long-term risks have been comprehensively studied. Contrary to early claims of wide-spread, permanent damage to the environment and impacts to

human health, almost no impacts were found except for the physical impacts of the spill itself, *e.g.*, smothering and the force of the spill.

State and federal agencies with responsibilities for protecting natural resources impacted by the Kingston spill, including TVA, have completed their analyses of those impacts. They concluded that the physical impact of the spill and subsequent ash dredging activities impacted the benthic invertebrate community in the river, but that "[t]here were no exceedances of sediment toxicity guidelines, and exceedances of adverse effects thresholds for fish and birds was extremely limited" (TDEC et al. 2015, page ES-2).

The Tennessee Department of Health in collaboration with the federal Agency for Toxic Substances and Disease Registry assessed the potential risks to human health from the Kingston ash spill (TDH 2010). These agencies found that the ash spill should not harm community health. Based on review of extensive monitoring data, they found no evidence of coal ash contamination in municipal drinking water or at private wells within four miles of the ash spill. This general determination was confirmed by Oak Ridge Associated Universities and Vanderbilt University Medical Center. They conducted independent, comprehensive health assessments of over 200 individuals in the Kingston area and found no evidence of adverse health effects associated with coal ash. (August 17, 2010 Press Release).

The findings from the agencies studying the health and environmental impacts of the Kingston ash spill, the most significant release of CCRs in the country, are consistent with the biological monitoring and whole-effluent toxicity testing that TVA has conducted for years around and near its coal plants. CCR impacts on ecological resources have not been discerned.

4.6 Water Quality

The quality of the region's water is critical to protection of human health and aquatic life. Water resources provide habitat for aquatic life, recreation opportunities, domestic and industrial water supplies and other benefits. Major watersheds in the TVA region include the entire Tennessee River basin, most of the Cumberland River basin, and portions of the lower Ohio, lower Mississippi, Green, Pearl, Tombigbee, and Coosa River basins. Fresh water abounds in much of this area and generally supports most beneficial uses, including fish and aquatic life, public and industrial water supply, waste assimilation, agriculture, and water-contact recreation, such as swimming. Water quality in the TVA region is generally good.

Regulatory Framework for Water Quality

The Federal Water Pollution Control Act, commonly known as the Clean Water Act (CWA) is the primary law that affects water quality. It establishes standards for the quality of surface waters and prohibits the discharge of pollutants from point sources unless a National Pollutant Discharge Elimination (NPDES) permit is obtained. NPDES permits also address CWA Section 316(b) requirements for the design, location, construction and capacity of cooling water intakes to reflect the best technology available for minimizing environmental impact. Section 404 of the CWA further prohibits the discharge of dredge and fill material to waters of the United States, which include most wetlands, unless authorized by a permit issued by the U.S. Army Corps of Engineers.

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The seven states in the TVA service area have enacted laws regulating water quality and implementing the Clean Water Act. As part of this implementation, the states classify water bodies according to their uses and establish water quality criteria specific to these uses. Each state has also issued an antidegradation statement containing specific conditions for regulated actions and designed to maintain and ptotect current uses and water quality conditions.

Causes of Degraded Water Quality
Causes of degraded water quality include:

- Wastewater discharges – Municipal sewage treatment systems, industrial facilities, concentrated animal feeding operations and other sources discharge waste into streams and reservoirs. These discharges are controlled through state-issued NPDES permits issued under the authority of the Federal CWA. NPDES permits regulate the amounts of various pollutants in the discharges (including heat) and establish monitoring and reporting requirements.
- Runoff discharges – Runoff from agriculture, forest management (silvicultural) activities, urban uses and mined land can transport sediment and other pollutants into streams and reservoirs. Runoff from some commercial and industrial facilities and some construction sites is regulated through state NPDES stormwater permitting programs. Runoff from agriculture, silvicultural and other sources not regulated under the NPDES program is referred to as “nonpoint source” runoff.
- Cooling Systems – Electrical generating plants and other industrial facilities withdraw water from streams or reservoirs, use it to cool facility operations, and discharge heated water into streams or reservoirs. The aquatic community may be impacted due to temperature changes in the receiving waters and from fish and other organisms being trapped against the intake screens or sucked into the facility cooling system. These water intakes and discharges are controlled through state-issued NPDES permits.
- Air pollution – Airborne pollutants (e.g., mercury) can affect surface waters through rainout and deposition.

Following is an overview of how power generation can affect water quality.

<u>Coal and Natural Gas Plant Wastewater</u> – Coal-fired power plants have several liquid waste streams that are released to surface waters following any required treatment. These include condenser cooling water, cooling tower blowdown, ash sluice water, metal-cleaning wastewaters and various low volume wastes including sumps and drains. Combined cycle natural gas plant wastewaters include cooling tower blowdown and various low volume wastewaters. Coal and gas plant sites use best management practices to control stormwater runoff such as retention ponds to capture sediment and oil/water separators. Discharges are regulated by each state under the NPDES program. Many of the waste streams receive treatment before they are discharged. Analytical monitoring and periodic toxicity testing ensure there are no acute or chronic toxic effects to aquatic life. Discharges from coal plants include those from CCR storage areas; these discharges can occur through permitted discharges and from seepage into groundwater which then enters surface waters. See Section 4.5 for further discussion of CCR discharges.

<u>Nuclear Plant Wastewater</u> – Liquid waste streams at nuclear plant sites include condenser cooling water, cooling tower blowdown, water treatment wastewaters, steam generator blowdown, liquid rad-waste and various low volume wastes including sumps and drains.

Periodic analytical monitoring and toxicity testing is performed on these discharges as required by the NPDES permit to ensure that plant wastes do not contain chemicals at deleterious levels that could affect aquatic life. Best management practices are used to control stormwater runoff and may include retention ponds to capture sediment and oil/water separators. The radiological component of discharges from nuclear plants is regulated by the Nuclear Regulatory Commission (NRC).

Thermal Plant Cooling Systems **–** All of TVA's coal-fired and nuclear plants and one combined cycle gas plant withdraw water from reservoirs or rivers for cooling and discharge the heated water back into the water body (see Section 4.7). In some cases, the cooling water is chemically treated to prevent corrosion or biofouling of the cooling system. TVA conducts extensive monitoring programs to help ensure permit compliance and to provide information about potential adverse effects from the heated and/or chemically treated discharges. Plant-specific monitoring includes concentrations of various chemicals, toxicity, discharge flow rates, discharge and receiving stream temperatures, dissolved oxygen (DO), fish communities, benthic organisms and wildlife observations.

Recent programs have also focused on spawning and development of cool-water fish species such as sauger, the attraction of fish to the heated discharges and changes in undesirable aquatic micro-organisms such as blue-green algae. In general, these monitoring programs have not detected significant negative effects resulting from release of heated water from TVA facilities in the Tennessee River drainage basin.

Runoff and Air Pollution. Many nonpoint sources of water pollution are not subject to government regulations or control. Principal causes of non-point source pollution are agriculture, including runoff from fertilizer, silvicultural activities, pesticide applications, erosion and animal wastes; mining, including erosion and acid drainage; and urban runoff. Pollutants reach the ground from the atmosphere as dust fall or are carried to the ground by precipitation.

Low Dissolved Oxygen Levels and Low Flow Downstream of Dams. A major water quality concern is low DO levels in reservoirs and in the tailwaters downstream of dams. Long stretches of river can be affected, especially in areas where pollution further depletes DO. In addition, flow in these tailwaters is heavily influenced by the amount of water released from the upstream dams; in the past, some of the tailwaters were subject to periods of little or no flow. Since the early 1990s, TVA has addressed these issues in the Tennessee River system by installing equipment and making operational changes to increase DO concentrations below 16 dams and to maintain minimum flows in tailwaters (TVA 2004: 4.4-3).

NPDES Permit Requirements – All of TVA's coal, combined cycle natural gas and nuclear generating facilities have state-issued NPDES permits for discharging to surface waters or pretreatment permits issued under state-approved programs for discharging into public sewer systems. At a minimum, these permits restrict the discharge of pollutants to levels established by EPA ELGs. Additional and sometimes more restrictive limits may also be included based on state water quality standards. EPA is currently updating the ELGs for steam-electric facilities and is required to issue them no later than September 30, 2015. The revised ELGs will most likely lead to significant changes in wastewater management at coal-fired plants across the nation, particularly those with FGD systems (scrubbers). The ELGs will likely set more stringent discharge limits for arsenic, mercury, selenium and nutrients.

Recently finalized 316(b) regulations for existing facilities (USEPA 2014b) require TVA and other utilities to perform additional evaluations of the impacts of their facilities and cooling water intakes and may require modifications to plant cooling systems and/or plant operations to reduce impacts to fish and other aquatic organisms.

Fuel Cycle Impacts. The extraction, processing, and transportation of fuel can affect water quality. Runoff and other discharges from coal and uranium mines, from natural gas well sites, and from fuel processing facilities can discharge sediment and other pollutants into surface waters. These discharges are typically subject to NPDES permit requirements, as well as permit requirements specific to coal and uranium mining. Mining operations can also result in the alteration and elimination of streams. Mining and natural gas extraction can also affect groundwater quality and quantity. Impacts to water quality from the extraction of natural gas by hydraulic fracturing are described in more detail in Section 7.2.1.

The Tennessee River System

The Tennessee River basin contains all except one of TVA's dams and covers a large part of the TVA power service area (Figure 4-1). A series of nine locks and dams built mostly in the 1930s and 1940s regulates the entire length of the Tennessee River and allows navigation from the Ohio River upstream to Knoxville (TVA 2004). Almost all the major tributaries have at least one dam, creating 14 multi-purpose storage reservoirs and seven single-purpose power reservoirs. The construction of the TVA dam and reservoir system fundamentally altered both the water quality and physical environment of the Tennessee River and its tributaries. While dams promote navigation, flood control, power generation and river-based recreation by moderating the flow effects of floods and droughts throughout the year, they also disrupt the daily, seasonal and annual flow patterns characteristic of a river. This system of dams and their operation is the most significant factor affecting water quality and aquatic habitats in the Tennessee River and its major tributaries. Portions of several rivers downstream of dams are included on state CWA Section 303(d) lists of impaired waters (e.g., TDEC 2014) due to low DO levels, flow modifications and thermal modifications resulting from impoundment. As mentioned above, TVA is working to reduce these impacts.

Major water quality concerns within the Tennessee River drainage basin include point and nonpoint sources of pollution that degrade water quality at several locations on mainstream reservoirs and tributary rivers and reservoirs. TVA regularly evaluates several water quality indicators as well as the overall ecological health of reservoirs through its Vital Signs Monitoring Program. This program evaluates five metrics: chlorophyll concentration, fish community health, bottom life, sediment contamination and DO (TVA 2004: 4.4-3, -4). Scores for each metric from monitoring sites in the deep area near the dam (forebay), mid-reservoir, and at the upstream end of the reservoir (inflow) are combined for a summary score and rating. Vital Signs ratings, major areas of concern, and fish consumption advisories are listed in Table 4-7.

Five of TVA's ten operating coal-fired power plants, one combined cycle natural gas plant and all of TVA's nuclear plants are in the Tennessee River watershed. All of these facilities depend on the river system for cooling water. Three of TVA's combustion turbine plants are along or close to the Tennessee River; they do not depend on it for cooling water.

Other Major River Systems

The Ohio, Green, and Mississippi Rivers each host a TVA coal-fired plant. TVA operates two coal-fired plants on the main stem of the Cumberland River and a small hydroelectric plant on a

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Cumberland River tributary. Combustion turbine and combined cycle plants are also located in the Hatchie, Obion and Tallahatchie River (tributaries to the Mississippi River) drainages and the Tombigbee and Pearl River drainages. Because of recent low summer flows in the Cumberland River due to repairs on Wolf Creek Dam by the U.S. Army Corps of Engineers and drought conditions, thermal discharges from the Cumberland Fossil Plant led the state of Tennessee to place a portion of the Cumberland River on the state 303(d) list of impaired waters (TDEC 2014). However, repairs to Wolf Creek Dam were completed in late 2013 and river flows were greatly improved in the summer of 2014. Fish consumption advisories are in effect for waters in the vicinity of Shawnee and Allen Fossil Plants. Otherwise, water resources conditions and characteristics in these river systems are generally similar to those in the Tennessee system.

Table 4-7 Ecological health ratings, major water quality concerns, and fish consumption advisories for TVA reservoirs with hydroelectric or thermal generating facilities. Source: TVA Data at http://www.tva.com/environment/ecohealth/index.htm and state water quality reports.

Reservoir	Ecological Health Rating - Score	Latest Survey Date	Concerns	Fish Consumption Advisories
Apalachia	Good - 76	2012	--	Mercury (NC statewide)
Blue Ridge	Good - 82	2011	--	Mercury
Boone	Poor - 48	2011	DO, chlorophyll, bottom life	PCBs, chlordane
Chatuge	Fair - 58	2012	DO, bottom life	Mercury
Cherokee	Poor - 50	2012	DO, chlorophyll, bottom life	Mercury (upstream of Poor Valley Creek)
Chickamauga	Fair - 67	2011	Chlorophyll, bottom life	Mercury (Hiwassee River embayment)
Douglas	Poor - 56	2011	DO, chlorophyll	None
Fontana	Fair - 69	2010	Bottom life	Mercury
Fort Loudoun	Fair - 60	2011	Chlorophyll, bottom life	PCBs, mercury (above US 129)
Fort Patrick Henry	Poor - 56	2011	Chlorophyll	None
Guntersville	Good - 76	2012	--	Mercury (vicinity of Widows Creek, Town Creek embayment)
Hiwassee	Fair - 68	2012	DO, chlorophyll	None
Kentucky	Fair – 69	2011	DO, chlorophyll, bottom life	Mercury (KY statewide)
Melton Hill	Fair – 67	2012	Fish, bottom life	PCBs, mercury (Poplar Creek embayment)
Nickajack	Fair - 71	2012	Chlorophyll	PCBs

Reservoir	Ecological Health Rating - Score	Latest Survey Date	Concerns	Fish Consumption Advisories
Norris	Fair - 64	2011	DO	Mercury (Clinch River portion)
Nottely	Poor – 48	2011	DO, chlorophyll, bottom life, sediment quality	Mercury
Parksville	Good - 73	2011	Sediment quality	None
Pickwick	Fair – 63	2012	Chlorophyll	None
South Holston	Fair - 59	2012	DO, bottom life	Mercury (Tennessee portion)
Tellico	Poor – 51	2011	DO, chlorophyll, bottom life	PCBs, mercury
Tims Ford	Poor – 51	2013	DO, chlorophyll, bottom life	None
Watauga	Fair - 71	2012	DO, bottom life	Mercury
Watts Bar	Fair - 61	2012	DO, chlorophyll, bottom life	PCBs
Wheeler	Poor - 55	2011	DO, chlorophyll, bottom life	Mercury (Limestone Creek, Round Island Creek embayments); PFOS* (Baker Creek embayment, river miles 296-303)
Wilson	Poor - 52	2012	DO, chlorophyll, bottom life	Mercury (Big Nance Creek embayment)

*PFOS – Perflourooctane sulfonate

4.7 Water Supply

The TVA power service area (Figure 4-1) contains most of the Tennessee River Basin, one of the most water-rich basins in the United States. The Tennessee River Basin, which is about half of the TVA service area, has been described as the most intensively used basin in the conterminous United States as measured by intensity of freshwater withdrawals in gallons per day per square mile (gal/d/mi^2) (Hutson et al. 2004). Conversely, the basin has the lowest consumptive use in the nation by returning about 96 percent of the withdrawals back for downstream use (Bohac and Bowen 2012).

In 2010, estimated average daily water withdrawals in the TVA service area totaled 16,395 million gallons per day (mgd) (Bohac and Bowen 2012, Bradley 2014). About 5.2 percent of these water withdrawals was groundwater and the remainder was surface water. The largest water use (84.4 percent of all withdrawals) was for thermoelectric generation as shown in Figure 4-28.

Since 1950, groundwater and surface water withdrawals by public supply systems in Tennessee have greatly increased (Figure 4-29). The magnitude and rate of growth of withdrawals of surface water has exceeded groundwater. The annual increase in groundwater withdrawals for public supply in Tennessee averaged about 2.5 percent and the increase in surface water

withdrawals averaged about 3.8 percent. Although these data are for Tennessee public water supplies, they are representative of the overall growth in water use for the TVA region.

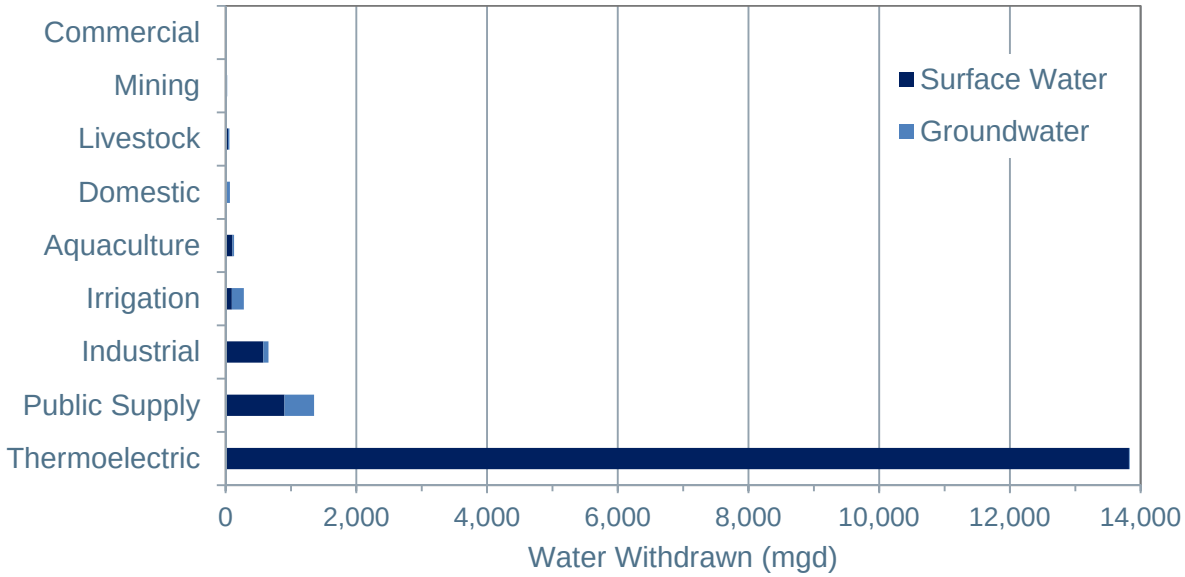

Figure 4-28 2010 water withdrawals in the TVA power service area by source and type of use. Source: Bohac and Bowen (2012), Bradley (2014).

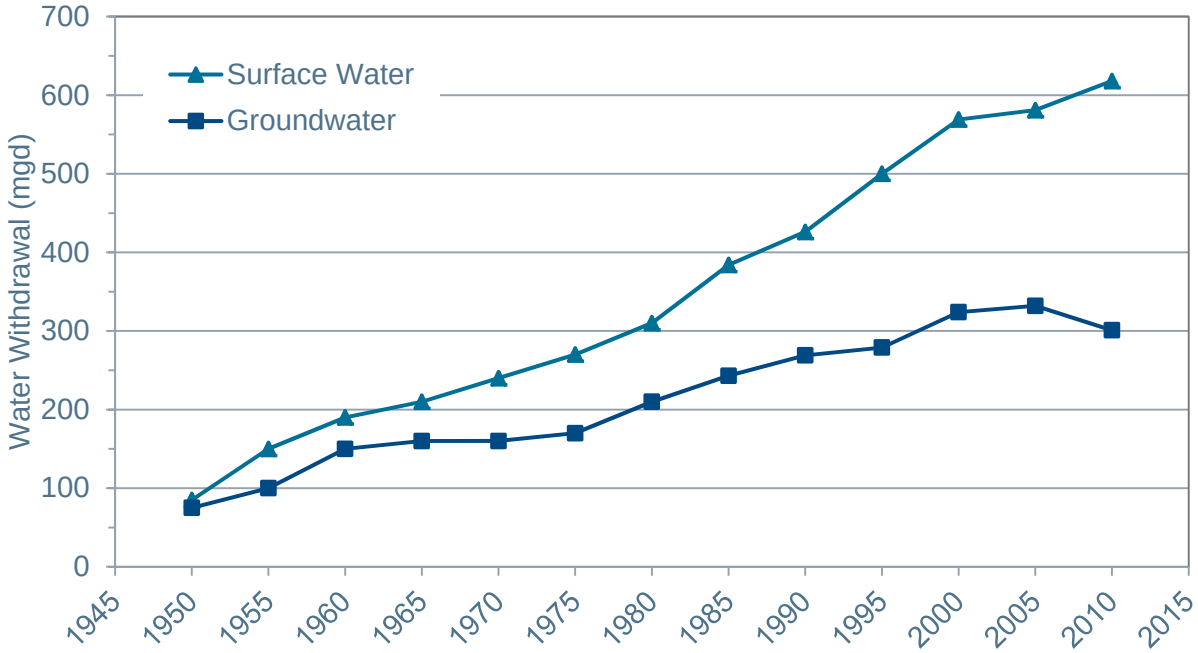

Figure 4-29 Groundwater and surface water withdrawals by public systems in Tennessee, 1950–2010. Source: Adapted from Webbers (2003). Additional Data: Kenny et al. (2009), and Bradley (2014).

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Regulatory Framework for Water Supply

The Safe Drinking Water Act established standards for drinking water quality and the protection of drinking water sources, including groundwater and springs. Section 316(b) of the CWA (described in more detail in Section 4-6) regulates the location, design and operation of cooling water intake structures. CWA Section 404 prohibits the construction of water withdrawal and discharge structures in waters of the U.S. unless authorized by permit. Section 26a of the TVA Act gives TVA a similar permitting authority in the Tennessee River watershed.

Groundwater Use

Groundwater data are compiled by the U.S. Geological Survey (USGS) and cooperating state agencies in connection with the national public water use inventory conducted every five years (Bohac and Bowen 2012, Bradley 2014). The largest use of groundwater is for public water supply, see Figure 4-28. Almost all of the water used for domestic supply and 66 percent of water used for irrigation in the TVA region is groundwater. Groundwater is also used for industrial and mining purposes.

The use of groundwater to meet public water supply needs varies across the TVA region and is the greatest in West Tennessee and Northern Mississippi. This variation is the result of several factors including groundwater availability and quality, surface water availability and quality, determination of which water source can be developed most economically and public water demand, which is largely a function of population. There are numerous sparsely populated, rural counties in the region with no public water systems. Residents in these areas are self-served by individual wells or springs.

Total groundwater use for public water supply in 2010 was 453 mgd in the TVA region. Approximately 60 percent of all groundwater withdrawals were supplied by Tertiary sand aquifers in West Tennessee and North Mississippi. Shelby County, Tennessee (Memphis, TN) accounted for about 38 percent of the total 2010 public supply regional pumpage. The dominance of groundwater use over surface water use in the western portion of the TVA region is due to the availability of prolific aquifers and the absence of adequate surface water resources in some areas.

Surface Water Use

The majority of water used for thermoelectric, public supply, aquaculture, and industrial uses is surface water (Figure 4-28). Large public supply withdrawals correspond to the population centers throughout the region. The top five counties for surface water public supply are Davidson/Rutherford Counties, Hamilton County, Knox County, Tennessee, and Madison County, Alabama. These five counties contain the large cities of Nashville/Murfreesboro, Chattanooga, Knoxville and Huntsville, respectively and account for 37 percent of all surface water public supply for the entire TVA region.

Thermoelectric withdrawal was down about 500 mgd in 2010 compared to 2005, largely as a result of a less power generation in 2010 (Bohac and Bowen 2012). Industrial, irrigation, and aquaculture uses were also down in 2010, but these trends are more variable because they are sensitive to weather and economic conditions.

Water Use for Thermoelectric Power Generation

Thermoelectric power generation uses steam produced from the combustion of fossil fuels or from a nuclear reaction. A significant volume of cooling water is required to condense steam into

water. All TVA coal-fired plants and nuclear plants are cooled by water withdrawn from adjacent rivers or reservoirs. The amount of water required is highly dependent on the type of cooling system employed. While the volume of water used to cool the plants is large, most of this water is returned to the adjacent rivers or reservoirs.

The most recent comprehensive survey of water use by TVA generating plants, plants supplying TVA purchased power, and other generating plants in the TVA region was completed in 2010 (Bohac and Bowen 2012, TVA unpubl. data). In 2010, TVA's 14 coal-fired plants and nuclear plants withdrew an average of 14,940 mgd (Table 4-8). The total plant water withdrawal (i.e., its water use) divided by the net generation is the water use factor. All TVA coal-fired plants except Paradise exclusively employ open-cycle (once-through) cooling. In open cycle systems, water is withdrawn from a water body, circulated through the plant cooling condensers and then discharged back to the water body. Plant water use factors for the coal plants, except for Paradise, range from about 35,000 to 76,500 gal/MWh of net generation. Differences in river temperature, plant design, atmospheric conditions and plant operation account for the variability in water use factors. Year-to-year variation in water use factors is typically less than 10 percent.

Table 4-8 2010 water use for TVA fossil and nuclear generating plants. Source: TVA data, Bohac and Bowen (2012), U.S. Department of Energy (2010b).

Facility	Units	Withdrawal (mgd)	Return (mgd)	Consumption (Withdrawal - Return, mgd)	Net Generation (MWh/year)	Water Use Factor (gallons/MWh)
Coal-Fired						
Allen	1-3	455.5	455.2	0.3	4,751,478	34,991
Bull Run	1	430.2	429.6	0.6	3,874,215	40,528
Colbert	1-5	1264.8	1263.4	1.4	6,035,467	62,191
Cumberland	1-2	2396.2	2388.7	7.5	14,063,031	76,489
Gallatin	1-4	864.0	863.5	0.5	6,717,606	46,945
John Sevier	1-4	625.3	625.0	0.3	3,840,431	67,981
Johnsonville	1-10	1173.8	1173.1	0.6	6,302,037	59,428
Kingston[1]	Varies	728.1	727.4	0.7	2,902,072	91,575
Kingston[2]	1-9	1280.0	1278.8	1.2	9,464,000	49,366
Paradise	1-3	334.6	303.7	30.9	14,208,546	8,596
Shawnee[3]	1-10	1125.3	1124.7	0.6	7,845,112	52,355
Widows Creek	1-8	1045.0	1042.9	2.1	5,702,492	66,887
Natural Gas-Fired Combined Cycle						
Caledonia	1-3	2.5	0.6	1.9	4,165,108	170
Lagoon Creek	1-3	2.2	0.5	1.7	1,024,515	305
Southaven	1-3	0.4	0.1	0.3	2,647,446	40
Nuclear						
Browns Ferry	2-3	2749.9	2741.0	10.3	24,771,135	40,519
Sequoyah	1-2	1538.56	1532.8	5.8	18,000,759	31,197
Watts Bar	1	207.4	191.4	16.0	9,738,457	7,773

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[1] Actual data for 2010 when Kingston ran at a reduced load due to ash disposal limitations.
[2] Data that is typical of Kingston under normal and future operations.
[3] Located outside of the TVA service area.

Paradise employs substantial use of cooling towers (closed-cycle cooling) resulting in a relatively low plant water use factor and less water returned to the river (Table 4-8). In closed-cycle systems, water from the steam turbine condensers is circulated through cooling towers where the condenser water is cooled by transfer of heat to the air by evaporation, conduction, and convection. The proportion of cooling water discharged to the river or reservoir is lower than for open-cycle systems, as are the overall volume of water required and the plant water use factor. The Browns Ferry and Sequoyah plants operate primarily in the open-cycle mode, with infrequent use of cooling towers. Watts Bar Nuclear Plant uses a combination of open-cycle and closed-cycle cooling.

Natural gas-fueled combined cycle generating plants require water for steam generation and condensation. All of TVA's combined cycle plants have cooling towers and use closed-cycle cooling. Water use by TVA's combined cycle plants operating in 2010 is shown in Table 4-8. Caledonia has contracted to use reclaimed wastewater and Southaven uses groundwater. The Lagoon Creek combined cycle plant went into service in September of 2010 and uses groundwater, as does the Magnolia combined cycle plant, which TVA purchased in 2011. The John Sevier combined cycle plant went into service in 2012 and uses river water, as will the planned Paradise combined cycle plant. The Allen combined cycle plant, scheduled to begin construction in 2016, will also use reclaimed wastewater. The water use factors for TVA combined cycle plants in 2014 are shown in Table 4-9. All of the combined cycle plants return their other, non-cooling process water to surface waters.

Table 4-9 TVA combined cycle generating plant water use for operational plants as of August 2014. Source: TVA Data.

Facility	Units	Withdrawal (mgd)	Return (mgd)	Consumption (Withdrawal – Return, mgd)	Net Generation (MWh/year)	Water Use Factor (gallons/MWh)
Caledonia[1]	1-3	3.26	0.81	2.44	4,510,500	264
John Sevier[2]	1-3	7.21	1.14	6.07	7,691,280	342
Lagoon Creek[1]	1-3	2.1	0.0	2.1	3,091,450	254
Magnolia[1]	1-3	2.3	0.65	2.12	4,579,191	187
Southaven[1]	1-3	2.3	0.4	1.9	4,334,898	197

[1]Based of 2012 withdrawal and net generation.
[2]From Environmental Assessment for John Sevier Combined-Cycle (TVA 2010).

Although TVA generates the majority of electrical energy in its service area and the Tennessee River basin, there are non-TVA power plants that used significant volumes of water in 2010 (Table 4-10). Three of the non-TVA plants (Red Hills, Decatur, and, until early 2015, Choctaw) sell all or a large amount of their electricity to TVA. The Asheville and Clinch River plants withdraw from surface water, but are located in the Tennessee River basin outside of the TVA service area. Within the TVA service area, Batesville, Morgan and Decatur withdraw surface water, Red Hills uses groundwater and does not discharge process water, and the Choctaw plant utilizes saline groundwater instead of fresh water. TVA recently purchased and now operates the Choctaw plant.

Table 4-10 2010 Regional non-TVA power generation and thermoelectric water use. Source: U.S. Department of Energy EIA-923 Database (2010).

Facility	Units	Withdrawal (mgd)	Return (mgd)	Consumption (Withdrawal – Return, mgd)	Net Generation (MWh/year)	Water Use Factor (gallons/MWh
Coal-Fired						
Asheville, NC	4	266.82	261.86	4.96	2,383,000	40,868
Clinch River, VA[1]	3	8.73	4.78	3.95	1,500,000	2,125
Red Hills, MS	1	5.06	0.00	5.06	3,323,315	556
Natural Gas-Fired Combined cycle						
Batesville, MS	3	3.32	0.69	2.63	2,348,530	516
Decatur Energy Center, AL		3.38	0.43	2.95	1,184,000	1,042
Morgan Energy Center, AL		3.85	0.50	3.35	1,297,000	1,082
Choctaw Gas, MS[2]		7.05			2,670,545	

[1]One 240-MW unit of this plant has subsequently been retired. The other two 240-MW units are to being converted to natural gas-fueled combined cycle units.
[2]Recently renamed Quantum Choctaw Power and purchased by TVA.

An additional non-TVA coal-fired generating plant, the Virginia City Hybrid Energy Center, began operating in 2012. This plant, located in the Tennessee River basin in southwest Virginia, uses an air-cooled condenser for cooling. Water consumption for all plant processes is less than 1 mgd and is provided by the local water utility from groundwater sources.

Trends in Thermoelectric Water Withdrawal

Nationally, water use factors have been declining since the 1960s. The national power plant water use factors have declined from a high of about 60,000 gal/MWh to a low of about 23,000 gal/MWh (EPRI 2002). The reduction was primarily due to increasing use of closed-cycle cooling, particularly in the western United States where water is relatively scarce. Figure 4-41 shows the total withdrawal from 2000 to 2010 and the combined water use factor for TVA's 14 coal-fired and nuclear plants. The combined water use factors for 2000 and 2005 were about 39,300 gal/MWh. They turned up slightly in 2010 to 42,300 gal/MWh, largely as a result of abnormal operation at Kingston Fossil Plant and reduced generation without commensurate withdrawal reductions at other plants such as Cumberland and Bull Run. TVA's water use factor is higher than the national average because the TVA system was designed and located to specifically take advantage of open-cycle cooling, resulting in a lower percentage of closed-cycle cooling systems than the national average.

In addition to recent historic combined water use factors, Figure 4-30 also shows the anticipated combined water use factor resulting from recent and planned coal unit retirements, generating plants completed since 2010 and new generating facilities under construction and/or formally approved. Coal unit retirements are listed in Section 3-3. New generating facilities include Watts Bar Nuclear Plant Unit 2, and the John Sevier, Paradise, and Allen combined cycle plants (Table 4-11 and Section 3.3). The retirements and additions would reduce the combined water

use factor for TVA fossil and nuclear plants to about 35,000 gal/MWh by 2019. Additional coal unit and/or plant retirements will further reduce the combined water use factor for the plants.

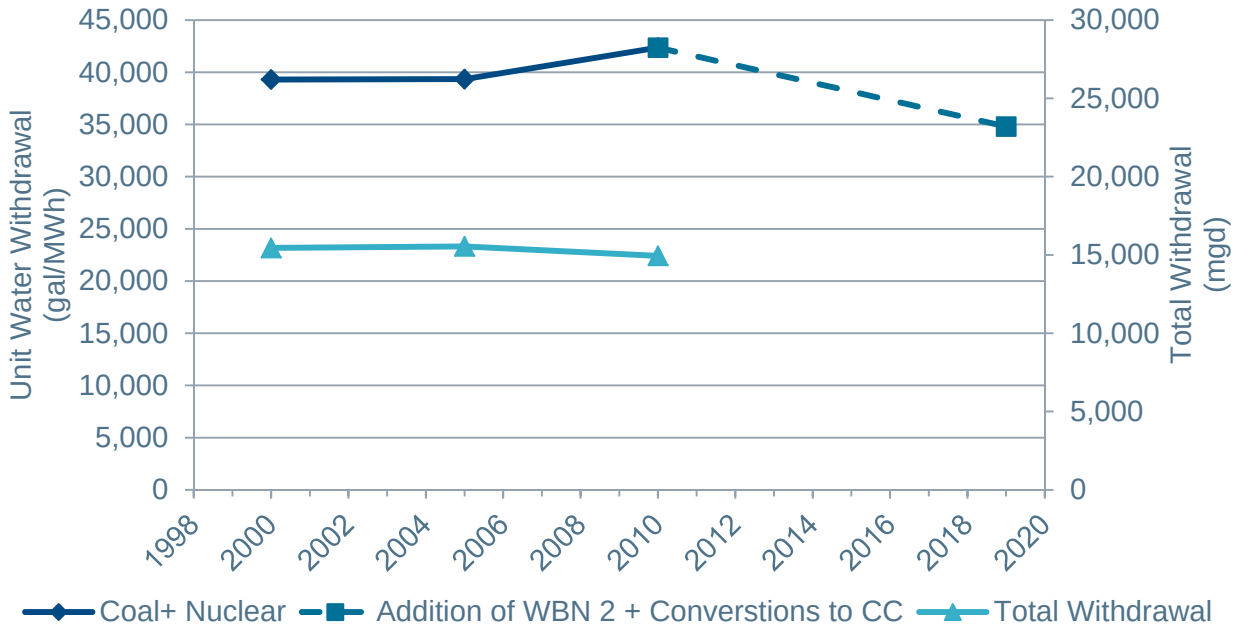

Figure 4-30 Total withdrawal and combined water use factor for 14 coal and nuclear plants.

Table 4-11 Changes in water use factors for unit additions and retirements.

Plant	Average Water Use Factor 2000 – 2010, gal/MWh	Water Use Factor after Change, gal/MWh
Allen[1]	33,801	364
John Sevier[2]	54,233	342
Paradise[1]	8,990	3,108
Watts Bar[3]	7,525	4,927

[1]Reflects completion of combined cycle units and retirement of Allen coal units and Paradise coal units 1 and 2.
[2]Reflects completion of combined cycle units and retirement of coal units.
[3]Reflects completion of Watts Bar Unit 2.

Watts Bar Unit 2 is expected to begin commercial operation in 2015; the projected water use by both units is shown in Table 4-12. Because Watts Bar Unit 2 will primarily operate in closed-cycle mode, the plant water use factor with both units operating will decrease but water consumption (withdrawal less return) will increase from that of Unit 1 operation. Current environmental regulations make it very difficult for new thermoelectric plants to use open-cycle cooling. EPA regulations effectively require all new power plants to install closed-cycle cooling technology.

Table 4-12 Projected water use factors for unit additions and conversions.

Facility	Units	Withdrawal (mgd)	Return (mgd)	Withdrawal - Return (mgd)	Net Generation (MWh/year)	Water Use Factor (gallons/MWh)
Watts Bar[1,2]	1-2	274.0	234.0	40.0	20,297,000	4,927
Allen[3]	2	4–10	0.9–1.5	3.1–8.5	TBD	208–521
Paradise[4]	1-2	7.6	1.9	5.7	TBD	374

[1] Withdrawal and Return are based on total two-unit generation of 2317 MW (Hopping 2010).
[2] Net Generation is shown as an example based on 2317 MW with capacity factor = 1.0 applied.
[3] TVA (2014d)
[4] TVA (2013b)

4.8 Aquatic Life

The TVA region encompasses portions of several major river systems including all of the Tennessee River drainage and portions of the Cumberland River drainage, Mobile River drainage (primarily the Coosa and Tombigbee Rivers), and larger eastern tributaries to the Mississippi River in Tennessee and Mississippi. These river systems support a large variety of freshwater fishes and invertebrates (including freshwater mussels, snails, crayfish, and insects). Due to the presence of several major river systems, the region's high geologic diversity (see Section 4.4), and the lack of glaciation, the region is recognized as a globally important area for freshwater biodiversity (Stein et al. 2000).

Regulatory Framework for Aquatic Life

Aside from the Endangered Species Act (ESA) and related state laws described in Section 4.10, and harvest regulations established by states, the Clean Water Act is the major law affecting aquatic life. Water quality standards and NPDES discharge limits are established, in part, to protect aquatic life. CWA Section 316 regulates the design and operation of cooling water intake structures and cooling water discharges in order to minimize adverse effects on aquatic life.

The Tennessee River Basin

The Tennessee River drainage basin is the dominant aquatic system within the TVA region and the most TVA generating facilities are within the watershed. The construction of the TVA dam and reservoir system fundamentally altered both the water quality and physical environment of the Tennessee River and its tributaries. While dams promote navigation, flood control, power benefits and river-based recreation, they also disrupt the daily, seasonal and annual flow patterns that are characteristic of a river. Damming of most of the rivers was done at a time when there was little regard for aquatic resources (Voigtlander and Poppe 1989). Beyond changes in water quality, flood control activities and hydropower generation have purposefully altered the flow regime (the main variable in aquatic systems) to suit human demands (Cushman 1985).

TVA has undertaken several major efforts (e.g., TVA's Lake Improvement Plan, Reservoir Release Improvements Plan and Reservoir Operations Study (ROS, TVA 2004)) to mitigate some of these impacts on aquatic habitats and organisms. While these actions have resulted in improvements to water quality and habitat conditions in the Tennessee River basin, the Tennessee River and its tributaries remain substantially altered by human activity.

Mainstem Reservoirs - The nine mainstem reservoirs on the Tennessee River differ from TVA's tributary reservoirs primarily in that they are shallower, have greater flows and retain the water in the reservoir for a shorter period of time. Although DO in the lower lake levels is often reduced, it is seldom depleted. Winter drawdowns on mainstem reservoirs are much less severe than tributaries, so bottom habitats generally remain wetted all year. This benefits benthic organisms, but promotes the growth of aquatic plants in the extensive shallow overbank areas of some reservoirs. Tennessee River mainstem reservoirs generally support healthy fish communities, ranging from about 50 to 90 species per reservoir. Good to excellent sport fisheries exist, primarily for black bass, crappie, sauger, white and striped bass, sunfish and catfish. The primary commercial species are channel and blue catfish and buffalo.

Tributary Reservoirs and Tailwaters - Tributary reservoirs are typically deep and retain water for long periods of time. The results from this include thermal stratification, the formation of an upper layer that is warmer and well oxygenated, an intermediate layer of variable thickness and a lower layer that is colder and poorly oxygenated. These aquatic habitats are simplified compared to undammed streams and fewer species are found. Aquatic habitats in the tailwater can also be impaired due to a lack of minimum flows and low DO levels which may restrict the movement, migration, reproduction and available food supply of fish and other organisms. Dams on tributary rivers affect the habitat of benthic invertebrates (benthos), which are a vital part of the food chain of aquatic ecosystems. Benthic life includes worms, snails and crayfish (which spend all of their lives in or on the stream beds), and aquatic insects, mussels and clams (which live there during all or part of their life cycles). Many benthic organisms have narrow habitat requirements that are not always met in reservoirs or tailwaters below dams. Farther downstream from dams, the number of benthic species increases as natural reaeration occurs and DO and temperatures rise.

Other Drainages in the TVA Region

The other major drainages within the TVA region (the Cumberland, Mobile, and Mississippi River drainages) share a diversity of aquatic life equal to or greater than the Tennessee River drainage. As with the Tennessee River, these river systems have seen extensive human alteration including construction of reservoirs, navigation channels and locks. Despite these changes (as with the Tennessee River drainage), remarkably diverse aquatic communities are present in each of these river systems.

Major TVA generating facilities located in these watersheds include Allen Fossil Plant (Mississippi River), Cumberland and Gallatin Fossil Plants (Cumberland River), Paradise Fossil Plant (Green River/Ohio River) and Shawnee Fossil Plant (Ohio River). All of TVA's free-standing natural gas-fueled generating facilities, except for the Marshall County facility in western Kentucky and the John Sevier facility in eastern Tennessee, are located in the Mississippi and Mobile River drainages.

4.9 Vegetation and Wildlife

The TVA region encompasses nine ecoregions (Omernik 1987) which generally correspond with physiographic provinces and sections (see Section 4.4 and Figure 4-27). The terrain, plant communities, and associated wildlife habitats in these ecoregions vary from bottomland hardwood and cypress swamps in the floodplains of the Mississippi Alluvial Plain to high elevation balds and spruce-fir and northern hardwood forests in the Blue Ridge. About 3,500 species of herbs, shrubs and trees, 55 species of reptiles, 72 species of amphibians, 182 species of breeding birds and 76 species of mammals occur in the TVA region (Ricketts et al.

1999, Stein 2002, TWRA 2005, TOS 2014). Although many plants and animals are widespread across the region, others are restricted to one or a few ecoregions. For example, high elevation communities in the Blue Ridge support several plants and animals found nowhere else in the world (Ricketts et al. 1999), as well as isolated populations of species typically found in more northern latitudes.

Regulatory Framework for Vegetation and Wildlife
Aside from the ESA and related state laws described in Section 4.10, there are few laws specifically focused on protecting plant species and plant communities. The Plant Protection Act of 2000 consolidated previous legislation and authorized the U.S. Department of Agriculture to issue regulations to prevent the introduction and movement of identified plant pests and noxious weeds. E.O. 11312 – Invasive Species directs Federal agencies to prevent the introduction of invasive species (both plants and animals), control their populations, restore invaded ecosystems and take other related actions.

Several species of wildlife are protected under the ESA and related state laws. In addition to these laws, the regulatory framework for protecting birds includes the Migratory Bird Treaty Act (MBTA) of 1918, the Bald and Golden Eagle Protection Act of 1940 and E.O. 13186 – Responsibilities of Federal Agencies to Protect Migratory Birds. The MBTA and E.O. 13186 address most native birds occurring in the U.S. The MBTA makes the taking, killing, or possession of migratory birds, their eggs, or nests unlawful, except as authorized under a valid permit. E.O. 13186 focuses on Federal agencies taking actions with the potential to have negative impacts on populations of migratory birds. It provides broad guidelines on avian conservation responsibilities and requires agencies whose actions affect or could affect migratory bird populations to develop a memorandum of understanding on migratory bird conservation with the U.S. Fish and Wildlife Service (USFWS).

Aside from state laws regulating the hunting, trapping or other capture, and possession of some species, most wildlife other than birds generally receives no legal protection.

Regional Vegetation
The southern Blue Ridge Ecoregion, which corresponds to the Blue Ridge physiographic province, is one of the richest centers of biodiversity in the eastern United States and one of the most floristically diverse (Griffith et al. 1998). The most prevalent land cover (80 percent) is forest, dominated by the diverse, hardwood-rich mesophytic forest and its Appalachian oak sub-type (Dyer 2006; USGS 2014). About 14 percent of the land cover is agricultural and most of the remaining area is developed. Relative to the other eight ecoregions, the Blue Ridge Ecoregion had the least change in land cover from 1973 through 2000 (USGS 2014).

Over half (56 percent) of the Ridge and Valley Ecoregion, which corresponds to the Valley and Ridge physiographic province, is forested. Dominant forest types are the mesophytic forest and Appalachian oak sub-type. In the southern portion of the region, the southern mixed forest and oak-pine sub-type (Dyer 2006, USGS 2014). About 30 percent of the area is agricultural and 9 percent is developed (USGS 2014).

The Cumberland Mountains physiographic section comprises the southern portion of the Central Appalachian Ecoregion. This ecoregion is heavily forested (83 percent), primarily with mesophytic forests including large areas of Appalachian oak (Dyer 2006, USGS 2014). The remaining land cover is mostly agriculture (7 percent), developed areas (3 percent) and mined

areas (3 percent). The dominant source of land cover change from 1973 through 2000 was mining (USGS 2014), and this ecoregion, together with the Southwestern Appalachian Ecoregion, comprises much of the Appalachian coalfield.

The Southwestern Appalachian Ecoregion corresponds to the Cumberland Plateau physiographic section. About 75 percent of the land cover is forest, predominantly mesophytic forest; about 16 percent is agricultural and 3 percent is developed (USGS 2014). The rate of land cover change from 1973 through 2000 is relatively high, mostly due to forest management activities.

The Interior Plateau Ecoregion consists of the Highland Rim and Nashville Basin physiographic sections. The limestone cedar glades and barrens communities associated with thin soils and limestone outcrops in the Nashville Basin support rare, diverse plant communities with a high proportion of endemic (i.e., restricted to a particular area) species (Baskin and Baskin 2003). About 38 percent of the ecoregion is forested, 50 percent in agriculture and 9 percent developed (USGS 2014). Forests are predominantly mesophytic, with a higher proportion of American beech, American basswood and sugar maple than in the Appalachian oak subtype (Dyer 2006). Eastern red cedar is also common. For the ecoregion as a whole, the rate of land cover change has been relatively low, with the predominant changes from forest and agriculture to developed. The rate of these changes from the 1970s to the present has been very high in the greater Nashville and Huntsville areas.

A small area in the northwest of the TVA region is in the Interior River Valley and Hills Ecoregion, which overlaps part of the Highland Rim physiographic section. This ecoregion is relatively flat lowland dominated by agriculture (almost two-thirds), with about 20 percent forested hills, 7 percent developed, and 5 percent wetlands (USGS 2014). It contains much of the Illinois Basin coalfield. Drainage conditions and terrain strongly affect land use. Bottomland deciduous forests and swamp forests were common on wet lowland sites, with mixed oak and oak-hickory forests on uplands. A large portion of the lowlands has been cleared for agriculture. The rate of land cover change from 1973 through 2000 is moderate and primarily from forest to agriculture and from agriculture and forest to developed.

The Southeastern Plains and Mississippi Valley Loess Plain Ecoregions correspond, respectively, to eastern and western portions of the East Gulf Coastal Plain physiographic section. These ecoregions are characterized by a mosaic of forests (52 percent of the land area), agriculture (22 percent), wetlands (10 percent) and developed areas (10 percent). Forest cover decreases and agricultural land increases from east to west. Natural forests of pine, hickory, and oak once covered most of the ecoregions, but much of the natural forest cover has been replaced by heavily managed timberlands, particularly in the Southeastern Plains (USGS 2014). The Southeastern Plains in Alabama and Mississippi include the Black Belt, an area of rich dark soils and prairies. Much of this area has been cleared for agricultural purposes and only remnant prairies remain. The rate of land cover change in the Southeastern Plains Ecoregion is the highest of the nine ecoregions in the TVA region, with intensive forest management practices the leading cause. The rate of land cover change in the Mississippi Valley Loess Plain Ecoregion is moderate to high relative to the other ecoregions.

The Mississippi Alluvial Plain is a flat floodplain area originally covered by bottomland deciduous forests. A large portion has been cleared for agriculture and subjected to drainage activities including stream channelization and extensive levee construction. Most of the land cover is

agricultural and the remaining forests are southern floodplain forests dominated by oak, tupelo and bald cypress. The rate of land cover change since the 1970s has been moderate (USGS 2014), with the major land cover change from agriculture to developed.

The major forest regions in the TVA region include mesophytic forest, southern-mixed forest, and Mississippi alluvial plain (Dyer 2006). The mesophytic forest is the most diverse with 162 tree species. While canopy dominance is shared by several species, red maple and white oak have the highest average importance values. A distinct section of the mesophytic forest, the Appalachian oak section, is dominated by several species of oak including black, chestnut, northern red, scarlet and white oaks. The Nashville Basin mesophytic forest has close affinities with the beech-maple-basswood forest that dominates much of the Midwest. The oak-pine section of the southern mixed forest region occurs in portions of Alabama, Georgia and Mississippi, where the dominant species are loblolly pine, sweetgum, red maple and southern red oak (Dyer 2006). The Mississippi alluvial plain forest region is restricted to its namesake physiographic region. The bottomland forests in this region are dominated by American elm, bald cypress, green ash, sugarberry and sweetgum.

Numerous plant communities (recognizable assemblages of plant species) occur in the TVA region. Several of these communities are rare, restricted to very small geographic areas and/or threatened by human activities. A disproportionate number of these imperiled communities occur in the Blue Ridge region; smaller numbers are found in the other ecoregions (NatureServe 2009). Many of the imperiled communities occur in the Southern Appalachian spruce-fir forest; cedar glades; grasslands, prairies and barrens; Appalachian bogs, fens and seeps; and bottomland hardwood forest ecosystems. Major threats to the Southern Appalachian spruce-fir forest ecosystem include invasive species such as the balsam wooly adelgid, acid deposition, ozone exposure and climate change (TWRA 2009). The greatest concentration of cedar glades is in the Nashville Basin; a few also occur in the Highland Rim and the Valley and Ridge. Cedar glades contain many endemic plant species, including a few listed as endangered (Baskin and Baskin 2003); threats include urban development, highway construction, agricultural activities, reservoir impoundment and incompatible recreational use. The category of grasslands, prairies and barrens includes remnant native prairies; they are scattered across the TVA region but most common on the Highland Rim. This category also includes the high elevation grassy balds in the Blue Ridge and the Black Belt prairie in the East Gulf Coastal Plain. Threats to these areas include agricultural and other development, invasive plants and altered fire regimes. Appalachian bogs, fens and seeps are often small, isolated, and support several rare plants and animals. Threats include drainage for development and altered fire regimes. Bottomland hardwood forests are most common in the Mississippi Alluvial Plain and East Gulf Coastal Plain; they also occur in other physiographic regions. About 60 percent of their original area is estimated to have been lost, largely by conversion to croplands (USEPA 2012).

Wildlife Population Trends

Many animals are wide-ranging throughout the TVA region; most species tolerant of humans have stable or increasing populations. The populations of many animals have been greatly altered by changes in habitats from agriculture, mining, forestry, urban and suburban development and the construction of reservoirs. While some species flourish under these changes, others have shown marked declines. For example, populations of some birds dependent on grassland and woodlands have shown dramatic decreases in their numbers (SAMAB 1996). Across North America, 48 percent of grassland-breeding birds are of conservation concern because of declining populations, as are 22 percent of forest-breeding

birds (NABCI 2009). A large number of the declining birds are Neotropical migrants, species that nest in the United States and Canada and winter south of the United States. Over 30 species of birds breeding in the TVA region are considered to be of conservation concern (USFWS 2008). Global amphibian declines have been well documented, but declines in amphibian populations in the TVA region also have been reported (Caruso and Lips 2012). The primary causes for these declines are the loss and fragmentation of habitats from urban and suburban development and agricultural and forest management practices. Introduced pathogens have also contributed to wildlife population declines. Populations of bats have been observed dying off in the TVA region after the introduction of a novel pathogen causing white nose-syndrome. In general gulls, wading birds, waterfowl, raptors, upland game birds (with the exception of the northern bobwhite) and game mammals are stable or increasing in the TVA region.

The construction of the TVA and Corps of Engineers reservoir systems created large areas of habitat for waterfowl, herons and egrets, ospreys, gulls and shorebirds, especially in the central and eastern portions of the TVA region where this habitat was limited. Ash and gypsum settling and storage ponds at TVA fossil plants also provide regionally important habitat for these birds and other wetland species. These increases in habitat, as well as the ban on the use of the pesticide DDT, have resulted in large increases in the local populations of several birds. Both long-term and short-term changes in the operation of the reservoir system affect the quality of habitat for these species (TVA 2004), as do pond management practices at fossil plants.

Invasive Species

Invasive species are species that are not native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health (NISC 2008). Invasive species include terrestrial and aquatic plants and animals as well as other organisms such as microbes. Human actions, both intentional and unintentional, are the primary means of their introductions.

Four plants designated by the U.S. Department of Agriculture as noxious weeds under the Plant Protection Act occur in the TVA region: hydrilla, giant salvinia, cogongrass and tropical soda apple. Hydrilla is a submersed aquatic plants present in several TVA reservoirs. Giant salvinia, also an aquatic plant, occurs in ponds, reservoirs and slow-moving streams. It primarily occurs south of the TVA region and has not yet been reported from the Tennessee River drainage. Cogongrass is an upland plant present in several TVA region counties in Alabama and Mississippi. It occurs on and near several TVA transmission line right-of-ways and can be spread by line construction and maintenance activities. Tropical soda apple has been reported from a few counties in the TVA region and primarily occurs in agricultural areas.

Several additional invasive plants considered to be of severe or significant threat (TEPPC 2009) occur on or near TVA generating facilities and transmission line right-of-ways. These include tree-of-heaven, Asian bittersweet, autumn olive, Chinese privet, kudzu, phragmites, Eurasian water-milfoil, multiflora rose, and tall fescue. Phragmites occurs in ash ponds at several TVA coal-fired plants and is otherwise uncommon in the TVA region.

Invasive aquatic animals in the TVA region that harm or potentially harm aquatic communities include the common, grass, bighead and silver carp, alewife, blueback herring, rusty crayfish, Asiatic clam and zebra mussel. Because of their potential to affect water intake systems, TVA

uses chemical and warm-water treatments to control Asiatic clams and zebra mussels at its generating facilities.

Invasive terrestrial animals at TVA generating facilities which occasionally require management include the rock pigeon, European starling, house sparrow, and fire ant. These species have little effect on the operation of TVA's power system.

4.10 Endangered and Threatened Species

The TVA region provides habitat for numerous species of plants and animals that have declining populations or are otherwise rare and considered to be endangered, threatened, or of special concern at the national and state level.

Regulatory Framework for Endangered and Threatened Species

The Endangered Species Act of 1973 (ESA; 16 U.S.C. §§ 1531-1543) was passed to conserve the ecosystems upon which endangered and threatened species depend and to conserve and recover those species. An endangered species is defined by the ESA as any species in danger of extinction throughout all or a significant portion of its range. A threatened species is likely to become endangered within the foreseeable future throughout all or a significant part of its range. Areas known as critical habitats, essential to the conservation of listed species, also can be designated under the ESA. The ESA establishes programs to conserve and recover endangered and threatened species and makes their conservation a priority for Federal agencies. Under Section 7 of the ESA, Federal agencies are required to consider the potential effects of their proposed action on endangered and threatened species and critical habitats. If the proposed action has the potential to affect these resources, the Federal agency is required to consult with the USFWS.

All seven states in the TVA region have enacted laws protecting endangered and threatened species. In a few states, only species listed under the ESA receive legal protection under these laws. In other states, the legal protections also apply to additional species designated by the state as endangered, threatened, or other classifications such as in need of management.

Endangered and Threatened Species in the TVA Region

Thirty-one species of plants, one lichen and 124 species of animals in the TVA region area are listed under the ESA as endangered or threatened or formally proposed for such listing by the USFWS. An additional eleven species in the TVA region have been identified by the USFWS as candidates for listing under the ESA. These candidate species receive no statutory protection under the ESA but by definition may warrant future protection. Several areas across the TVA region are also designated as critical habitat essential to the conservation of listed species. In addition to the species listed under the ESA, about 1,600 plant and animal species are formally listed as protected species by one or more of the states or otherwise identified as species of conservation concern species.

The highest concentrations of terrestrial and aquatic species listed under the ESA occur in the Blue Ridge, Appalachian Plateaus and Interior Low Plateau regions. Relatively few listed species occur in the Coastal Plain and Mississippi Alluvial Plain regions. The taxonomic groups with the highest proportion of species listed under the ESA are fish and mollusks. Factors contributing to the high proportions of vulnerable species in these groups include the high number of endemic species in the TVA region and the alteration of their habitats by reservoir

construction and water pollution. River systems with the highest numbers of listed aquatic species include the Tennessee, Cumberland and Coosa Rivers.

Populations of a few listed species have increased, primarily because of conservation efforts, to the point where they are no longer listed under the ESA (e.g., bald eagle, peregrine falcon, Tennessee coneflower) or their listing status has been downgraded from endangered to threatened (e.g., snail darter, large flowered skullcap, small whorled pogonia). Among the listed species with populations that continue to decline are the American hart's tongue fern and the Indiana bat. The formerly common northern long-eared bat was resently listed under the ESA due to recent dramatic population declines caused by white-nose syndrome. In the TVA region, this pathogen was first reported in 2011 and signs of mortality it caused were first observed in 2014. Population trends of many other listed species in the TVA region are poorly understood.

Thirty-seven species listed under the ESA occur in the immediate vicinity of the TVA reservoir system and are potentially affected by its operation (TVA 2004, USFWS 2006). The major reservoir system habitats supporting listed species are flowing (unimpounded) mainstem reaches and warm tributary tailwaters. Other habitats in the TVA region less associated with the TVA reservoir system and supporting high concentrations of listed species include free-flowing rivers, caves and limestone cedar glades. TVA has taken several actions to minimize the adverse effects of its operation of the reservoir system on endangered and threatened species (TVA 2004, USFWS 2006) and to conserve listed species occurring in other habitats.

At least 16 species listed or proposed for listing under the ESA occur on or very TVA generating facility reservations. These include the following:

- Large-flowered skullcap, *Scutellaria montana* – Threatened.
- Ruth's golden aster, *Pityopsis ruthii* – Endangered.
- Gray bat, *Myotis grisescens* – Endangered.
- Northern long-eared bat, *Myotis septentrionalis* – Threatened.
- Indiana bat, *Myotis sodalis* – Endangered.
- Dromedary pearlymussel, *Dromus dromas* – Endangered.
- Fanshell, *Cyprogenia stegaria* – Endangered.
- Pink mucket, *Lampsilis abrupta* – Endangered.
- Ring pink, *Obovaria retusa* – Endangered.
- Rough pigtoe, *Pleurobema plenum* – Endangered.
- White wartyback, *Plethobasis cicatricosus* – Endangered.
- Fluted Kidneyshell – *Ptychobranchus subtentum* – Endangered.
- Rabbitsfoot – *Quadrula cylindrica cylindrica* – Threatened.
- Slabside pearlymussel, *Lexingtonia dolabelloides* – Endangered.
- Spectaclecase, *Cumberlandia monodonta* – Endangered.
- Anthony's river snail, *Athernia anthonyi* – Endangered.

Species listed and under consideration for listing under the ESA that occur on or very near TVA transmission line right-of-ways include the following:

- Braun's rock-cress, *Arabis perstellata* – Endangered.
- Cumberland sandwort, *Minuartia cumberlandensis* – Endangered.
- Fleshy-fruit gladecress, *Leavenworthia crassa* – Endangered.
- Green pitcher plant, *Sarracenia oreophila* – Endangered.
- Large-flowered skullcap, *Scutellaria montana* – Threatened.

- Leafy prairie-clover, *Dalea foliosa* – Endangered.
- Monkey-face orchid, *Platanthera integrilabia* – Candidate for listing.
- Mohr's Barbara Buttons, *Marshallia mohrii* – Threatened.
- Price's potato-bean, *Apios priceana* – Threatened.
- Pyne's ground plum, *Astragalus bibullatus* – Endangered.
- Spring Creek bladderpod, *Lesquerella perforata* – Endangered.
- Whorled sunflower – *Helianthus verticillatus* – Endangered.
- Gray bat, *Myotis grisescens* – Endangered.
- Northern long-eared bat, *Myotis septentrionalis* – Threatened.
- Indiana bat, *Myotis sodalis* – Endangered.

TVA transmission lines also cross many streams supporting aquatic species listed under the ESA. In addition to ESA-listed species, several species listed by TVA-region states occur on or very near TVA generating facilities and transmission lines.

4.11 Wetlands

Wetlands are areas that are inundated or saturated by water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions (EPA regulations at 40 C.F.R § 230.3(t)). Wetlands generally include swamps, marshes bogs and similar areas. Wetlands are highly productive and biologically diverse ecosystems that provide multiple public benefits such as flood control, reservoir shoreline stabilization, improved water quality and habitat for fish and wildlife resources.

Regulatory Framework for Wetlands

Section 404 of the CWA prohibits the discharge of dredge and fill material to waters of the United States, which include most wetlands, unless authorized by a permit issued by the U.S. Army Corps of Engineers. The scope of this regulation includes the most construction activities in wetlands. E.O. 11990 – Protection of Wetlands requires Federal agencies to minimize the destruction, loss, or degradation of wetlands and to preserve and enhance their natural and beneficial values.

Wetlands in the TVA Region

Wetlands occur across the TVA region and are most extensive in the south and west where they comprise 5 percent or more of the landscape (USGS 2012). Wetlands in the TVA region consist of two main systems: palustrine wetlands such as marshes, swamps and bottomland forests dominated by trees, shrubs, and persistent emergent vegetation, and lacustrine wetlands associated with lakes such as aquatic bed wetlands (Cowardin et al. 1979). Riverine wetlands associated with moving water within a stream channel are also present but relatively uncommon. Almost 200,000 acres of wetlands are associated with the TVA reservoir system, where they are more prevalent on mainstem reservoirs and tailwaters than tributary reservoirs and tailwaters (TVA 2004). Almost half of this area is forested wetlands; other types include aquatic beds and flats, ponds, scrub/shrub wetlands and emergent wetlands. Emergent wetlands occur on many TVA generating facility sites, often in association with ash disposal ponds and water treatment ponds. Although ash and water treatment ponds are excluded from regulation under CWA Section 404, these wetlands can have high ecological value such as providing uncommon types of wildlife habitat. Scrub-shrub and emergent wetlands occur within the right-of-ways of many TVA transmission lines. A large proportion of these wetlands were forested until cleared during transmission line construction.

National and regional trends studies have shown a large, long-term decline in wetland area both nationally and in the southeast (Dahl 2000, Dahl 2006, Hefner et al. 1994). Wetland losses have been greatest for forested and emergent wetlands, and have resulted from drainage for agriculture, forest management activities, urban and suburban development and other factors. The rate of loss has significantly slowed over the past 15 years due to regulatory mechanisms for wetland protection. While the rate of wetland loss has slowed, urbanization continues to impact the ecological function of wetlands across the southeast. Threats to wetlands associated with urbanization include habitat fragmentation, invasive species, hydrologic alteration and changes in species composition due to global climate change (Wright et al. 2006).

4.12 Parks, Managed Areas and Ecologically Significant Sites

Numerous areas across the TVA region are recognized and, in many cases, managed for their recreational, biological, historic and scenic resources. These areas are owned by federal and state agencies, local governments, non-governmental organizations such as the Nature Conservancy and regional land trusts and private corporations and individuals.

Parks, managed areas and ecologically significant sites are typically managed for one or more of the following objectives:

- Recreation—areas managed for outdoor recreation or open space. Examples include national, state and local parks and recreation areas; reservoirs (TVA and other); picnic and camping areas; trails and greenways; and TVA small wild areas.
- Species/Habitat Protection—places with endangered or threatened plants or animals, unique natural habitats, or habitats for valued fish or wildlife populations. Examples include national and state wildlife refuges, mussel sanctuaries, TVA habitat protection areas and nature preserves.
- Resource Production/Harvest—lands managed for production of forest products, hunting and fishing. Examples include national and state forests, state game lands and wildlife management areas and national and state fish hatcheries.
- Scientific/Educational Resources—lands protected for scientific research and education. Examples include biosphere reserves, research natural areas, environmental education areas, TVA ecological study areas and federal research parks.
- Historic Resources—lands with significant historic resources. Examples include national battlefields and military parks, state historic sites and state archeological areas.
- Scenic Resources—areas with exceptional scenic qualities or views. Examples include national and state scenic trails, scenic areas, wild and scenic rivers and wilderness areas.
- Agricultural Resources – lands with significant local agricultural production and open space value, often in areas where suburban development is increasing. Examples include working family farms protected by conservation easements.

Numerous parks, managed areas and ecologically significant sites occur throughout the TVA region in all physiographic areas. They are most concentrated in the Blue Ridge and Mississippi Alluvial Plain physiographic areas. Individual ecologically significant areas vary in size from a few acres to thousands of acres. Many areas cross state boundaries or are managed cooperatively by several agencies.

Parks, managed areas, and ecologically significant sites occur on or very near many TVA generating plant reservations, including Allen, Colbert, Gallatin, Kingston, Paradise and Shawnee Fossil Plants, Watts Bar Nuclear Plant and the Bellefonte site. This is especially the case at hydroelectric plants, where portions of the original reservation lands have been developed into state and local parks. TVA transmission line right-of-ways cross eleven National Park Service units, nine National Forests, six National Wildlife Refuges and numerous state wildlife management areas, state parks, and local parks.

4.13 Land Use

This section describes the range of land uses in the TVA region.

Regulatory Framework for Land Use

Use of Federal lands is generally regulated by the organic acts establishing the various agencies as well as other laws. For example, the TVA Act gives TVA the authority to regulate the use of lands it manages and some types of development along streams in the Tennessee River watershed. The Farmland Protection Policy Act directs Federal agencies to evaluate the potential impacts of their actions on highly productive “prime” farmland and, when the actions would surpass a defined impact threshold, consider alternative actions. Various state laws and local ordinances regulate land use, although a large portion of land in the TVA region is not subject to local zoning ordinances.

Major Land Uses in the TVA Region

Major land uses in the TVA region include forestry, agriculture and urban/suburban/industrial (USDA 2013). About three percent of the TVA region is water, primarily lakes and rivers. This proportion has increased slightly since 1982, primarily due to the construction of small lakes and ponds. About 5.5 percent of the land area is Federal land, which has also increased slightly since 1982. Of the remaining non-Federal land area, about 12 percent is classified as developed and 88 percent as rural. Rural undeveloped lands include farmlands (28 percent of the rural area) and forestland (about 60 percent of the rural area). The greatest change since 1982 has been in developed land, which almost doubled in area due to high rates of urban and suburban growth in much of the TVA region. The rate of land development was high during the 1990s and early 2000s and slowed in the late 2000s. Both cropland and pastureland have decreased in area since 1982 (USDA 2013).

Approximately 53 percent of the TVA region is forested (USFS 2014). Forestland increased in area through much of the 20th Century; this rate of increase has slowed and/or reversed in parts of the TVA region in recent years (Conner and Hartsell 2002, USDA 2013). Forestland is predicted to decrease between 1992 and 2020 in the majority of counties in the TVA region, with several counties in the vicinity of Memphis, Nashville, Huntsville, Chattanooga, Knoxville and the Tri-Cities area of Tennessee predicted to lose more than 10 percent of forest area (Wear et al. 2007). Most of the TVA region in Mississippi, as well as some rural parts of Tennessee and Kentucky are predicted to show little change or a small increase in forestland by 2020.

Agriculture – Agriculture is a major land use and industry in the TVA region. In 2012, 41 percent of the land area in the TVA region was farmland that comprised 151,000 individual farms (USDA 2013). Average farm size was 160 acres, a 6.3 percent increase since 1982. The proportion of land in farms has decreased by 4.2 percent since 1982; since 2007, the decrease was 0.3 percent. Over the 1982–2012 period, the number of farms decreased by 14.7 percent while

the average size of farms increased by 6.3 percent. Farm size in the TVA region varies considerably with numerous small farms and a smaller number of large farms. The median farm size in most counties is generally less than 100 acres, and increases from east to west (USDA 2013). Almost half of the farmland (47.0 percent) was classified in 2012 as cropland, which includes hay and short-rotation woody crops (USDA 2013). A quarter (24.6 percent) of the farmland was pasture and the remainder was woodland or devoted to other uses such as buildings and other farm infrastructure.

Farms in the TVA region produce a large variety of products that varies across the region. While the proportion of land in farms is greatest in Mississippi, southern Kentucky and central and western Tennessee, the highest farm income occurs in northern Alabama and Georgia (EPRI and TVA 2009). Compared to farms in the southern and western portions of the TVA region, farms in the eastern and northern portions tend to be smaller and receive a higher proportion of their income from livestock sales than from crop sales. Region-wide, the major crop items by land area are forage crops (hay and crops grown for silage), soy, corn and cotton. The major farm commodities by sales are cattle and calves, poultry and eggs, grains and beans, cotton and nursery products (USDA 2013).

Although the area of irrigated farmland is small (5.7 percent of farmland), it quadrupled between 1982 and 2012 to 1,271,043 acres (USDA 2013). Much of this increase was due to individual farmers increasing the acreage they irrigated, as the number of irrigated farms slightly more than doubled during this period. The area of irrigated farmland is likely to increase in the future as temperature and precipitation patterns become less predictable or if drought conditions become more prevalent (EPRI and TVA 2009).

Crops grown specifically to produce biomass for use as fuels (dedicated energy crops) are a potentially important commodity in the TVA region. In 2002, the Census of Agriculture began recording information on short rotation woody crops, which grow from seed to a harvestable tree in 10 years or less. These crops have traditionally been used by the forest products industry for producing pulp or engineered wood products and are also a potential source of biomass for power generation. In 2012, there were 117 farms in the TVA region growing at least 2,704 acres of short rotation woody crops, a large decrease from the 286 farms in 2007. The Census of Agriculture has also recently begun recording information on the cultivation of switchgrass, a bioenergy crop that can be directly used as fuel and for producing ethanol. In 2012, it was grown by 18 farms that harvested at least 1,800 acres (USDA 2013). Most of these farms were located in eastern Tennessee and grew switchgrass as part of research studies at the University of Tennessee. Three facilities in the TVA region produce ethanol from corn, primarily for use as biofuels with a total production capacity of 258 million gallons per day (Renewable Fuels Association 2014). A large proportion of their corn feedstock is likely grown within the TVA region. Corn grown in the TVA region is also likely used by ethanol producers elsewhere.

Prime Farmland - The Farmland Protection Policy Act recognizes the importance of prime farmland and the role that federal agencies can have in converting it to nonagricultural uses. The act requires federal agencies to consider the potential effects of their proposed actions on prime farmland and consider alternatives to actions that would adversely affect prime farmland.

Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber and oilseed crops, and is available for these uses (NRCS 2014a). Prime farmland has the combination of soil properties, growing season, and moisture

supply needed to produce sustained high yields of crops in an economic manner if it is treated and managed according to acceptable farming methods. Prime farmland is designated independently of current land use, but it cannot be areas of water, urban, or built-up land.

Approximately 22 percent[1] of the TVA region is classified as prime farmland (NRCS 2014b). An additional 4 percent of the TVA region would be classified as prime farmland if drained or protected from flooding.

Forest Management - About 97 percent of the forestland in the TVA region is classified as timberland (USFS 2014), forestland that is producing or capable of producing more than 20 cubic feet of merchantable wood per acre per year and is not withdrawn from timber harvesting by law. About 14 percent of timberland is in public ownership, primarily in national forests. About 20 percent is owned by corporations and the remainder is in non-corporate private ownership. While the majority of corporate timberlands have historically been owned by forest industries, this proportion has decreased in recent years as many forest product companies have sold timberlands due to changing market conditions.

4.14 Cultural Resources

Cultural resources include prehistoric and historic archaeological sites, districts, buildings, structures, and objects, as well as locations of important historic events that lack material evidence of those events. Cultural resources are considered historic properties if included in, or considered eligible for inclusion in, the National Register of Historic Places (NRHP) maintained by the National Park Service. The eligibility of a resource for inclusion in the NRHP is based on the Secretary of the Interior's criteria for evaluation (36 CFR 60.4), which state that significant cultural resources possess integrity of location, design, setting, materials, workmanship, feeling and association, and:

- are associated with important historical events; or
- are associated with the lives of significant historic persons; or
- embody distinctive characteristics of a type, period, or method of construction or represent the work of a master, or have high artistic value; or
- have yielded or may yield information (data) important in history or prehistory.

Regulatory Framework for Cultural Resources

Because of their importance to the Nation's heritage, historic properties are protected by several laws. Federal agencies, including TVA, have a statutory obligation to facilitate the preservation of historic properties, stemming primarily from the National Historic Preservation Act (NHPA; 16 U.S.C. §§ 470 et seq.). Other relevant laws include the Archaeological and Historic Preservation Act (16 U.S.C. §§ 469-469c), Archaeological Resources Protection Act (16 U.S.C. §§ 470aa-470mm) and the Native American Graves Protection and Repatriation Act (25 U.S.C. §§ 3001-3013).

[1] This estimate does not include about 20 counties for which soil survey information is incomplete or not available.

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Section 106 of the NHPA requires Federal agencies to consider the potential effects of their actions on historic properties and to allow the Advisory Council on Historic Preservation an opportunity to comment on the action. Section 106 involves four steps: 1) initiate the process; 2) identify historic properties; 3) assess adverse effects; and 4) resolve adverse effects. This process is carried out in consultation with the State Historic Preservation Officer (SHPO) of the state in which the undertaking takes place and with any other interested consulting parties, including federally recognized Indian tribes.

Section 110 of the NHPA sets out the broad historic preservation responsibilities of Federal agencies and is intended to ensure that historic preservation is fully integrated into their ongoing programs. Federal agencies are responsible for identifying and protecting historic properties and avoiding unnecessary damage to them. Section 110 also charges each Federal agency with the affirmative responsibility for considering projects and programs that further the purposes of the NHPA, and it declares that the costs of preservation activities are eligible project costs in all undertakings conducted or assisted by a Federal agency.

Archaeological Resources

Human occupation in the TVA region began at the end of the Ice Age with the Paleo-Indian Period (13,500 – 11,000 years before present, or “B.P.”). In the Tennessee Valley, prehistoric archaeological chronology is generally broken into four broad time periods: following the Paleo-Indian Period are the Archaic (11,000 – 3,000 B.P.), Woodland (3,000 – 1,100 B.P.), and Mississippian (1,100 – 500 B.P.) periods. Archaeological sites from all these periods, as well as from the more recent historic period, are very numerous throughout the TVA region. They occur on a variety of landforms and in a variety of environmental contexts. Sites are rarely found on steep slopes, with the exception of rockshelters, which have been used throughout the prehistoric and historic periods and often contain artifacts and features with value to archaeology and history. Areas affected by construction, mining, civil works projects and highways, for example, tend to lack significant archaeological resources due to modern ground disturbing activities.

The most reliable information about the locations of archaeological sites is produced during Phase I archaeological surveys conducted for compliance with Section 106. Numerous surveys have been conducted along reservoir shorelines, within reservoirs, and on power plant reservations. However, large areas remain that have not been surveyed. Some TVA transmission line corridors and many highways have also been surveyed. But outside of TVA reservoirs and plant reservations, the density of surveys is low and relatively little is known about archaeological site distributions.

The earliest documentation of archaeological research in the region dates back to the 19th Century when entities such as the Smithsonian Institute and individuals such as Cyrus Thomas undertook some of the first archaeological excavations in America to document the history of Native Americans (Guthe 1952). TVA was a pioneer in conducting archaeological investigations during the construction of its dams and reservoirs in the 1930s and early 1940s (Olinger and Howard 2009). Since then, TVA has conducted numerous archaeological surveys associated with permitting, power generation, and transmission system construction and maintenance. These surveys, as well as other off-reservoir projects, have identified more than 2000 sites, including over 250 associated with transmission system activities within the TVA region. A large proportion of these sites have not been evaluated for NRHP eligibility. The number eligible or potentially eligible for listing on the NRHP is unknown.

Archaeological survey coverage and documentation in the region varies by state. Each state keeps records of archaeological resources in different formats. While digitization of this data is underway, no consistent database is available for determining the number of archaeological sites within the TVA region. Survey coverage on private land has been inconsistent and is largely project-based rather than focusing on high-probability areas, so data is unlikely to be representative of the total population of archaeological sites. Based on a search through TVA's data and reports of archaeological surveys on reservoirs, TVA estimates that over 11,000 archaeological sites have been recorded on TVA reservoir lands, including submerged lands. Significant archaeological excavations have occurred as a result of TVA and other Federal projects and have yielded impressive information regarding the prehistoric and historic occupation of the Southeastern U.S. Notable recent excavations and related projects in the region include those associated with the Townsend, Tennessee highway expansion; Shiloh Mound on the Tennessee River in Hardin County, Tennessee; the Ravensford site in Swain County, North Carolina; and documentation of prehistoric cave art in Alabama and Tennessee. TVA is in the process of nominating Hiwassee Island Archaeological District (Meigs County, Tennessee) to the NRHP.

Historic Structures

Historic architectural resources are found throughout the TVA region and can include houses, barns and public buildings. Many historic structures in the region have been either determined eligible for listing or have been listed in the NRHP. However, historic architectural surveys have been conducted in only a fraction of the land area within the region.

Over 5,000 historic structures have been inventoried in the vicinity of TVA reservoirs and power system facilities. Of those evaluated for NRHP eligibility, at least 85 are included in the NRHP and about 250 are considered eligible or potentially eligible for listing. TVA power system facilities listed in the NRHP include the Ocoee 1, Ocoee 2, Great Falls, and Wilson dams and hydroelectric plants. Wilson Dam is also listed as a National Historic Landmark. Several power system facilities have been determined in consultation with SHPOs to be eligible or potentially eligible for the NRHP: Blue Ridge, Chatuge, Hiwassee, Nottely, Ocoee 3, Apalachia, Fontana, Norris, Watts Bar, Pickwick and Guntersville dams; the decommissioned (and non-extant) Watts Bar Steam Plant; Shawnee Fossil Plant; and the retired John Sevier Fossil Plant. The Alabama SHPO has expressed an opinion that Widows Creek Fossil Plant is eligible for listing in the NRHP. Based on a TVA-wide inventory of facilities, it is TVA's opinion that Browns Ferry Nuclear Plant is eligible for listing in the NRHP, but TVA has not consulted with the SHPO on its eligibility. The various SHPOs have agreed with TVA that the Paradise, Allen, Cumberland, Kingston and Gallatin Fossil Plants in Tennessee are not eligible. The switch houses at several TVA substations are also likely eligible for listing, and some of the oldest transmission lines are potentially eligible for listing. In addition, other TVA facilities have been determined eligible for listing such as the Muscle Shoals (Colbert County, Alabama) Historic District, which TVA is in the process of nominating to the NRHP and plans to sell at least some parts to outside parties.

4.15 Solid and Hazardous Wastes

This section focuses on the solid and hazardous wastes produced by the construction and operation of generating plants and transmission facilities. Wastes typically produced by construction activities include vegetation, demolition debris, oily debris, packing materials, scrap lumber and domestic wastes (garbage). Non-hazardous wastes typically produced by common facility operations include sludge and demineralizers from water treatment plant operations, personal protective equipment, oils and lubricants, spent resins, desiccants, batteries and

domestic wastes. Between 2010 and 2013, TVA facilities produced approximately 21,000 tons of solid waste per year. However, the amount of waste produced at any one facility can vary significantly from year to year due to maintenance, decommissioning, and asset improvement activities. In an effort to reduce waste generation, especially hazardous waste, TVA has incorporated into its procedures waste minimization efforts including reuse and recycling, substitution of less hazardous products and chemical traffic control.

Hazardous, non-radiological wastes typically produced by common facility operations include paint and paint solids, paint thinners, discarded out-of-date chemicals, parts washer liquids, sand blast grit, chemical waste from cleaning operations and broken fluorescent bulbs. The amount of these wastes generated varies with the size and type of facility. Hazardous wastes and wastes requiring special handling (TSCA and universal waste; see explanations below) generated from routine facility operations (Table 4-13) are generally shipped to Waste Management's Emelle, Alabama facility for disposal. Special projects such as large scale renovations, demolitions, decommissioning and boiler cleaning are considered non-routine and are not reflected in this table.

Table 4-13 Average annual quantities (in kilograms) hazardous, TSCA, and universal waste plus used oil generated by routine operations at TVA facilities, 2010–2013.

Waste Class	Type of Facility				
	Coal Plant	Nuclear Plant	Hydro Plant	Natural Gas Plant	Other*
Hazardous	13,287	8,570	5,247	630	7,803
TSCA and universal	13,388	1,541	6,497	0	18,284

*Includes maintenance bases, substations, office space and laboratories.

Hazardous wastes are defined by the Resource Conservation and Recovery Act to include those that meet the regulatory criteria of ignitability, corrosively, reactivity, or toxicity. They can include such materials as paints, solvents, corrosive liquids and discarded chemicals. TSCA wastes are regulated under the Toxic Substances Control Act (TSCA). TSCA wastes typically encountered at TVA sites include polychlorinated biphenyls (PCBs), historically used in insulating fluids in electrical equipment. PCB items are typically shipped to Trans Cycle Industries in Pell City, Alabama or handled through Clean Harbor's Tucker, Georgia facility.

Used oil, if not recycled is considered a waste. Used oils include gear oils, greases, mineral oils and an assortment of other petroleum- and synthetic-based oils. The majority of TVA's used oil, approximately 35,000 kilograms, is recycled annually by TVA. Used oil containing 50 or greater ppm PCB is regulated by TSCA and must be disposed of as PCB-contaminated oil.

Universal wastes are a subset of hazardous wastes that are widely available, easily recyclable, and generally pose a relatively low threat. However, these wastes can contain materials that cannot be released into the environment. This classification includes batteries, pesticides, fluorescent bulbs and equipment containing mercury. On average, approximately 800 kilograms of universal waste are disposed of annually by TVA.

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Coal-fueled generating plants produce large quantities of ash and other coal combustion solid wastes and nuclear plants produce radioactive wastes. These wastes are described in more detail below.

Coal Combustion Solid Wastes

The primary solid wastes produced by coal combustion are fly ash, bottom ash, boiler slag, char, spent bed material and FGD residue. The properties of these wastes (also known as coal combustion residuals (CCRs) or coal combustion products) vary with the type of coal plant, the chemical composition of the coal, and other factors. Ash and slag are formed from the non-combustible matter in coal and small amounts of unburned carbon. Fly ash is composed of small, silt- and clay-sized, mostly spherical particles carried out of the boiler by the exhaust gas. Bottom ash is heavier and coarser with a grain size of fine sand to fine gravel and falls to the bottom of the boiler where it is typically collected by a water-filled hopper. Boiler slag, a coarse, black, granular material, is produced in cyclone furnaces when molten ash is cooled in water. Ash and slag are primarily composed of silica (SiO_2), aluminum oxide (Al_2O_3), and iron oxide (Fe_2O_3). Spent bed material is produced in fluidized bed combustion boilers (e.g., the now-retired Shawnee Fossil Plant Unit 10). FGD residue is formed in FGD systems (scrubbers) by the interaction of sulfur in the flue gas with finely ground limestone or slaked lime. TVA's currently operating FGD systems use limestone as the reagent to bond with the sulfur, producing hydrated calcium sulfate ($CaSO_42H_2O$), also known as synthetic gypsum. The FGD systems currently being installed at the Gallatin Fossil Plant and scheduled to be installed on Shawnee Fossil Plant Units 1 and 4, will use slaked lime as the reagent and produce calcium sulfite ($CaSO_3$). Unlike the other plants with FGD systems, which segregate the ash and FGD residue waste streams, these CCRs will be combined in a single dry waste stream at Gallatin and Shawnee.

During 2013, TVA produced approximately 4.2 million tons of CCRs, with approximately half being synthetic gypsum and 33 percent being fly ash (Table 4-14). Of the 4.2 million tons, 0.9 million tons, or 21 percent, were utilized or marketed, which is a decrease the from the 2.8 million ton annual average for 2006–2008, mostly due to reduced demand resulting from the recent recession. In 2014, the beneficial reuse rate of CCRs increased to 29 percent. The main beneficial uses of coal combustion solid wastes are in the manufacture of wallboard, roofing, cement, concrete and other products. Opportunities for reuse of the combined fly ash and FGD residue CCR that will be produced at Gallatin and Shawnee are currently very limited.

Table 4-14 Coal combustion residuals generated by TVA from 2010 – 2013.

	Production (tons)		Utilization (percent)	
Type	2010–2012 Average	2013	2010–2012 Average	2013
Fly Ash	1,798,352	1,389,857	18.8%	30.1%
Bottom Ash	356,975	288,543	0.2%	0.0%
Boiler Slag	482,986	409,385	63.9%	71.0%
Char	9,018	0	0.0%	0.0%
Spent Bed Material*	2,829	0	0.0%	0.0%
Synthetic Gypsum	2,406,276	2,150,356	23.3%	22.6%
Total	5,056,435	4,238,141	17.7%	20.6%

*Produced by Shawnee Fossil Plant Unit 10, which ceased operating in 2010.

The CCRs that are not sold for reuse are stored in landfills and impoundments at or near coal plant sites. Five TVA plants use dry ash collection/storage systems, and six plants use wet ash collection/storage system. TVA has committed to converting all wet ash and gypsum storage facilities, present at six of its plants, to dry storage and disposal facilities. These projects are expected to be completed in four to six years.

Nuclear Waste

The nuclear fuel used for power generation produces liquid, gaseous, and solid radioactive wastes ("radwaste") that require storage and disposal. These wastes are categorized as high-level waste and low-level waste based on the type of radioactive material, the intensity of its radiation, and the time required for decay of the radiation intensity to natural levels.

High-Level Waste **–** About 99 percent of high-level waste generated by nuclear plants is spent fuel, including the fuel rod assemblies. Nuclear fuel is made up of small uranium pellets placed inside long tubular metal fuel rods which are grouped into fuel assemblies and placed in the reactor core. In the fission process, uranium atoms split in a chain reaction yielding heat. Radioactive fission products—the nuclei left over after the atom has split—are trapped and gradually reduce the efficiency of the chain reaction. Consequently, the oldest fuel assemblies are removed and replaced with fresh fuel at about 18-month intervals. Because nuclear plants normally operate continuously at full load, spent fuel production varies little from year to year. The six operating nuclear units produce about 650 tons of high-level waste per year.

After it is removed from the reactor, spent fuel is stored at the nuclear plants in pools (steel-lined, concrete vaults filled with water). The spent fuel pools were originally intended to store spent fuel onsite until a monitored retrievable storage facility and a permanent repository were built by the Department of Energy as directed by the Nuclear Waste Policy Act of 1982. Because these facilities have not yet been built, the storage capacity of the spent fuel pools at Sequoyah and Browns Ferry nuclear plants has been exceeded. TVA, like other utilities, has begun storing spent fuel at Sequoyah and Browns Ferry in above-ground dry storage casks constructed of concrete and metal. The Watts Bar plant is scheduled to start using dry storage casks by 2017.

Low-Level Waste **–** Low-level waste consists of items that have come into contact with radioactive materials. At nuclear plants, these wastes consist of solids such as filters, spent resins (primarily from water filtration systems), sludge from tanks and sumps, cloth and paper wipes, plastic shoe covers, tools and materials; liquids such as tritiated waste (i.e., containing radioactive tritium), chemical waste, and detergent waste; and gases such as radioactive isotopes created as fission products and released to the reactor coolant. Nuclear plants have systems for collecting these radioactive wastes, reducing their volume, and packaging them for interim onsite storage and eventual shipment to approved processing and storage facilities. Dry active waste, which typically have low radioactivity, are presently shipped to a processor in Oak Ridge, Tennessee for compaction and then to a processor in Clive, Utah for disposal. Wet active wastes with low radioactivity are shipped to the Clive processor. Other radioactive wastes are currently shipped to and stored at the Sequoyah plant. Table 4-15 lists the amounts of low level waste produced at TVA nuclear plants in recent years.

Table 4-15 Low level waste (in cubic feet) generated at TVA nuclear plants 2010–2013.

Plant	2010	2011	2012	2013
Browns Ferry	50,656	49,898	69,480	85,599
Sequoyah	7,995	13,148	8,063	15,284
Watts Bar	9,781	14,543	8,212	9,450
Total	68,432	77,589	85,755	110,333

Mixed Waste – Mixed Waste is a classification of waste that is dually regulated as radioactive and contains some other component regulated by additional environmental regulations (i.e. RCRA or TSCA). Examples of mixed waste, usually generated during maintenance activities, include lead paint chips, cleanup debris, resin and unpunctured aerosol cans that cannot be radiologically cleared. Because of the dual regulation, this material is extremely difficult to find a properly permitted outlet for disposal. Recent outlets include Energy Solutions and previously EnviroCare and Permafix. Table 4-16 show the mixed waste sent for disposal from TVA sites during 2010–2013.

Table 4-16 Mixed waste (in kilograms) generated at TVA nuclear plants 2010–2013.

Plant/Facility	2010	2011	2012	2013
Browns Ferry	0	0	101	0
Sequoyah	0	0	86	731
Watts Bar	0	0	0	0
Power Service Shops	0	0	1,066	0
Totals	0	0	1,253	731

4.16 Socioeconomics

This section describes socioeconomic conditions in the TVA region with the focus on the TVA service area consisting of the 178 counties where TVA provides electric power and or has large

generating facilities (Figure 1-1). In addition to population, economy, employment and income, it describes the relative size and location of minority and low income populations.

Population

The estimated population of the TVA power service area was 9.74 million in 2013 (Bureau of Census 2014a). This represents a 16 percent increase over the 2000 population and a 1.9 percent increase over the 2010 population. The rate of increase from 2000 to 2013 is greater than the 13.4 percent increase for the U.S. as a whole and the 14.3 percent increase for the Southern U.S. The 2010–2013 rate of increase for the TVA region is lower than both the national rate of 2.5 percent and the rate for the Southern U.S. of 3.3 percent (Bureau of Census 2014b). The annual rate of population growth in the TVA region is expected to continue to decline to about 0.5 percent by 2043 (TVA data).

Population varies greatly among the counties in the region (Figure 4-31). The larger population concentrations tend to be located along major river corridors: the Tennessee River and its tributaries from northeast Tennessee through Knoxville and Chattanooga into north Alabama; the Nashville area around the Cumberland River; and the Memphis area on the Mississippi River. Low population counties are scattered around the region, but most are in Mississippi, the Cumberland Plateau of Tennessee and the Highland Rim of Tennessee and Kentucky.

An increasing proportion of the region's total population, 66.1 percent in 2000 and 68.1 percent in 2010, lives in metropolitan areas[2] (Table 4-17). Two of these areas have populations greater than one million: Nashville, almost 1.7 million, and Memphis, 1.3 million. The Knoxville and Chattanooga metropolitan areas have populations greater than 500,000. These four metropolitan areas account for about 46 percent of the region's population.

Although the proportion of the region's population living in metropolitan areas is lower than the national average of 84 percent, it is has been increasing and this trend appears likely to continue in the future. A substantial part of this increase is likely to follow the pattern of increases in the geographic size of metropolitan areas as growth spreads out from the central core of these areas. Conversely, several lifestyle and economic concerns, including commuting time and costs and proximity to social amenities, have led to increased residential populations in the urban core areas of several cities in the regions, including the largest cities.

[2] The Chattanooga metropolitan statistical area (MSA) has one county outside the TVA region, Dade County, GA; the Memphis MSA has three counties outside the TVA region, Crittenden County in Arkansas and DeSoto and Tunica counties in Mississippi.

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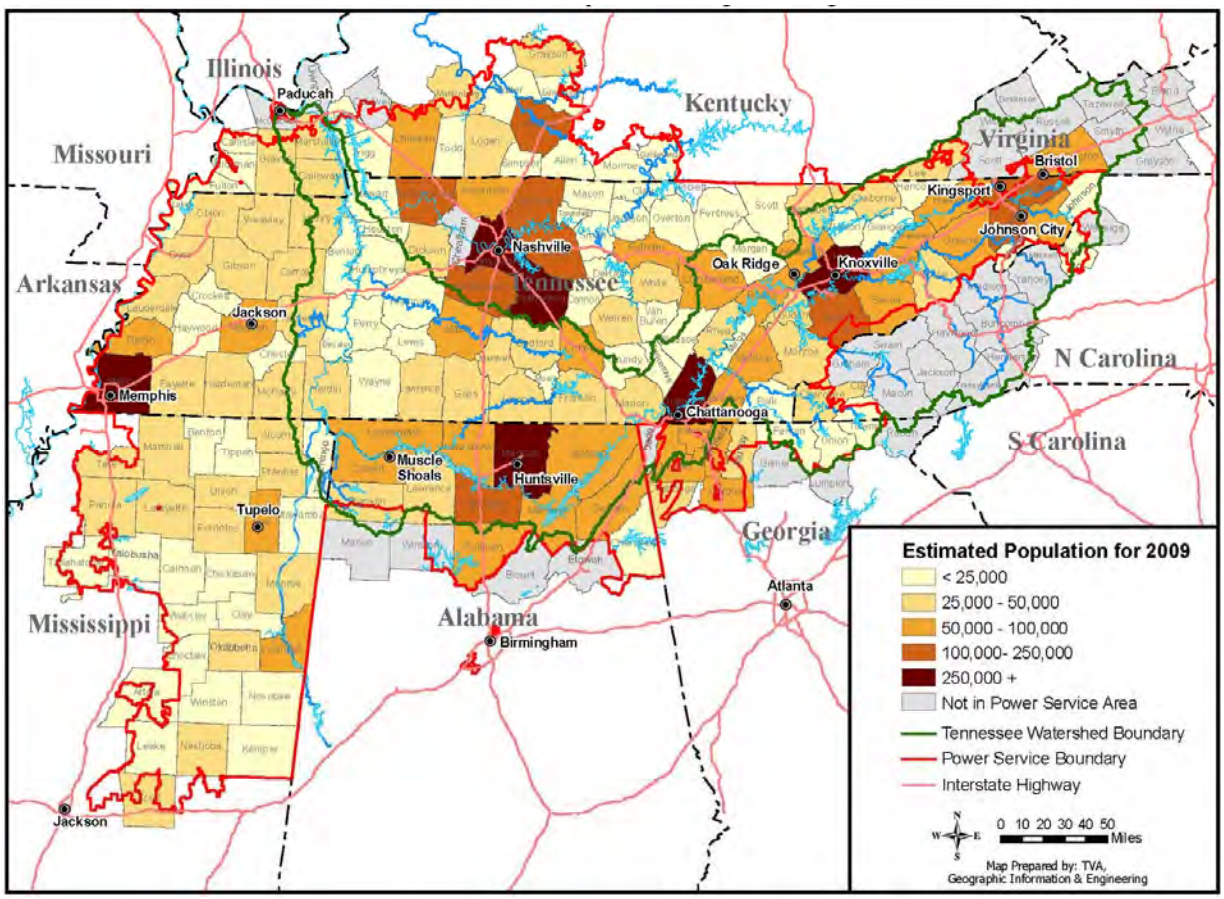

Figure 4-31 TVA region estimated 2009 population by county. Source: Bureau of Census (2010).

Table 4-17 TVA region metropolitan areas (Source: Bureau of Census 2010. 2010 Census Population and Housing Tables – Population Change for Metropolitan and Micropolitan Statistical Areas in the United States and Puerto Rico: 2000 to 2010 (CPH-T-5). Available at http://www.census.gov/population/www/cen2010/cph-t/cph-t-5.html.

	Population	
Metropolitan Area	2000	2010
Bowling Green, KY	134,976	158,599
Chattanooga, TN-GA	476,531	528,143
Clarksville, TN-KY	219,630	260,625
Cleveland, TN	104,015	115,788
Dalton, GA	120,031	142,227
Decatur, AL	145,867	153,829
Florence-Muscle Shoals, AL	142,950	147,137

Huntsville, AL	342,376	417,593
Jackson, TN	121,909	130,011
Johnson City, TN	181,607	198,716
Kingsport-Bristol-Bristol, TN-VA	298,484	309,544
Knoxville, TN	748,259	837,571
Memphis, TN-AR	1,213,230	1,324,829
Morristown, TN	102,422	113,951
Nashville- Davidson-Murfreesboro-Franklin, TN	1,381,287	1,670,890
Total	5,733,574	6,509,453

Economy and Employment

In 2013, the TVA region had an economy of almost $400 billion in gross product and total personal income of about $365 billion, about 2.5 percent of the national total (USBEA 2014). Total employment was approximately 5.2 million. While income levels in the region have increased relative to the nation over the past several decades, average income is still below the national level. 2013 per capita personal income averaged about $37,463, 84 percent of the national average (BEA 2014).

In November 2014, the average unemployment rate for counties in the TVA region was 6.9 percent (BLS 2015). Although there is considerable geographic variation in unemployment rates with adjacent counties sometimes having large differences, the counties with the highest unemployment rates in the TVA region are somewhat concentrated in east-central Mississippi, in non-urban counties near the Mississippi River, and in the northern Cumberland Plateau in Tennessee. The metropolitan areas generally had lower unemployment rates, ranging from a low of 4.8 percent in the Huntsville, Alabama area to a high of 8.4 percent in the Dalton, Georgia area.

The TVA region is more rural and the economy depends more on manufacturing than does the nation as a whole. Manufacturing employment comprises about 11 percent of regional employment and about 10 percent of regional personal income (BEA 2014). The relative importance of manufacturing has been declining for a number of years, both nationally and regionally. The current estimated manufacturing employment in the TVA region is about 547,000, a sharp decrease from its level of almost 852,000 in the late 1990s. Manufacturing in the TVA region accounts for about 2.5 percent of all manufacturing earnings in the nation, and is expected to maintain this share. Factors contributing to the high proportion of manufacturing include location with good access to markets in the Northeast, Midwest, Southwest, the rest of the Southeast, good transportation, relatively low wages and cost of living, right-to-work laws and abundant, relatively low-cost resources including land and electricity.

While the mix of manufacturing industries varies considerably across the region, there has been a continuing shift from non-durable goods, such as apparel, to durable goods, such as automobiles. In 1990, about 48 percent of manufacturing jobs were in durable goods. That share has increased to about 53 percent and this increase is expected to continue. Nondurable

goods manufacturing peaked about 1993; the most notable decline has been in apparel and other textile products, which has declined from about 13 percent of regional manufacturing in 1990 to less than 2 percent. Nationally, there has been a slight increase in the share of non-durable goods, from about 40 percent in the year 2000 to a little more than 41 percent.

Farm employment comprises about 3 percent of regional employment and about 1 percent of regional personal income (BEA 2014). The region also has a larger proportion of agricultural workers than the nation as a whole. The total market value of farm products produced in the TVA region in 2012 was $10.7 billion; about 60 percent of this total was from the sale of livestock, poultry, and their products and the remainder was primarily from the sale of crops (USDA 2014). The regional farm sector provides approximately 142,000 jobs, about 2.7 percent of all jobs in the region (BEA 2014). This is greater than the national average of 1.5 percent of workers employed in farming, and, like the national average, has decreased in recent decades. Part of this decrease is due to efficiency increases. Much of the farming in the region is done on a part-time basis and the majority of farm operators report farming as a secondary occupation. Consequently, the net cash farm income for most farm operators is only a few thousand dollars (USDA 2014).

There is a large amount of diversity among farms in the region. For example, cotton is an important crop in parts of Mississippi and the western part of Tennessee. Soybeans and corn are common through much of the region and fruit and vegetable farming is widespread but generally in small operations. Pork and beef production are widespread, while large-scale poultry production is concentrated in a few areas of Alabama and Mississippi. Wholesale production of trees and shrubs for the commercial nursery industry is important in the southeastern Highland Rim of Tennessee.

The service sector is a significant share of the regional economy, accounting for almost a third percent of nonfarm workers, slightly lower than the national average. The service sector and other non-farming, non-manufacturing sectors of the regional economy have continued to grow, increasing by about 21 percent and 9 percent, respectively, in the region since 2000. This growth was due to increases in services employment and, to a lesser extent, in civilian government. Employment in the region has declined or remained essentially level in other sectors. Nationally, services grew somewhat more slowly than in the region, while civilian government grew only slightly faster.

Income

Per capita personal income in the region in 2013 was $37,463, about 84 percent of the national average of $44,765 (BEA 2014). However, there was wide variation within the region. The few counties with incomes above the national average are, in descending order, Williamson, Davidson, Fayette and Trousdale in Tennessee, and Hickman in Kentucky. Davidson, Williamson and Trousdale Counties are within the Nashville metropolitan area and Hickman County, Kentucky is rural. At the other extreme only one county, Hancock County, Tennessee, had per capita income less than half the national average (about 46 percent).

Minority Populations

The minority population of the region, as of 2013, is estimated to be about 2.4 million; 24.5 percent of the region's total population of about 9.7 million (Bureau of Census 2014c). This is well below the national average minority population share of 37.4 percent. About 4.5 percent of minorities in the region are white Hispanic and the rest are nonwhite. Minority populations are

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largely concentrated in the metropolitan areas in the western half of the region and in rural counties in Mississippi and western Tennessee (Figure 4-32).

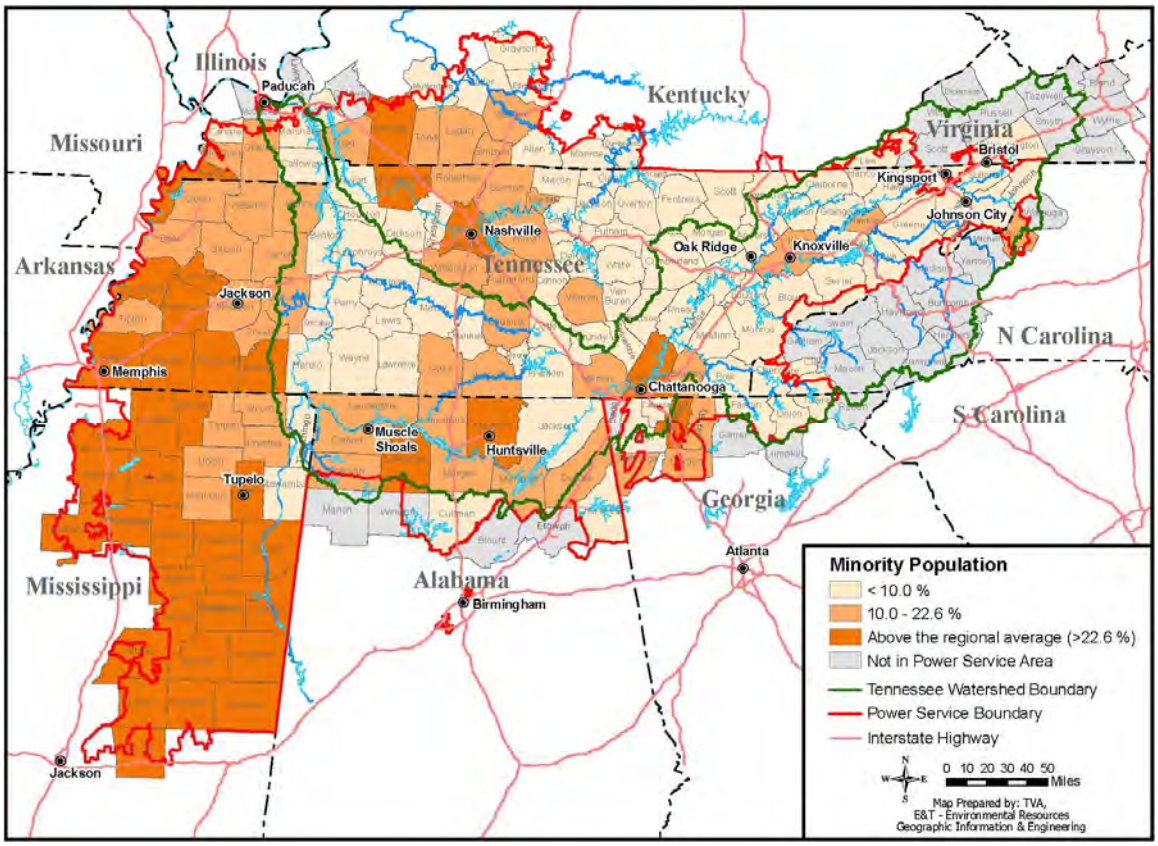

Figure 4-32 Percent minority population of TVA region counties in 2013. Source: Bureau of Census (2014c).

Low Income Populations

The estimated poverty level for TVA region counties, as of 2013, is 18.5 percent, an increase from the 15.8 percent in 2008 and higher than the 2013 national poverty level of 15.8 percent (Bureau of Census 2014d). Counties with the higher poverty levels are generally outside the metropolitan areas and most concentrated in Mississippi (Figure 4-33).

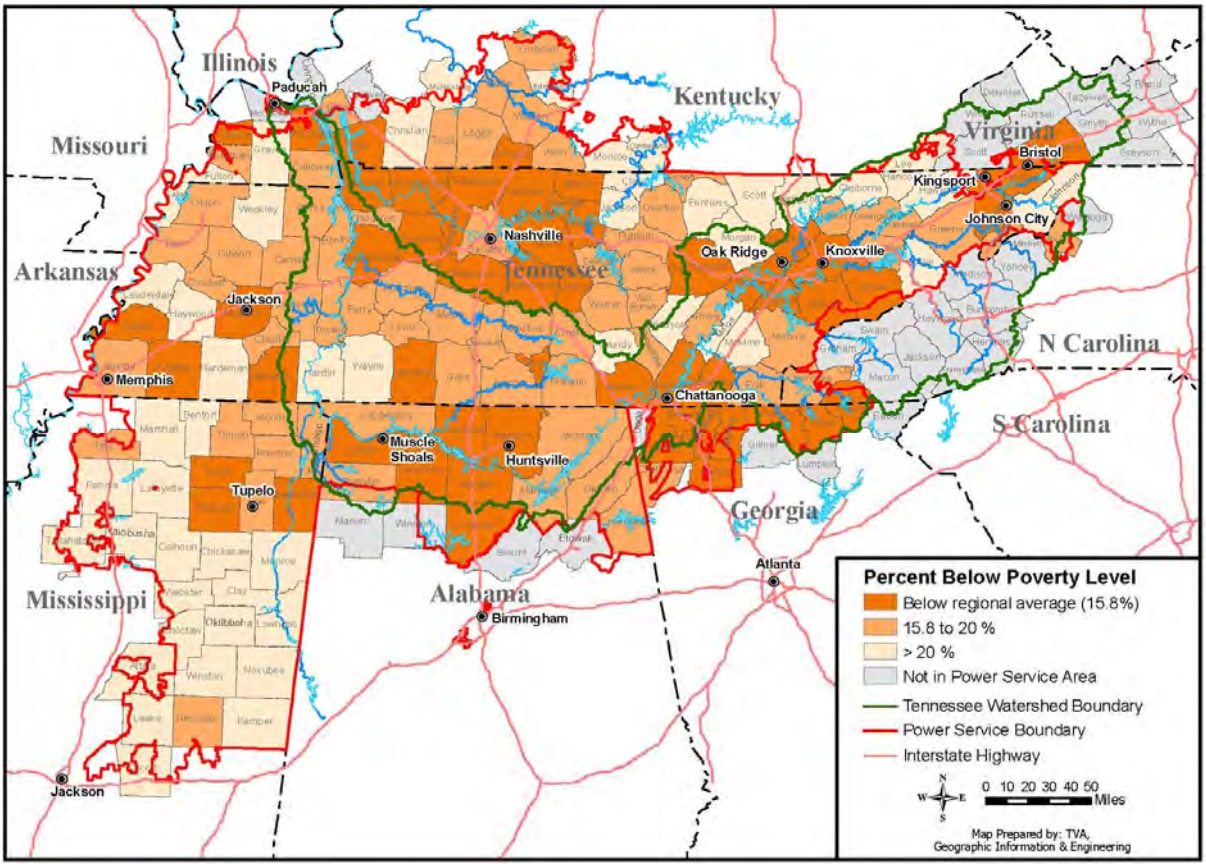

Figure 4-33 Percent of population below the regional average poverty level of 18.5 percent in 2013. Source: Bureau of Census (2014d).

4.17 Availability of Renewable Energy Resources

The alternative strategies being evaluated include the potential for increased reliance on renewable generating resources. TVA includes all renewable resources in its definition of renewable energy, including hydroelectric generation. This assessment of the availability of renewable resources does not include TVA's existing hydroelectric facilities and considers renewable resources in the context of many state renewable portfolio standards to include solar, wind, small hydroelectric (see Section 5.3.3) and upgrades to existing large hydroelectric plants, biomass (including biogas), and geothermal energy. Geothermal generation using currently available and near-term emerging technologies is not considered further because of the lack of a developable resource in the TVA region (Augustine 2011).

Following is an assessment of the availability of potential renewable resources for generating electricity in and near the TVA region.

4.17.1 Wind Energy Potential

The suitability of the wind resource in an area for generating electricity is typically described in terms of wind power classes ranging from Class 1, the lowest, to Class 7, the highest (Elliott et al. 1986). The seven classes are defined by their average wind power density (in units of watts/m^2) or equivalent average wind speed for a specified height above ground. Areas designated Class 3, corresponding to a windspeed of at least 6.4 meters/second (m/s;

14.3 mph) or greater at a height of 50 m above ground usually have adequate wind for most commercial wind energy developments. Based on wind resource assessments at the 50-m height, relatively little of the TVA region is suitable for commercial wind energy development.

Raichle and Carson (2009) presented the results of a detailed wind resource assessment at the 50-m height in the southern Appalachian Mountains. Measured annual wind speeds at nine representative privately owned sites ranged from 4.4 m/s on the Cumberland Plateau in northwest Georgia to 7.3-7.4 m/s on sites in the Blue Ridge Mountains near the Tennessee/North Carolina/Virginia border. Two sites in the Cumberland Mountains and one site in the Blue Ridge Mountains were categorized as Class 3 and two sites in the Blue Ridge Mountains were categorized as Class 4. The Class 3 and Class 4 sites had capacity factors of 28–36 percent and an estimated energy output of 2.8–3.5 GWh per MW of installed capacity. Capacity factor is the ratio (in percent) of energy a facility actually produced over a given period of time (typically a year) to the amount of the energy that would have been produced if the facility had run at full capacity during the same time period. All sites had significantly less wind during the summer than during the winter and significantly less wind during the day than at night during all seasons. Due to the configuration of ridge tops within this area in relation to prevailing wind directions, potential wind projects would likely be linear in extent and relatively small.

More recent wind assessments have shifted from a power class rating to increased focus on wind speed and potential capacity factor, and to higher elevations of 80 m and 100 m above ground, tower heights more representative of current wind turbines (NREL 2010a). Wind speeds of at least 6.5 m/s at 80-m height and a capacity factor of at least 30 percent are generally considered suitable for wind energy development. This re-evaluation showed an increased potential for wind generation in the western portion of the TVA region, especially at a height of 100 m (Figures 4-34, 4-35). Due to the spatial resolution of these data (2.5 km for the 80-m analysis, 2 km for the 100-m analysis), the ridgetop potential in the TVA region may be underestimated. These maps also show the greater potential for wind energy development in the upper Midwest and the Great Plains, where TVA currently acquires most of its wind energy (see Section 3.4). The acquisition of additional wind energy from these areas, as well as from within the TVA service area, is among the energy resource options considered in this IRP (see Section 5.3.3).

Based on a 30 percent gross capacity factor (not adjusted for losses) and excluding undevelopable areas such as national and state parks, wilderness areas, wildlife refuges, and recreation areas, the potential installed wind capacity in the TVA region is 450–1,300 MW depending on elevation. The corresponding generation values are 1,200 and 3,400 GWh, respectively. The Eastern Wind Integration and Transmission Study conducted by the National Renewable Energy Laborator (NREL 2010b) further supplements this data by estimating a wind potential of 1,247 MW in the TVA region, with an expected annual energy generation value between 3,500–4,000 GWh. Additional wind speed data collection from high elevation towers (minimum of 50 m) is necessary to develop a more precise wind resource estimate for the TVA region.

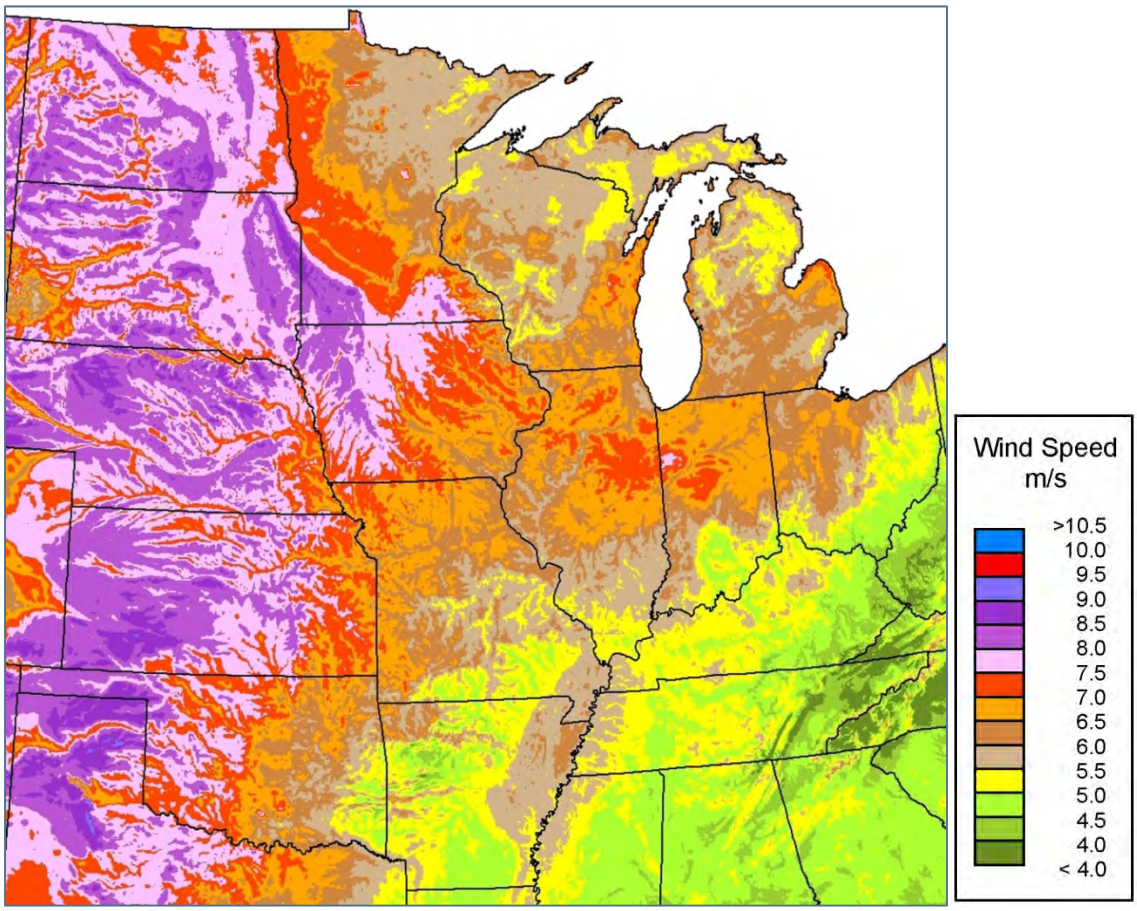

Figure 4-34 Wind resource potential of the eastern and central U.S. at 80 m above ground. Source: Adapted from NREL (2011).

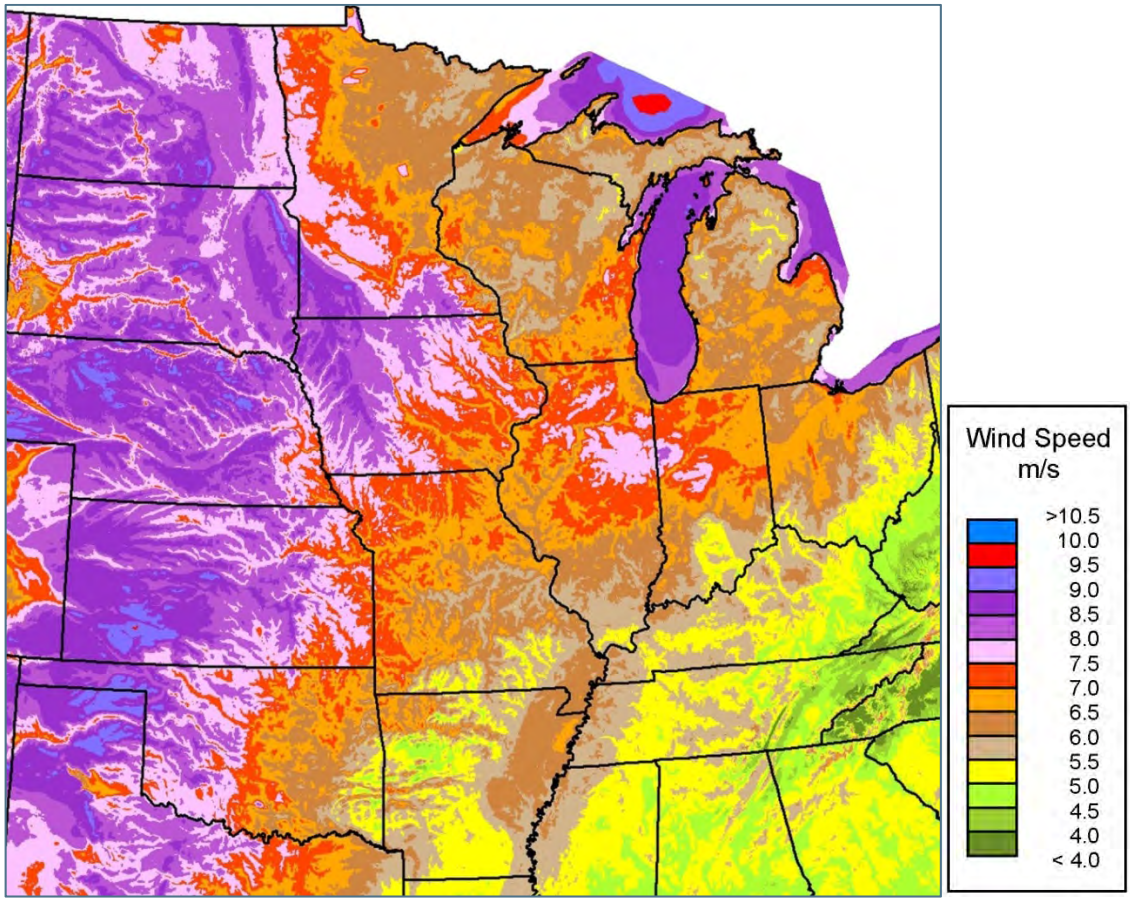

Figure 4-35 Wind resource potential of the eastern and central U.S. at 100 m above ground. Source: Adapted from NREL (2013).

4.17.2 Solar Energy Potential

Solar energy resource potential is a function of average daily solar insolation (see Section 4-2) and is expressed as kWh/m^2/day (available energy (kWh) per unit area (square meters, m^2) per day). Solar resource measurements are reported as either direct normal radiation (no diffuse light) or total radiation (a combination of direct and diffuse light). Diffuse or scattered light, which is common in eastern North America, is caused by cloud cover, humidity, or particulates in the air. Photovoltaic (PV) panels are capable of generating with both direct and diffuse light sources. These measurements do not incorporate losses from converting PV-generated energy (direct current) to alternating current or the reduced efficiency of some PV panels at high temperatures. Figure 4-36 shows the solar generation potential for flat plate PV panels; all current and foreseeable solar generation is PV as concentrated solar technologies are not economically feasible in areas with high amounts of diffuse light. The PV potential assumes flat-plate panels are oriented to the south and installed at an angle from horizontal equal to the latitude of the location. Most of the TVA region has 4–5 kWh/m^2/day of available solar insolation for flat-plate PV panels.

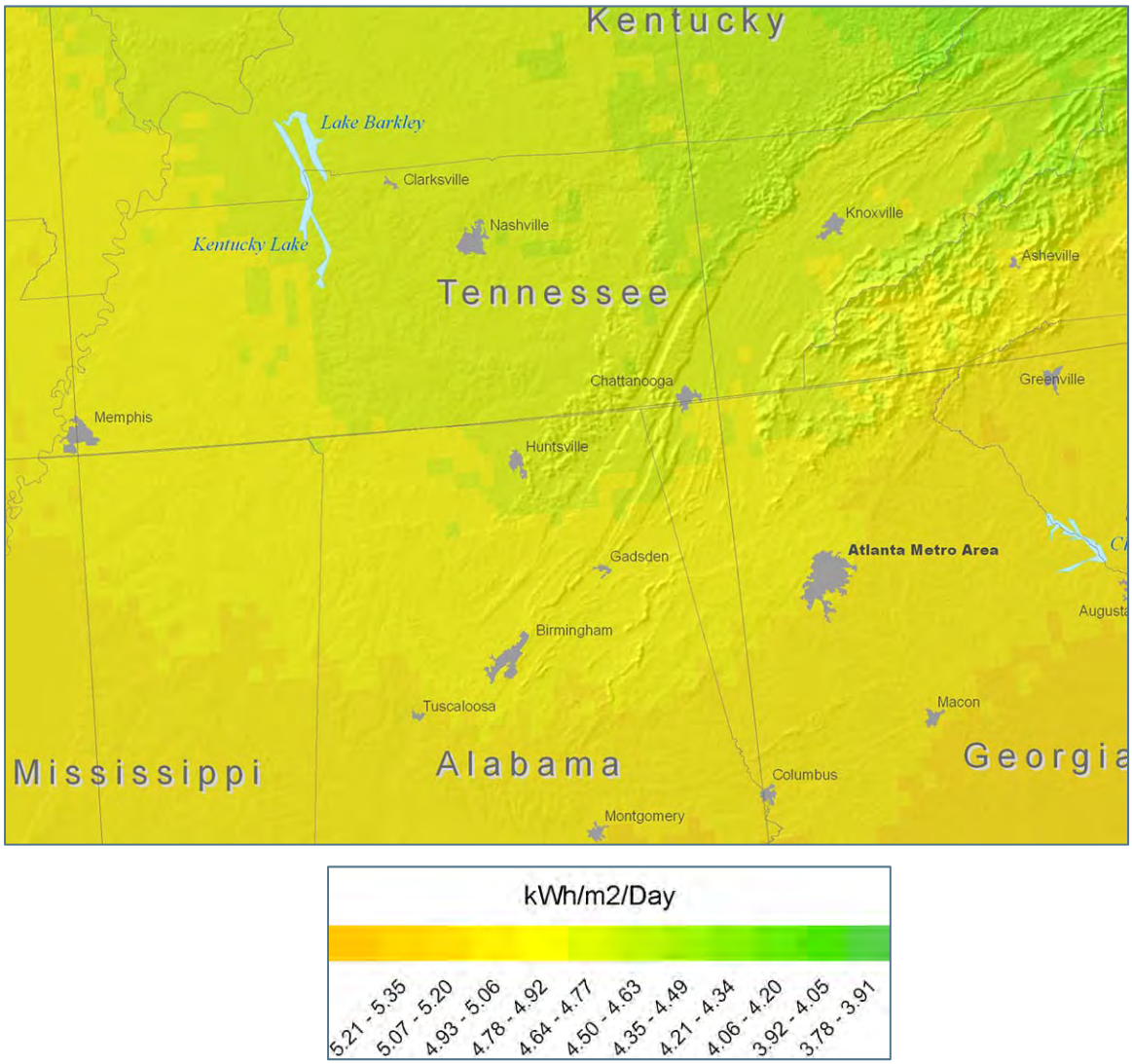

Figure 4-36 Solar photovoltaic generation potential in the TVA region. Source: Adapted from NREL (2008).

Because PV is the most abundant and easily deployable renewable resource, it is difficult to accurately assess a feasible potential value for the TVA region. Following are two distinct evaluation cases developed by the NREL. The first case examines the land area required to meet the entire 2005 TVA electrical load for each state in the TVA region. The second case explores the rooftop PV potential for states in the TVA region.

Land Area Relative to Electrical Load - Denholm and Margolis (2007) studied the land area of each state necessary to meet the state's entire electrical load by PV generation. To determine the annual PV generation per unit of module power, hourly insolation values were used for 2003–2005 from 216 sites in the lower 48 U.S. states. Net PV energy density (the annual energy produced per unit of land area) for each state was calculated using the weighted average of three distinctive PV technologies (polycrystalline silicon, monocrystalline silicon and thin film) which vary in their generating efficiency. Various panel orientations including fixed positions and 1- and 2-axis tracking were included. Tracking panels (i.e., on mounts that pivot to

follow the sun) produce more energy per unit area than fixed panels although their initial installation costs are higher.

The resulting state-level solar electric footprint shows that achieving all of the electrical load is theoretically possible (Figure 4-37). Because PV generation is not a base load resource (only generates during the day), a scaling factor of 1.23 was applied to compensate for losses associated with back-up battery storage. Generating all of the region's electricity by PV is not a practical goal unless very inexpensive and very high capacity energy storage devices become available. Therefore, the conclusion of this analysis is not to assign a specific theoretical solar potential but to point out that the solar resource in the TVA region is plentiful. Relative to other states, the seven TVA region states ranked between 14th (Alabama) and 29th (Kentucky) in PV energy density (Denholm and Margolis 2007).

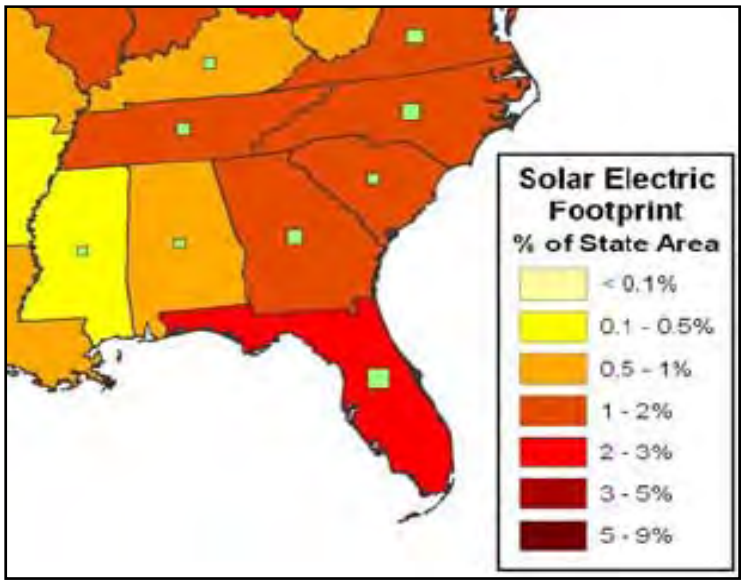

Figure 4-37 Solar electric footprint of southeastern states (2003-2005). Source: Adapted from Denholm and Margolis (2007).

Available Rooftop Area - Paidipati et al. (2008) examined the technical potential of rooftop area available for solar by considering both the PV system power density and available roof space. PV power density is defined as the deployable peak power per unit of land area (expressed in MW peak direct current per million square feet). The power density is based on a weighted-average module efficiency using the market share values for the three most prevalent solar technologies. An additional packing factor of 1.25 was applied to account for space needed for the PV array (e.g., access between modules, wiring, and inverters). The analysis assumed both rooftop areas and solar panel system efficiencies grow over time. The TVA power service area PV rooftop potential in 2010 was roughly 23,000 MW of solar capacity and 27,000 GWh of annual generation. The expected potential in 2015 is roughly 30,000 MW of capacity and 35,500 GWh of annual generation (Figure 4-38).

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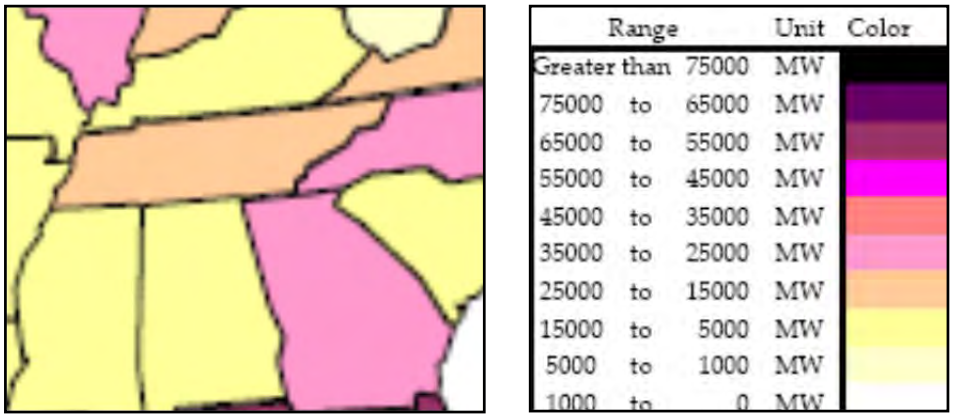

Figure 4-38 Rooftop PV technical potential for states in the TVA region. Source: Adapted from Paidipati et al. (2008).

4.17.3 Hydroelectric Energy Potential

Hydroelectric generation (excluding the Raccoon Mountain pumped storage facility) presently accounts for about 10 percent of TVA's generating capacity (see Section 3.3). TVA has gradually increased this capacity by upgrading the hydro turbines and associated equipment. To date, this program has increased TVA's hydro generating capacity by about 15 percent. This capacity increase would qualify as renewable energy under most renewable portfolio standards.

Hall et al. (2006) surveyed the potential for development of low power (<2 MW) and small hydro (between 2 and 60 MW) projects to be developed in ways that would not require the stream to be obstructed by a dam, such as partial stream diversion through a penstock to a conventional turbine and unconventional ultra-low head and in-stream kinetic energy turbines (see Section 5.3.3) turbines. Feasibility criteria, in addition to the water energy resource, included site accessibility, load or transmission proximity and land use or environmental constraints that would inhibit development. The study identified numerous small hydro and low power sites with an estimated total feasible capacity of 1,770 MW. The study did not evaluate the hydrokinetic potential of sites with little or no elevation difference and thus likely underestimates this potential resource.

Hadjerioua et al. (2012) surveyed the nation-wide potential for hydroelectric generation of at least 1 MW capacity at existing dams lacking hydroelectric generators. The potential of each dam was determined from regional precipitation and runoff, stream flow data and characteristics of the individual dams. Within the Tennessee River watershed, the survey identified a potential capacity of 38.5 MW and potential generation of 144 GWh/year. This total includes six TVA dams with a total potential capacity of 27.5 MW and potential generation of 103 GWh/year. Non-power dams elsewhere in the TVA service area have a potential capacity of about 135 MW; most of these dams are in the Tennessee-Tombigbee, Green River (Kentucky), Tallahatchie River and Green River (Mississippi) drainages and are operated by the U.S. Army Corps of Engineers.

A second recent study by Kao et al. (2014) surveyed the nation-wide potential for hydroelectric generation on undeveloped (i.e., without dams) stream reaches. The total potential capacity in the Tennessee River watershed, assuming the new hydroelectric projects are operated with run-of-river flows, was 1,363 MW and the potential generation was about 8,000 GWh/year. The potential capacity of other watersheds within the TVA service area is less than that of the

Tennessee River watershed. The incorporation of environmental attributes such as protected land designation (e.g., National Parks, Wild and Scenic Rivers, wilderness areas), presence of species listed under the ESA, and recreational uses substantially reduces this potential.

4.17.4 Biomass Fuels Potential

NREL (Milbrandt 2005, NREL 2014) analyzed geographic patterns in the availability of biomass suitable for power generation. These analyses included the solid biomass resources of crop residues, forest residues, primary and secondary mill residues, urban wood waste and dedicated energy crops, and biogas. Biogas is methane produced by the biological breakdown of organic matter in the absence of oxygen. Feedstocks for biogas can come from a variety of sources, including landfills, livestock and poultry manure management, wastewater treatment, and various other industrial and commercial organic wastes and byproducts. If not used for generating power, much biogas would otherwise be burned in open flares. Its use for generating power can replace fossil fuels, therefore resulting in a net reduction in GHG emissions.

Many TVA region counties had a total biomass resource potential of over 100,000 tons/year; these counties are concentrated in Kentucky, western Tennessee, Mississippi and Alabama (Figures 4-39, 4-40). The total potential biomass resource for the TVA region was estimated in 2010 to be approximately 36 million tons/year. This equates to a potential of up to 47,000 GWh[3] of annual biomass energy generation. The TVA region biomass resource potential for each resource type is shown in Figure 4-41.

Forest residues consist of logging residues and other removable material left after forest management operations and site conversions, including unused portions of trees cut or killed by logging and left in the woods. Mill residues consist of the coarse and fine wood materials produced by mills processing round wood into primary wood products (primary mill residues) and residues produced by woodworking shops, furniture factories, wood container and pallet mills and wholesale lumberyards (secondary mill residues) (Milbrandt 2005). Crop residues are plant parts that remain after harvest of traditional agricultural crops; the amount available was adjusted to account for the amount left in fields for erosion control and other purposes. Methane sources include landfills, domestic wastewater treatment plants, and emissions from farm animal manure management systems.

[3] Based on assumed heating values for agricultural crops and wood residues of 7,200–8,570 Btu/lb and for methane of 6,400–11,000 Btu/lb, depending on feedstock type. Assumed generating unit heat rates are 13,500 Btu/kWh for crop and wood residues and 12,500 Btu/kWh for methane.

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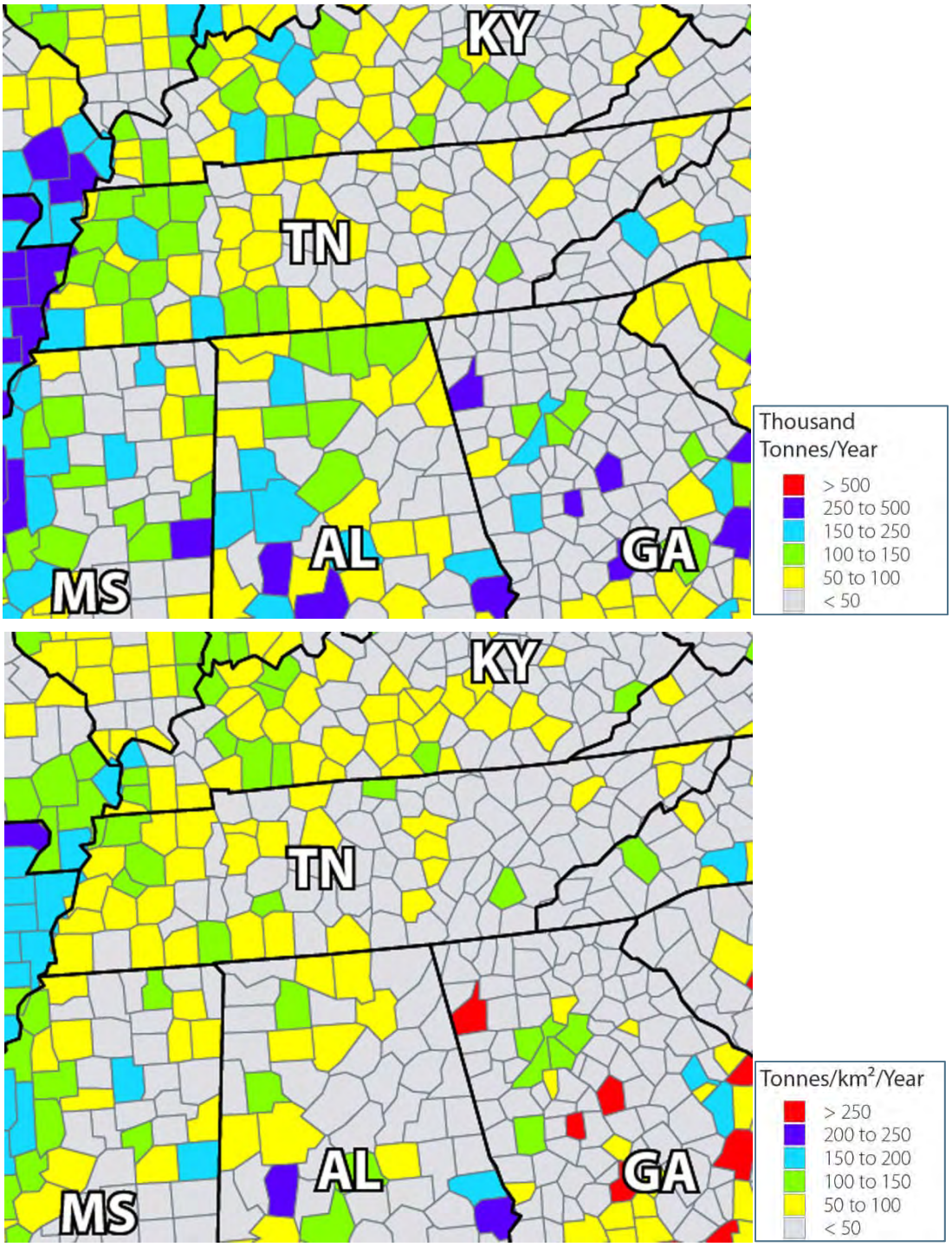

Figure 4-39 Total solid biomass resources in metric tons potentially available in the TVA region by county (top) and per square kilometer by county (bottom). Source: Adapted from NREL (2014).

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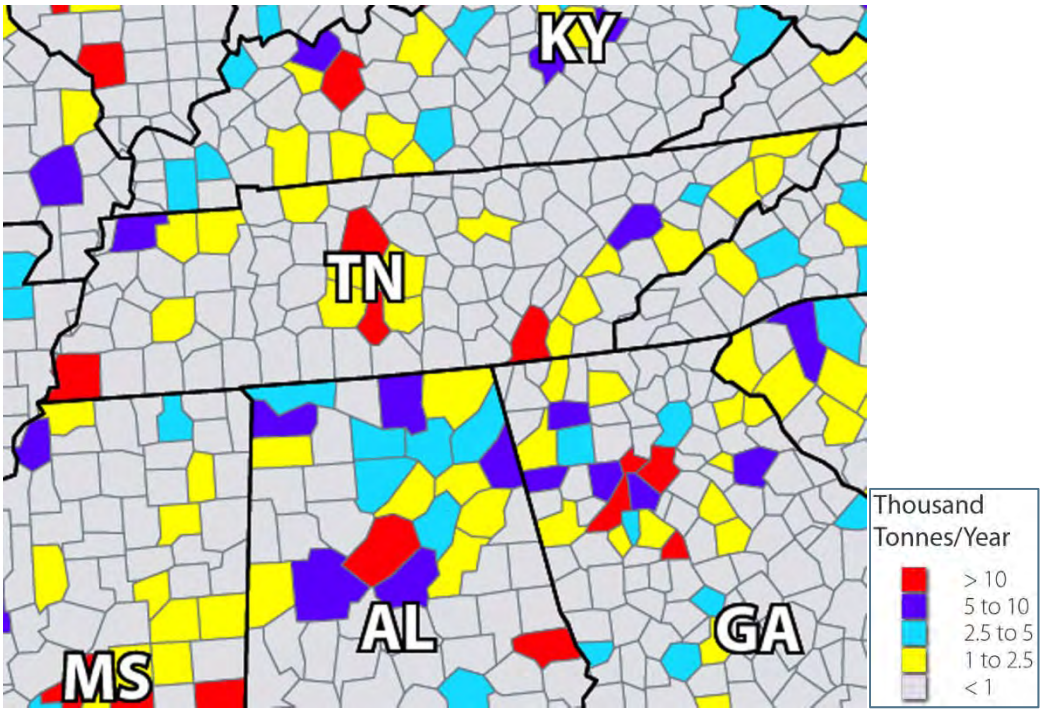

Figure 4-40 Total biogas (methane) resources in metric tons potentially available in the TVA region by county. Source: Adapted from NREL (2014).

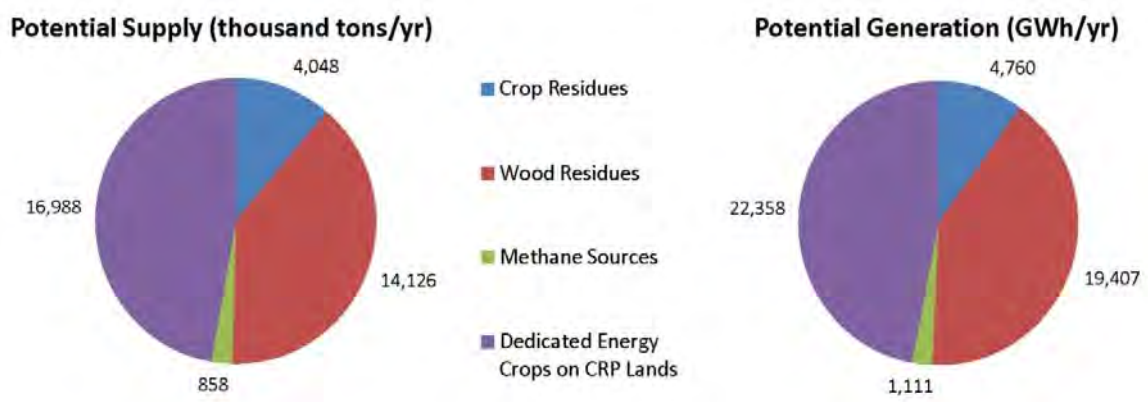

Figure 4-41 TVA region potential biomass resource supply (left) and generation (right). Source: Adapted from Milbrandt (2005) and NREL (2014).

Dedicated energy crops are crops grown specifically for use as fuels, either by burning them or converting them to a liquid fuel, such as ethanol, or a solid fuel, such as wood pellets or charcoal. They can include traditional agricultural crops, non-traditional perennial grasses and short rotation woody crops. Traditional agricultural crops grown for fuels include corn, whose kernels are fermented to produce ethanol and soybeans, whose extracted oil can be converted to biodiesel. Sorghum is also a potential fuel feedstock. Non-traditional perennial grasses suitable for use as fuel feedstocks include switchgrass (*Panicum virgatum*) and miscanthus, also known as E-grass (*Miscanthus x giganteum*, a sterile hybrid of *M. sinensis* and *M.*

sacchariflorus) (Dale et al. 2010). Short rotation woody crops are woody crops that are harvested at an age of 10 years or less. Trees grown or potentially grown for short rotation woody crops in the TVA region include eastern cottonwood, hybrid poplars, willows, American sycamore, sweetgum and loblolly pine (UT 2008; Dale et al. 2010). Plantations of these trees are typically established from stem cuttings or seedlings. With the exception of loblolly pine, these trees readily re-sprout from the stump after harvesting. As described in Section 4.13, the area of short rotation woody crops in the TVA region is small. Milbrandt (2005) analyzed the potential production of dedicated energy crops on Conservation Reserve Program lands, a voluntary program that encourages farmers to address natural resource concerns by removing land from traditional crop production. Growing dedicated energy crops on conservation reserve lands reduces their impact on food production.

The estimate of 36 million potential tons/year does not consider several important factors and may be optimistic. The analysis assumes that all of the biomass is available for use without regard to current ownership and competing markets. Growth in use of biomass will likely result in increased competition for biomass feedstock and reduce the feasibility of some biomass. Some biomass may also not meet environmental and operational standards for electrical generation. The distance between sourcing areas and the generating facility is also important; economical sourcing areas for woody biomass fuels are typically considered to be within a 50 to 75-mile radius of the generating facility (EPRI 2014). Economical transport distances for other biomass fuels are lower. Finally, there is currently no established infrastructure in the TVA region to transport, process and utilize biomass for generating electricity. As biomass fuel markets develop in and near the TVA region, better resource estimates should become available.

TVA has commissioned studies of the biomass potentially available for fueling its coal-fired generating plants. A 1996 study (ORNL 1996) addressed the potential supply of short rotation woody crop and switchgrass biomass grown on crop and pasture lands. The potential supply is greatly influenced by the price paid for biomass, which influences its profitability relative to the profitability of conventional crops. With higher prices, larger amounts of more productive farmland would likely be converted from food production to biomass production, and the western portion of the TVA region has the greatest potential for producing large energy crop supplies.

In a more recent study, Tillman (2004) surveyed the availability of woody biomass for cofiring at eight TVA coal-fired plants (all except Bull Run, Cumberland, and Gallatin). Potential sources included producers of primary and secondary mill residues as described above. These sources produced about 433,000 dry tons/year (approximately 7,153,000 MBtu/yr) of potential biomass fuels within economical haul distances of TVA coal-fired plants. The most abundant material type was sawdust (about 57 percent of the total) and only about two percent of the biomass was not already marketed. At a 2004 price of $1.25–1.50/MBtu, sufficient biomass would be available to support 75–80 MW of generating capacity and the annual generation of 300,000–450,000 MWh of electricity.

Chapter 5 – Energy Resource Options

5.0 Energy Resource Options

This chapter describes the various supply-side and demand-side energy resource options evaluated during the development of the IRP. The descriptions include the general characteristics of the options and the configurations considered in the various IRP strategies.

5.1 Options Evaluation Criteria

While preparing the 2011 IRP, TVA developed a long list of potential energy resource options to include in the various IRP strategies. This list was based on TVA staff expertise, public input during the IRP public scoping and suggestions from the IRP Stakeholder Review Group. To determine the options considered in the 2015 IRP, TVA reviewed the options considered for the 2011 IRP, literature on emerging energy resources, and suggestions received during public scoping and from individuals on the IRP Working Group. TVA also convened the Renewable Information Exchange and Energy Efficiency Information Exchange to obtain additional information about potential resource options from knowledgeable and interested individuals.

The following criteria were used to evaluate the viability of energy resource options:

1. The option must use a proven technology or one that has reasonable prospects of becoming commercially available during the planning period.
2. The option must either be available to TVA within the TVA region or energy from the option must be available to be imported into the TVA region.
3. The option must be economical and contribute to the reduction of emissions of air pollutants, including greenhouse gases (GHGs), from the TVA power supply portfolio in alignment with TVA objectives.

5.2 Options Excluded From Further Evaluation

Section 5.3 of the 2011 IRP EIS (TVA 2011a: 139-143) identified energy resource options considered but eliminated during development of the 2011 IRP. The list of options suggested during scoping for the 2015 IRP/EIS was considerably shorter than the 2011 list. Following is a list of options identified during scoping that, for the reasons stated, are excluded from further evaluation (Table 5-1). Depending on future events, some of these resource options may be considered in more detail in future updates to the IRP.

Chapter 5 – Energy Resource Options

Table 5-1 Energy resource options or actions identified during IRP scoping but excluded from further evaluation.

Energy Resource Option	Reason for Exclusion
Nuclear	
Molten salt thorium-fueled reactor	In research phase and likely not ready during IRP planning period
Traveling wave reactor	In research phase and likely not ready during IRP planning period
Solar	
Remove the cap on purchases of power from residential solar installations	This is a resource acquisition issue outside the scope of the IRP
Prioritize purchase of power from solar farms of 100–500 kW capacity	Solar farms of this capacity are encompassed in the small commercial solar expansion option
Provide financing through incentive programs such as those used by other facilities	This is a resource acquisition issue outside the scope of the IRP
Promote the development of 100-kW solar facilities with integrated thermal storage and backup generation systems	The solar facility is already a candidate for TVA's Renewable Standard Offer program
Hydroelectric	
Install hydroelectric generating units on all suitable non-power dams	This was determined to not be economically viable
Biomass	
Do not use power generated from energy crops grown on land suitable for food production or where forest was cleared to grow energy crops	Biomass energy purchases through TVA's Renewable Standard Offer program must meet fuel standards described at http://www.tva.com/renewablestandardoffer/index.htm. TVA will carefully evaluate the fuel source for any other biomass energy projects
Promote the cultivation of hemp for use in biomass plants or for co-firing with coal	The promotion of hemp cultivation as an energy crop is outside the scope of the IRP. TVA will carefully evaluate the fuel source for biomass energy projects
Combined Heat and Power (CHP)	
Accelerate the use of CHP and waste heat and power generation	While the IRP does not specifically address these energy resources, they are candidates for TVA's renewable energy power purchases and customer-owned demand reduction programs
Address barriers to the use of combined heat and power including discriminatory standby rates and burdensome interconnection standards	This is a resource acquisition issue outside the scope of the IRP

5.3 Options Included in IRP Evaluation

Following is a description of the options included in the various IRP strategies. All of these options meet the criteria listed in Section 5.1. Environmental characteristics of these options, such as land requirements, air emission rates, water use, fuel consumption and waste

production are described in Chapter 7. TVA assumes that all current energy resources will continue to be utilized, subject to scheduled retirements and expiration of PPAs.

5.3.1 Fossil-Fueled Generation

Coal – Existing Facilities

TVA has 44 coal-fired generating units at 10 plant sites with a total capacity of approximately 12,222 MW (Section 3.3, Table 3-2). Several of these units are scheduled to be retired through 2020, at which time TVA anticipates having about 7,900 MW of coal generating capability at seven sites.

TVA purchases the power generated by the 432-MW Red Hills coal-fired generating plant under a PPA extending through 2032. Unlike TVA's coal plants, the Red Hills plant burns low-Btu lignite mined from an adjacent surface mine in circulating fluidized bed boilers.

Coal – New Facilities

Because of the TVA objective to reduce GHG emissions, and in anticipation of regulations restricting GHG emissions, options for new coal generating facilities included facilities with carbon capture and storage (CCS) technology. Two coal generating technologies, supercritical pulverized coal (SCPC) and integrated gasification combined cycle (IGCC), are considered in six configurations. All of these plant types are suitable for base load generation. Because of uncertainty over the viability of CCS, it is unlikely that CCS-equipped plants would be available before 2028.

CCS is a process of reducing GHG emissions by capturing CO_2 produced in a power plant, compressing it, and transporting it to storage (see Section 4.4). The major components of a CCS system include CO_2 capture equipment, a pipeline to transport CO_2 from the plant to the sequestration site, and a compressor for injecting CO_2 into the storage medium. CCS systems add to the cost of a power plant and, because of the energy required to operate them, reduce the efficiency of the plant. There also are legal concerns about potential liabilities for harm that could occur if CO_2 is released during the storage process or after it has been stored.

<u>Supercritical Pulverized Coal</u> – In a pulverized coal plant, finely ground coal is injected into the boiler (furnace) with sufficient air for combustion. The resulting heat boils water circulating in tubes within the boiler to produce steam which turns one or more turbines to generate electricity. Major plant components include the coal receiving and storage area, boiler, steam turbine generator, air emissions control systems, stack, ash and scrubber waste handling and storage facilities, condenser cooling system and associated water supply, wastewater treatment system, office and maintenance buildings, and transformer yard and switchyard connected to the area electrical grid.

SCPC plants produce SO_2, NOx, mercury, CO_2 and ash as a result of burning coal. SO_2 is typically controlled by flue gas desulfurization systems (FGD or "scrubbers"). After fly ash is removed, the exhaust gases are mixed with finely ground limestone or pebble lime; the acidic SO_2 reacts with the basic calcium carbonate to form calcium sulfate or calcium sulfite and CO_2. If the calcium carbonate is in an aqueous solution, water is also produced by the reaction. The calcium-based FGD residue is removed from the waste stream and sold for commercial use or deposited in a landfill. NOx is typically controlled by selective catalytic reduction (SCR) systems. In SCR systems, ammonia is mixed with the exhaust gases as they pass through a catalyst chamber. The resulting chemical reactions produce nitrogen and water. The

combination of SCR, FGD, and particulate control systems also removes much of the mercury. Activated carbon injection may also be used for additional mercury control. SCPC plants require large volumes of water for operation of cooling towers. As previously stated in Chapter 4, new fossil and nuclear plants are assumed to have closed-cycle cooling systems that, relative to open-cycle cooling, decrease the volume of water used and heat discharged to the river but increase the amount of water consumed.

Four configurations of new SCPC plants are considered as supply-side options:

- Single-unit 1x8 800-MW SCPC plant with one steam generator and without CCS
- Single-unit 1x8 600-MW SCPC plant with one steam generator and with CCS
- Two-unit 2x8 1600-MW SCPC plant with two steam generators and without CCS
- Two-unit 2x8 1,200 SCPC plant with two steam generators and with CCS

The differences in capacity between the configurations with and without CCS are due to the energy necessary to operate the CCS systems.

Integrated Gasification Combined Cycle (IGCC) – An IGCC plant converts coal into gas and then burns the gas in a CC plant. The gasification process involves crushing the coal and then heating it in the presence of oxygen and steam. The resulting synthesis gas is cleaned by removing water vapor, CO_2, and sulfur compounds, which can be marketed. The synthesis gas, consisting primarily of hydrogen and carbon monoxide, can then be burned with very low SO_2 and NOx emissions. Heat is typically rejected to the atmosphere in a mechanical draft cooling tower. IGCC plants can burn a wide range of coals and be designed to use other carbon-based fuels, such as biomass. The gasification process can also be modified to produce liquid fuels and various chemicals.

Major plant components include the coal receiving and storage area, air separation unit, gasifier, synthesis gas treatment system (including CO_2 removal), combustion turbines, heat recovery steam generator, gasification ash and chemical byproduct handling systems, condenser cooling system and associated water supply, discharge water treatment system, office/maintenance building, transformer yard and switchyard connected to the area electric grid, pipeline to CO_2 sequestration site, and CO_2 injection wells. The gasification components of an IGCC plant are complex and, at present, relatively expensive. The operating efficiency of an IGCC plant, however, is higher than a CT or conventional coal plant. Although there are few commercial-scale IGCC generating plants operating in the United States, several plants are currently under construction or proposed. The addition of CCS requires CO_2 capture equipment, compressors, pipeline to CO_2 sequestration site, and CO_2 injection wells, which increase the plant construction and operating costs. However, relative to a SCPC plant with CCS, the energy required to operate a CCS system on an IGCC plant is low. TVA does not presently operate any IGCC plants, although it has considered an IGCC plant in the past (TVA 1997).

Two configurations of IGCC plants are considered as supply-side options:

- 500-MW IGCC plant without CCS
- 469-MW IGCC plant with CCS.

Natural Gas – Existing Facilities

TVA operates 15 natural gas-fueled generating facilities: 9 combustion turbine (CT) plants with a total capacity of 5,052 MW and 6 combined cycle (CC) plants with a total capacity of 4,520

MW (see Table 3-5). TVA is also constructing the 1,002-MW three-unit Paradise CC plant, scheduled for completion in 2017, and the 995-MW, two-unit Allen CC plant, scheduled for completion in 2018. CT and CC generating plants are described in more detail below. TVA also purchases power from one CC facility (see Table 3-6).

Combustion Turbine – A simple cycle CT generator consists of an air compressor, combustor, and expansion turbine. Fuel is burned in the combustor, and the heated, high pressure combustion products drive the turbine, which drives the compressor and electric generator. The main fuel is natural gas, with fuel oil being the back-up fuel for most TVA CTs. CTs have low capital cost, short construction times and rapid start-up, and are used for generating peaking power. Both emissions and efficiency are relatively low. Major plant components include the combustion turbines, generators, pipeline connection to the natural gas supply, fuel oil storage tanks, office/maintenance building, and transformer yard and switchyard connected to the area electric grid.

Combined Cycle – A CC plant combines one or more CT generators with a heat recovery steam generator (HRSG). The hot exhaust gases from the CTs pass through the HRSGs, where the steam powers a turbine-generator. Steam turbine exhaust is condensed and returned to the HRSG as feedwater and heat is rejected to the atmosphere in a mechanical draft cooling tower. The primary fuel is natural gas. CC plants are among the most efficient of conventional generators and have been typically used for intermediate capacity additions. They are, however, increasingly being used for base-load generation. Additional power can be generated by duct-firing, where natural gas is combusted in the CT exhaust gas stream to produce additional steam. Duct-firing, however, reduces overall plant efficiency. The main CC plant emissions are NOx, which is usually controlled by SCR systems, and CO_2. CO_2 emissions rates are the lowest of conventional fossil-fueled generators. Major plant components include the combustion turbines, heat recovery steam generator, air emissions control system, forced draft condenser cooling system and associated water supply, pipeline connection to the natural gas supply, office/maintenance building, and transformer yard and switchyard connected to the area electric grid.

Natural Gas – New Facilities

The following configurations of new natural gas generating facilities are considered in the IRP:

Combustion Turbine

- Upgrade of TVA's existing Gleason plant from 360 to 530 MW
- New 590 MW plant with three CTs
- New 786 MW plant with four CTs

Combined Cycle

- 670 MW plant consisting of two CTs and one HRSG
- 1,005 MW (1,152 MW with duct firing) plant consisting of three CTs and one HRSG

The resource options also include short-term "market" purchases and long-term purchases of power from existing CT and CC plants.

Petroleum

As noted above, TVA uses fuel oil as a backup fuel for many of its CT plants. Fuel oil is also used during the startup of coal units. TVA owns a 9-MW diesel-fueled generating plant that serves the Meridian Air Station in Mississippi. TVA also has several PPAs, for a total of 112 MW

of electricity generated by diesel units; these PPAs are expected to be phased out during the planning period. These plants use diesel-fueled internal combustion engines to drive electric generators to provide peaking generation. No additional diesel- or other petroleum-fueled plants are considered in the IRP evaluations, in part due to their high emissions of air pollutants.

5.3.2 Nuclear Generation

Nuclear – Existing Facilities

TVA operates three pressurized water reactors at two sites and three boiling water reactors at one site; these units have a total capacity of 6,708 MW (Table 3-4). The 1,150-MW pressurized water Watts Bar Unit 2 is scheduled to begin generating power in late 2015. Nuclear plants provide base load generation by operating continuously at full power except during refueling or other outages.

Nuclear generating plants use nuclear fission reactions to heat water to produce steam, which is then used to generate electricity. Nuclear plants in the United States are cooled and moderated by ordinary water. The two types of these “light water” reactors are pressurized water reactors and boiling water reactors. In the more common pressurized water reactors, coolant water is pumped under high pressure to the reactor core, and then the heated water transfers thermal energy to a steam generator. High pressure in the primary coolant loop prevents the water from boiling within the reactor. In boiling water reactors, coolant water pumped through the core boils and the steam then directly drives the turbine. In both designs, steam exiting the turbines is cooled in a condenser and recirculated. A separate water system cools the condenser, either with water circulated directly from a nearby reservoir or other water source, or circulated through a cooling tower. Major nuclear plant components include the reactor containment building housing the reactor vessel; the steam generators and reactor coolant pumps; turbine generators; spent fuel storage facility; condenser cooling system and associated water supply; office, control, and service buildings; wastewater treatment facility; transformer yard; and switchyard connected to the area electric grid. Nuclear plants produce very few air emissions, no direct CO_2 emissions, and discharge few water pollutants. They require large volumes of cooling water and, if operated in closed-cycle cooling mode, consume large volumes of water (see Section 4.7). Spent nuclear fuel is highly radioactive and requires careful management.

Nuclear – New Facilities

In addition to the continued operation of the existing nuclear units and the completion of Watts Bar Unit 2, nuclear energy options available for selection in the IRP include the following:

Pressurized Water Reactor – Under this option, TVA would complete one or both of the partially constructed 1,260-MW Bellefonte Nuclear Plant Units 1 and 2 pressurized water reactors. Following the completion of the 2011 IRP, TVA issued a Final Supplemental EIS and Record of Decision for the completion and operation of Bellefonte Nuclear Plant Unit 1 (TVA 2011d). TVA began construction of this unit and the adjacent Bellefonte Unit 2 at the Bellefonte site in the 1970s and proceeded until 1988 when work was halted due to the forecasted decreased load growth. TVA cancelled the construction permits for both units in 2005. In early 2009, the Nuclear Regulatory Commission (NRC) reinstated the permits at TVA’s request. After a 2011–2013 increase in engineering and other work on Unit 1, TVA reduced spending on it in FY 2014 while continuing to maintain both units for eventual completion.

Advanced Pressurized Water Reactor – This option is characterized by the 1,117-MW Advanced Passive 1000 (AP1000) pressurized water reactors that TVA has evaluated for

construction at its Bellefonte Nuclear Plant site. Similar AP1000 plants are under construction by other utilities at the Vogtle site in Georgia and the Sumner site in South Carolina.

In 2007, TVA, as a member of the NuStart Energy Development consortium, submitted a Combined Licensing Application to NRC for the construction and operation of two Westinghouse AP1000 advanced passive pressurized light water nuclear units at its Bellefonte Nuclear Plant site. The two AP1000 units would have a total capacity of about 2,200 MW. TVA has not yet proposed constructing the two AP100 units and, at TVA's request, NRC deferred processing the licensing application.

Extended Power Uprate of the Three Browns Ferry Units – Under this option, the capacity of each of TVA's Browns Ferry units would be increased by 134 MW, for a potential total capacity increase of 402 MW. The uprates would require modifications to several plant components including the reactor feed pumps, condensate pump motors and main generators. TVA previously evaluated these uprates in earlier NEPA reviews and the TVA Board approved proceeding with the uprate actions in 2001 and 2002. TVA expects to resubmit the necessary license amendment requests to NRC and anticipates sequentially completing the three uprate projects by 2020.

Small Modular Reactor (SMR) – SMRs are a new nuclear power plant design using factory-built reactors of less than 300 MW. Several designs are under development. The characteristics of the SMR option are based on the Babcock & Wilcox mPower SMR and consist of a two-unit configuration with a net summer dependable capacity of 334 MW.

TVA has worked with Babcock & Wilcox since 2009 on the development of the mPower SMR. In 2012, the project won a Department of Energy grant to help fund the design and licensing of the mPower SMR. The licensing activities included the development of a license application for the construction and operation of up to four 180-MW (nameplate capacity) SMR units by TVA at TVA's Clinch River Site in Roane County, Tennessee. Babcock & Wilcox recently slowed its development of the mPower SMR. TVA subsequently shifted to developing an application for a NRC early site permit for the potential construction of SMRs at the Clinch River Site. The early site permit would not specify the specific SMR design to be built on the site. TVA has not yet decided whether to propose construction and operation of SMRs at this site or elsewhere.

5.3.3 Renewable Generation

TVA presently provides renewable energy produced from TVA facilities and acquired by PPAs. The renewable energy sources are hydroelectric, solar, wind and biomass-fueled facilities. As described below, renewable energy from these sources is considered in the IRP. Geothermal generation is not considered because it is not available in or near the TVA region.

Hydroelectric – Existing Facilities

TVA presently operates 109 conventional hydroelectric generating units at 29 dams with a combined capacity of 3,802 MW (Section 3.3). As described in Section 3.3, TVA anticipates continuing its program of modernizing hydroelectric turbines, although this program is not evaluated in this IRP process as a capacity expansion option. This program, along with projected long-term changes in regional hydrology, is anticipated to increase hydroelectric capacity by about 109 MW during the planning period. TVA has a long-term PPA for 405 MW of hydroelectric capacity from SEPA (see Section 3.-4). TVA hydroelectric plants are primarily operated to provide peaking power; during periods of abundant precipitation, they may also be operated to provide intermediate power. Their operation is described in more detail in the

Reservoir Operations Study (TVA 2004). All of the TVA conventional hydroelectric units are assumed to operate through the IRP planning period.

Hydroelectric generation uses the gravitational force of falling or flowing water to generate electricity. It is a form of renewable energy, as the water is not consumed while generating electricity. Operating costs are very low and no air pollutants are emitted. The reservoirs necessary for most conventional hydroelectric projects require large areas of land, but typically provide benefits in addition to electricity such as flood control, water supply, and recreation. Typical components of conventional hydroelectric generating facilities include a dam, penstock (a pipe or sluice that transmits water from the dam to the turbine), gates to control the flow of water through the penstock, turbines, generators, and electrical transformers and switchyard connected to the area electrical grid. The turbines and generators are typically enclosed in a powerhouse, which may be located on the downstream face of the dam or at some distance downstream of the dam. The generating potential is proportional to the head: the difference in elevation between the water upstream of the dam and the turbines.

Hydroelectric – New Facilities

Conventional Hydroelectric Facilities – In addition to the continued operation of the existing hydroelectric plants, the IRP evaluates the following conventional hydropower options:

- Addition of a 40-MW turbine to an existing TVA hydroelectric plant to capture energy in water that is presently being spilled (i.e., released without passing through a generator) during high flow periods
- Addition of a 30-MW turbine to an existing hydroelectric TVA dam where there is available space

The conventional hydroelectric resource options also include purchases of power from existing hydroelectric facilities. The Brookfield Renewable Energy Group hydroelectric facilities on the Little Tennessee River system are potential candidates for these purchases. TVA previously had long-term PPAs for power from these four facilities when they were owned by the Tapoco Company and Alcoa Power Generating Inc., subsidiaries of Alcoa, Inc.

Run of River Hydroelectric Facilities – As described in Section 4.17.3, the potential exists to develop small (between 2 and 60 MW) and low power (<2 MW) hydroelectric facilities on streams in the TVA region. These facilities include generators not requiring a dam, as well as the addition of small turbines to existing dams. Hydroelectric generators not requiring a dam, often called kinetic energy turbines or hydrokinetic generators, are currently under development by several companies in the U.S. and elsewhere and are largely experimental at this time. The IRP evaluates the addition of run-of-river hydroelectric generation in 25-MW blocks potentially composed of multiple generating facilities.

Wind – Existing Facilities

TVA purchases wind energy from nine wind farms with a total nameplate capacity of 1,542 MW (Section 3.4, Table 3-7). Wind turbines generate electricity by capturing the wind's energy with blades that operate as airfoils. Land-based utility-scale wind turbines are a mature technology and one of the most rapidly growing sources of electricity generation. Most utility-scale wind turbines presently being deployed have generating capacities of 1.7–3.3 MW, towers 100 m tall, and blade diameters of 82–120 m. Turbines have increased in size for several years and the average capacity of turbines installed in 2014 was 2.1 MW (AWEA 2015). Commercial wind turbines are usually deployed in arrays commonly called wind farms. The average size of wind

farms has also increased and new wind farms often exceed 200 MW in capacity. The layout of turbines within a wind farm depends on the local terrain and land use conditions. On Appalachian ridges, such as Buffalo Mountain wind farm, turbines are typically in single or multiple strings along ridgetops. On Midwestern farmland and Great Plains grasslands and shrublands, turbines are frequently arranged in clusters or parallel strings (Denholm et al. 2009). In addition to the wind turbines, the other major wind farm components are an electrical substation connected to the area electric grid, access roads, and electrical lines (typically underground) connecting the turbines to the substation.

Wind – New Facilities

Because TVA is not eligible for investment and production tax credits available to private wind developers, TVA assumes future additions of wind generating capacity will be through PPAs where the use of these financial incentives by developers can lower the cost to TVA. The IRP evaluates the acquisition of wind energy from three source areas, which differ in capacity factor and other operating characteristics:

- In-Valley – wind energy generated within the TVA service area. Wind capacity additions in this area are evaluated as 120-MW blocks.
- MISO/SPP – wind energy generated within the service areas of the Midcontinent Independent System Operator (MISO) and the Southwest Power Pool (SPP). The MISO territory includes much of the Midwest and the Dakotas. The SPP territory includes Kansas, Missouri, Oklahoma, and the Texas panhandle. Almost all of TVA's current wind energy is generated in these regions. Wind capacity additions in these areas are evaluated as 200-MW blocks.
- HVDC – wind energy generated in the SPP and the rest of Texas and transmitted by proposed high voltage direct current (HVDC) transmission lines to the western edge of the TVA service area. This option is similar to the proposed Clean Line Plains and Eastern HVDC line that would terminate in the Oklahoma panhandle, and the Pattern Energy Southern Cross HVDC line that would connect to the Texas transmission grid in eastern Texas. Both of these proposed lines are designed to transmit renewable energy (primarily wind energy) eastward to the southeastern U.S. Wind capacity additions delivered by HVDC transmission lines are evaluated as 200-MW blocks.

Solar – Existing Facilities

TVA owns 16 small photovoltaic (PV) installations with a combined capacity of about 400 kW. TVA currently purchases about 68 MW (direct current, equivalent to about 58 MW AC) of power from numerous PV installations through the Renewable Standard Offer and Green Power Providers programs (see Section 3.5). The capacity limits for individual facilities have influenced the sizes of facilities in these programs. Of the approximately 230 facilities having greater than 50 kW DC capacity (i.e., large commercial, industrial, and utility-scale facilities) enrolled in these programs, 60 percent have capacities of 50–200 kW, 35 percent have capacities of 200 kW–1 MW, and 5 percent have capacities greater than 1 MW.

Although there are several types of solar electrical generation, all of the current and foreseeable solar generation in the TVA region is by PV systems. Most of these use crystalline silicon PV panels consisting of multiple PV cells packaged in flat, glass-faced modular rectangular panels with an area of 15–20 square feet and a capacity of 250–350 watts DC. Thin-film PV panels have received limited use in the TVA region. PV panels are mounted on buildings or on free-standing frames and are aligned to face south. The use of mounting systems that track the sun

along one or two axes results in increased power generation but also increases installation costs. Less than 5 percent of solar generation in the TVA region is currently generated by tracking systems. A more recent and still evolving approach is to integrate PV cells into building materials such as roofing and siding.

Solar – New Facilities

As with wind generation, TVA is not eligible for investment and production tax credits available to private solar developers. TVA therefore assumes the great majority of future additions of solar generating capacity will be obtained through PPAs and purchases through the Green Power Providers program. TVA is considering four solar expansion options through PPAs which differ in cost and performance characteristics:

- Utility Scale 1-Axis Tracking in 25 MW AC (29.4 MW DC) blocks each consisting of one or more PV facilities with a minimum capacity of 1 MW
- Utility Scale Fixed Tilt in 25 MW AC blocks consisting of one or more PV facilities with a minimum capacity of 2.5 MW
- Large Commercial Scale in 25 MW AC blocks consisting of multiple primarily rooftop PV facilities
- Small Commercial Scale in 25 MW AC blocks consisting of multiple primarily rooftop PV facilities

Biomass – Existing Facilities

Biomass power plants can provide base load power and are one of few renewable resources with generation that can be scheduled. TVA generates electricity by co-firing methane from a nearby sewage treatment plant at Allen Fossil Plant and by co-firing wood waste at Colbert Fossil Plant. This co-firing provides a total capacity of about 15 MW. TVA presently purchases about 64 MW of biomass-fueled generation, 53 MW through the Renewable Standard Offer and Green Power Providers programs and 11 MW through other PPAs. Following is a description of the types of biomass-fueled generating facilities in the TVA region.

<u>Biogas-Fueled Facilities</u> – Landfill gas, a mixture of methane and CO_2, is produced by the decomposition of organic material in landfills. Air quality regulations require many landfills to prevent the release of this methane to the atmosphere. These landfills have installed methane collection systems. When used for generating electricity, the gas is cleaned to remove sulfur and other compounds and then used to fuel internal combustion engine-generators (modified diesel generator sets) with typical outputs of about 1 MW. System components include gas collection wells, pipes to transport the gas to a central point, the gas cleanup facility, a flare to burn excess gas, engine-generators, and a connection to the area electricl grid. The engine-generators are usually housed in a small building. Typical system components for generating electricity from methane produced by composition of other types of organic material, particularly from sewage treatment plants and livestock manure management systems, are, except for the gas collection system, similar to those used for landfill gas systems. TVA currently purchases 43 MW of power generated by landfill gas systems.

Methane from wastewater treatment is another biomass-derived fuel. Many treatment plants collect methane generated during anaerobic digestion processes. This methane can be used to fuel internal combustion engine-generators similar to those that burn landfill gas. TVA currently purchases power from a 1-MW facility of this type. TVA also generates power by injecting methane from a Memphis wastewater treatment plant into boilers at the Allen Fossil Plant.

Solid Biomass-Fueled Facilities – The most readily available types of solid biomass are forest residues, mill residues, and crop residues (Section 4.17.4). Municipal solid waste is a potential fuel in urban areas. While TVA does not anticipate constructing or operating facilities using municipal solid waste as fuel, TVA would consider purchasing power from such a facility. Dedicated biomass crops are also a potential fuel, although their supply in the TVA region is presently very limited. The two principal types of solid-fueled biomass generation are co-firing at coal plants and dedicated biomass facilities. TVA periodically co-fires wood waste at the Colbert plant and has experimentally co-fired wood waste at the Allen and Kingston plants. Fuel availability and cost are major factors for both co-firing and dedicated biomass facilities. Because of transportation expenses, fuel sourcing areas are typically no farther than 50-75 miles from the biomass plant (EPRI 2014). This constraint can limit the amount of co-firing or the size of a dedicated facility.

TVA currently buys about 20 MW of power generated by mill waste and wood chips at a Weyerhaeuser plant in Mississippi. This is part of the plant's total output from boilers that produce steam and electricity to operate the plant. TVA also buys about 1.2 MW of power from two small dedicated biomass -generating facilities burning waste wood. One of these facilities directly burns the wood and the other gasifies the wood to produce methane burned in an internal combustion engine-generator.

Biomass – New Facilities

TVA is considering two options for new biomass generation. For both these options, electricity would be the only product (i.e., they would not be combined heat and power facilities):

- New 115-MW dedicated biomass facility
- 75-MW repowered coal unit

Dedicated Biomass Facility – The most common types of dedicated facilities using solid biomass fuels are stoker boilers, cyclone boilers and circulating fluidized bed boilers (EPRI 2010). Because of fuel availability constraints, the typical capacity of these facilities has been about 50 MW. Typical components of these facilities include the fuel receiving and unloading system, fuel screening and grinding system, fuel stockpile area, fuel conveyor and feed bunker, boiler, turbine generator, cooling water supply and mechanical draft cooling tower, air heater, air emissions control systems, stack, transformers and electrical switchyard, connection to the area electrical grid, and office and service buildings. Emissions control systems typically consist of fabric filters or electrostatic precipitators to control particulates and SCR or selective non-catalytic reduction systems to control NOx. Biomass gasification also has potential for power generation, although most facilities built to date have been relatively small and used in combined heat and power applications (EPRI 2010).

Repowered Coal Unit – An alternative to the construction of new dedicated biomass facilities is the conversion of existing coal-fired boilers to only burn biomass. The required plant changes depend on the type of fuel and its pretreatment, and can require construction of a new fuel handling system and extensive boiler modifications. Dedicated biomass facilities are technically suitable for baseload generation but fuel sourcing limitations and costs have made repowering coal units to burn biomass infeasible in the past.

5.3.4 Energy Storage

Energy storage facilities are used to store energy generated at times of low demand and then return it to the grid at times of high demand. The energy stored in the facility is typically

generated by low-cost facilities such as nuclear and large coal units which operate most efficiently at a constant full load. Stored energy can also be generated by intermittent facilities, such as wind farms, operating at off-peak times. Using the stored energy during high peak demand periods can offset the need for more expensive, less efficient generation such as combustion turbines. Storage facilities can provide both peak and intermediate power.

Energy Storage – Existing Facilities
TVA operates one large energy storage facility, the Raccoon Mountain Pumped Storage Plant. This plant has a capacity of 1,615 MW and can generate 1,532 MW for 20 hours when fully charged. Its continued operation is assumed in the IRP.

Pumped storage facilities operate by pumping water from a lower reservoir through pipes to a higher reservoir. The pumps can then be reversed to operate as turbine-generators when water flows from the higher reservoir to the lower reservoir. The amount of electricity generated is a function of the size of the storage reservoirs and the elevation difference (head) between the higher and lower reservoirs. Typical components of pumped storage facilities include the lower reservoir (which, in the case of Raccoon Mountain, may be an existing reservoir), upper reservoir, pipes connecting the reservoirs, reversible pump/turbine generators, electrical transformers and switchyard, connection to the area electrical grid, and office and service buildings. Depending on whether the pipes connecting the reservoirs are on the surface or underground, the pump/generators are located in an above-ground powerhouse or in an underground chamber. Large pumped storage facilities such as Raccoon Mountain have an efficiency of about 80 percent, meaning that for every 5 units of electricity used to pump water into the upper reservoir, 4 units are recovered during the generating cycle. Although pumped storage facilities are net consumers of energy, they can be economically desirable because they consume energy during low-value periods and produce energy during high-value periods. Their operating regime also complements the operation of intermittent resources such as solar and wind generation.

Energy Storage – New Facilities
The following new energy storage facilities are considered in the IRP:

- Pumped storage facility with a capacity of 850 MW
- Compressed air energy storage facility with a capacity of 330 MW

Compressed air energy storage (CAES) combines features of combustion turbines and pumped-hydro storage to provide peaking or intermediate power. CAES uses off-peak energy to compress air by a motor/generator compressor train, inject it into wells, and store it in an underground reservoir. During periods of high demand, the stored, pressurized air is released, heated, and passed through natural gas-fired high- and low-pressure turbines which drive the motor/generator. Turbine exhaust gas is used to heat the released air. A variation of this basic design, CAES with humidification, adds water vapor to the air entering the high-pressure turbine. A CAES facility would be used primarily for peaking power generation.

Surface facilities include the power block with the motor/generator compressor train, electrical transformers and switchyard, and office and service buildings, as well as the well field, compressed air pipelines, and a natural gas supply pipeline. TVA has investigated potential sites in northeast Mississippi that would use depleted natural gas fields in the Black Warrior geologic formation for the reservoir.

5.3.5 Energy Efficiency and Demand Response Options

TVA's current EEDR portfolio is described in Section 3.5. TVA is continuously evaluating its EEDR portfolio and will make modifications, including the adoption of new programs, in response to market conditions, emerging technologies, and other factors.

For the IRP modeling, EE options were defined as discrete 10-MW blocks for the residential, commercial, and industrial sectors. The capacity factors for these sectors are 57 percent for residential, 68 percent for commercial, and 80 percent for industrial. Blocks associated with each sector have additional specific attributes including their EE program components (as listed in Section 3.5) and characteristics including energy (GWh), growth rate, service life, and cost. Within each sector blocks were grouped into three pricing tiers. The defined blocks available as selectable options during the modeling are similar to other energy options. See IRP Appendix C.

Chapter 6 – Alternatives

6.0 Alternatives

As described in Chapter 2, TVA developed five resource planning strategies and a set of associated capacity expansion plans corresponding to the five scenarios. These five strategies, A through E, are the basis for the action alternatives in this SEIS. The No-Action Alternative is the Baseline Case, a resource plan that was developed using the current methodology of resource optimization, consistent with the direction established by the 2011 IRP. The Baseline Case also incorporates asset decisions approved by the TVA Board after the completion of the 2011 IRP.

This chapter describes the capacity expansion plans associated with each alternative strategy, presents the metrics used to evaluate the strategies and summarizes the environmental impacts of the alternatives. It also describes the Target Power Supply developed following the public review of the Draft IRP and SEIS.

6.1 Alternative Strategies and Associated Capacity Expansion Plans

Following is a summary of the capacity expansion plans, also known as resource portfolios, developed for each of the alternative strategies. Capacity additions and reductions are quantified in megawatts (MW) and energy additions and reductions are quantified in gigawatt hours (GWh).

All capacity expansion plans are based on the assumption that Watts Bar Nuclear Plant Unit 2, the Paradise CC plant, and the Allen CC plant will be completed as currently scheduled. These three plants are not included in the discussions of nuclear and gas-fired capacity expansions in the following strategy descriptions. The capacity expansion plans are also based on the assumption that all pending coal unit or plant retirements described in Section 3.3 will occur as scheduled, with all retired by 2020. Several current PPAs are assumed to expire during the planning period, including wind energy PPAs from 2024 through 2032, PPAs for diesel-generated power totaling 115 MW, and the Red Hills lignite coal plant PPA in 2032.

All capacity expansion plans considered in the IRP have the following common features:

- Extended power uprate of the three Browns Ferry Nuclear Plant units, adding 402 MW of capacity in 2018–2019
- No other nuclear capacity expansion
- No coal, biomass or energy storage capacity expansion
- Continuation of the current Renewable Standard Offer (RSO) and related Solar Solution Initiative (SSI) programs until 2020, adding a total of at least 325 MW of predominantly solar capacity and small amounts of wind and biomass-fueled generation
- All other solar capacity additions are utility scale, either 1-axis tracking or fixed tilt.

In the following descriptions of the alternative strategies, the stated capacities are net summer dependable capacities (see Section 2.2) except for wind and solar generation, which are nameplate capacities. For wind and solar generation, net summer dependable capacities are significantly less than nameplate capacities due to their intermittent nature. For the other energy resources, the difference between net summer dependable capacities and nameplate capacities is relatively small.

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6.1.1 Baseline Case – No Action Alternative

The Baseline Case was developed using the current methodology of resource optimization, consistent with the direction established by the 2011 IRP under conditions similar to the Current Outlook Scenario. The Baseline Case also incorporates asset decisions approved by the TVA Board, subsequent to the completion of the 2011 IRP. Energy efficiency and renewable energy expansions are scheduled inputs with fixed capacities instead of the discrete selectable units in Strategies A–E.

Figure 6-1 shows the cumulative capacity expansions by resource type, as well as the overall capacity mix and energy mix at the end of the planning period for the Baseline Case. The primary sources of new generation are natural gas-fueled, from six new 786-MW CT plants beginning in the early 2020s and one new 1,005-MW CC plant in the early 2030s. Additional air pollution control equipment would be installed on the seven less-controlled Shawnee Fossil Plant coal units in the mid-2020s. No additional coal retirements beyond those already announced would occur. Demand response would average about 360 MW until 2030 and then decline to 0. Energy efficiency would increase by about 70–120 MW per year to a total of 2,026 MW by 2033. Non-hydro renewable energy increases would be relatively modest and restricted to the RSO and SSI programs early in the planning period. Total non-hydro renewable generation would decline late in the planning period due to the expiration of wind PPAs.

6.1.2 Strategy A – The Reference Plan

Strategy A is TVA's traditional least-cost optimization plan developed without any targets for particular types of energy resources. Solar capacity expansion is capped at 300 MW/year and 4,000 MW of total capacity reflective of a reasonable development schedule for utility-scale expansion; no other constraint is placed on the selection of energy resources. Following is a summary of the five capacity expansion plans developed for Strategy A and illustrated in Figure 6-2 by resource type.

- Demand Response (DR) – Expansion from 322 MW (Scenarios 2 and 5) to 515 MW (Scenario 1).

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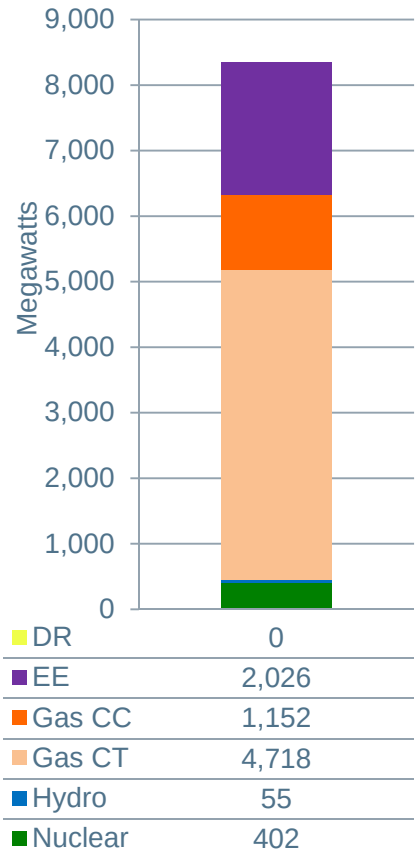

Figure 6-1 No Action Alternative capacity expansion by resource type.

- Energy Efficiency (EE) – Expansion to an average of about 2,720 MW by 2033 with some variation among the scenarios in the timing of the expansion.
- Natural Gas-fired Generation – New CT plants added under all scenarios, with the number ranging from one plant at the end of the planning period under Scenario 4 to five to six new plants beginning in the early 2020s under Scenarios 1, 2 and 3. No new CC plant would be built. Under Scenarios 1 and 3 there would be PPAs for CC gas-fired generation which expire by 2033. Varying amounts of power from CT and CC plants would be acquired by short-term market purchases, primarily early in the planning period for CCs and from the early 2020s on for CTs.
- Coal – Under Scenarios 1, 2, 4 and 5, the seven Shawnee units without FGD and SCR systems continue to operate until 2025, when they would be retired. Under Scenario 3, they receive FGD and SCR systems and operate through the end of the planning period. Under Scenarios 4 and 5, Kingston Fossil Plant is retired in the early 2020s, and all Shawnee units are retired in the mid-2020s. The operating coal capacity at the end of the planning period in 2033 would be 6,610–7,506 MW under Scenarios 1, 2 and 3 and about 5,000 MW under Scenarios 4 and 5.

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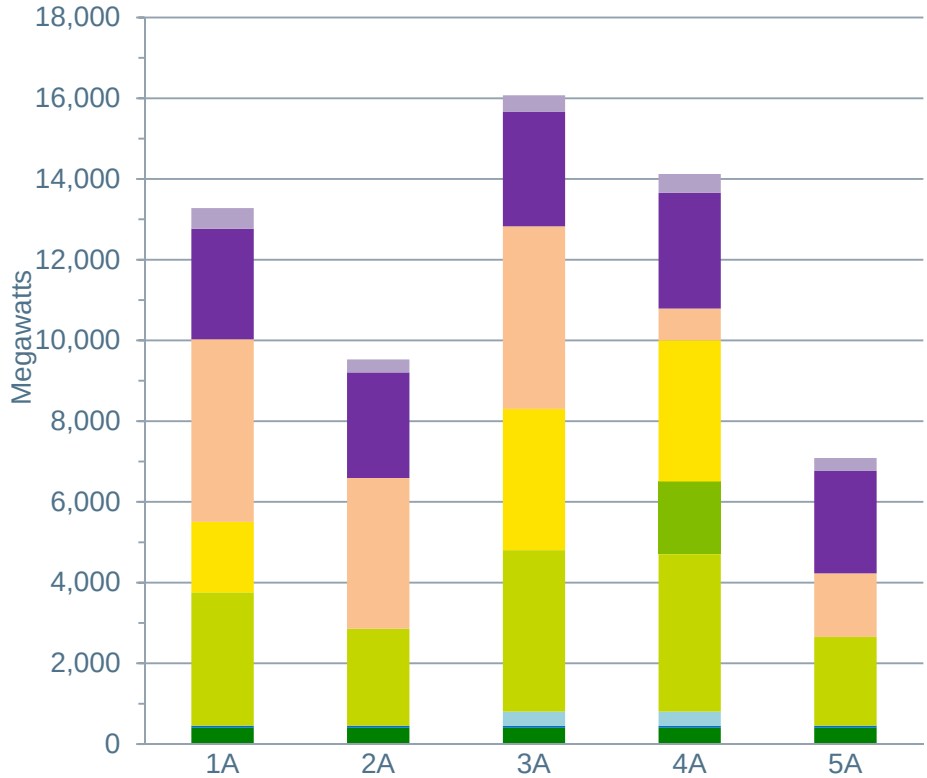

	1A	2A	3A	4A	5A
DR	515	322	414	469	322
EE	2,735	2,616	2,834	2,864	2,537
Gas CT	4,522	3,736	4,522	786	1,573
Wind HVDC	1,750	0	3,500	3,500	0
Wind MISO	0	0	0	1,800	0
Solar Tracking	3,300	2,400	4,000	3,900	2,200
Hydro PPA	0	0	347	347	0
Hydro	55	55	55	55	55
Nuclear	402	402	402	402	402

Figure 6-2 Strategy A capacity additions through 2033 by resource type for the five scenarios.

- Wind – Under Scenario 1, wind energy generated by 1,750 MW of wind capacity in the southern Great Plains/Texas would be imported to TVA via HVDC transmission; this quantity would double under Scenarios 3 and 4. An additional 1,800 MW of wind capacity in the MISO area would be acquired under Scenario 4. Wind energy additions begin in 2020 under Scenario 4 and occur near the end of the planning period under Scenarios 1 and 3.
- Solar – At least 2,200 MW of utility scale, tracking solar PV is added under all scenarios; under Scenarios 3 and 4, almost twice that amount is added. The solar additions start in the early 2020s under Scenarios 1, 3 and 4, and in the mid-2020s under Scenarios 2

and 5. For all scenarios, solar capacity increases fairly uniformly through the end of the planning period.

- Hydroelectric – New hydro capacity is provided by the run-of-river and existing dam space addition options under all scenarios. Hydro PPAs are also selected under Scenarios 3 and 4.

6.1.3 Strategy B – Meet an Emission Target

Strategy B contains the target of reducing system-wide direct emissions of CO_2 by 50 percent (to 557 lbs/MWh) by 2033 and by 80 percent by 2050 from 2005. This strategy is not designed to analyze compliance with any proposed GHG emissions reduction legislation or regulation, such as the former American Clean Energy and Security Act of 2009 or the currently proposed Clean Power Plan. Instead, Strategy B is designed to compare energy resource portfolios constructed to achieve the specified CO_2 reduction targets with other portfolios developed without this constraint. Solar capacity expansion is capped at 300 MW/year and 4,000 MW of total capacity. Any new coal units must have CCS. Following is a summary of the five capacity expansion plans developed for Strategy B and illustrated in Figure 6-3 by resource type.

- Demand Response (DR) – Expansion varies from 271 MW under Scenario 2 to 575 MW under Scenario 1.
- Energy Efficiency (EE) – Expansion to an average of about 2,730 MW by 2033 with some variation among the scenarios in the timing of the expansion.
- Natural Gas-fired Generation – New CT plants added under all scenarios with the number ranging from one 786-MW plant at the end of the planning period under Scenario 4 to five to six new 786-MW plants beginning in the early 2020s under Scenarios 1, 2 and 3. No new CC plants would be built and there would be no new power purchase agreements (PPAs) for gas-fired generation. Varying amounts of power from CT and CC plants would be acquired by short-term market purchases, primarily early in the planning period for CCs and from the early 2020s and beyond for CTs.
- Coal – The same retirement of coal units described for Strategy A would occur under Strategy B on the same schedule. The operating coal capacity at the end of the planning period in 2033 would be the same as Strategy A with 6,610–7,506 MW under Scenarios 1, 2 and 3 and about 5,000 MW under Scenarios 4 and 5.
- Wind – As with Strategy A, wind capacity would be added under Scenarios 1, 3 and 4. The quantities and general schedule would be similar to Strategy A except that Strategy B contains an additional 1,000 MW of HVDC wind under Scenario 1 and 800–1,600 of additional MISO wind under Scenarios 3 and 4 respectively.
- Solar – Solar capacity additions would be similar to those for Strategy A and on approximately the same schedule.
- Hydroelectric – Hydroelectric capacity additions are the similar to Strategy A.

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	1B	2B	3B	4B	5B
DR	575	271	471	283	322
EE	2,735	2,675	2,834	2,882	2,537
Gas CT	4718	3,932	3,932	786	1,573
Wind HVDC	1,750	0	3,500	3,500	0
Wind MISO	0	0	800	1,600	0
Solar Tracking	3,175	2,350	4,000	3,900	2,200
Hydro PPA	0	0	347	347	0
Hydro	55	55	55	55	55
Nuclear	402	402	402	402	402

Figure 6-3 Strategy B capacity additions through 2033 by resource type for the five scenarios.

6.1.4 Strategy C – Focus on Long-Term, Market-Supplied Resources

Strategy C is designed to constrain capital spending by TVA and, instead of building its own new generating plants, TVA would meet most new capacity needs by market purchases and long-term PPAs. There would be no constraints on TVA spending for EE and DR programs. As in Strategies A and B, solar capacity expansion is capped at 300 MW/year and a total of 4,000 MW of total capacity. As originally defined in the Draft IRP and SEIS, Strategy C allowed PPAs to be selected with contract terms of 10 to 20 years. Recent market assessments indicated few facilities in the TVA service area and surrounding markets available to enter into such PPAs. As pointed out by stakeholders, longer term PPA commitments would likely be required to attract investments in new generating facilities. TVA therefore revised Strategy C to only include 20-

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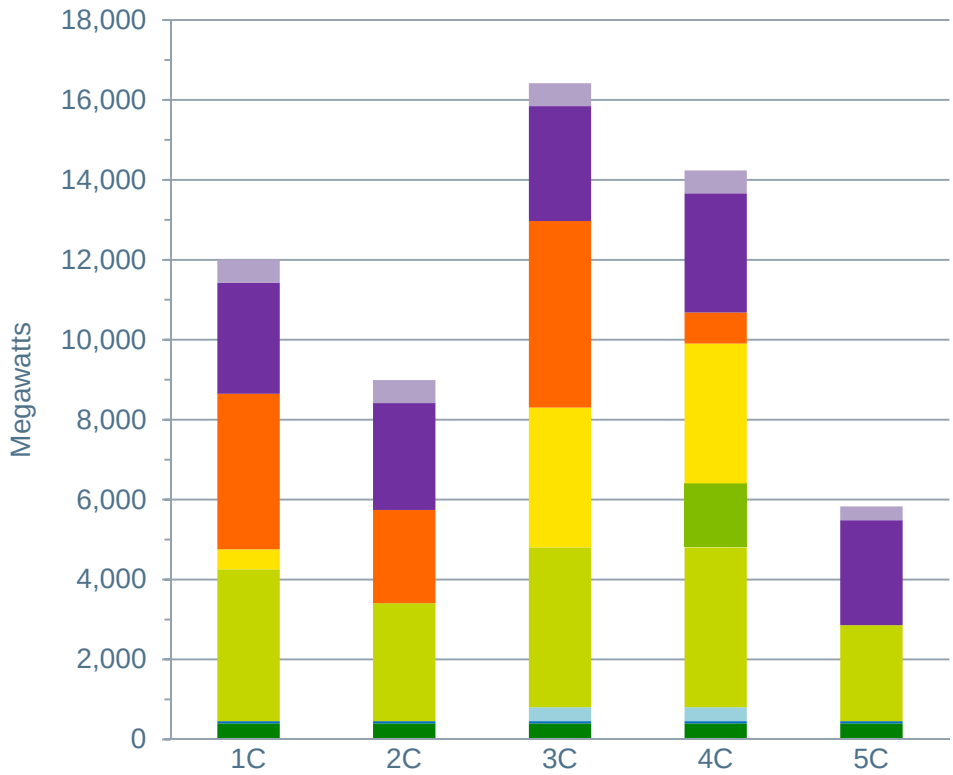
year contract terms. This resulted in some changes in the Strategy C capacity expansion plans presented in the Draft IRP and DEIS.

Following is a summary of the five revised capacity expansion plans developed for Strategy C. Capacity additions by resource type are illustrated in Figure 6-4.



	1C	2C	3C	4C	5C
DR	575	575	575	575	345
EE	2,784	2,675	2,873	2,980	2,626
Gas CT PPA	3,890	2,334	4,668	778	0
Wind HVDC	500	0	3,500	3,500	0
Wind MISO	0	0	0	1,600	0
Solar Tracking	3,800	2,950	4,000	4,000	2,400
Hydro PPA	0	0	347	347	0
Hydro	55	55	55	55	55
Nuclear	402	402	402	402	402

Figure 6-4 Strategy C capacity additions through 2033 by resource type for the five scenarios.

- Demand Response (DR) – Expansion of about 350 MW under Scenario 5 and about 575 MW under the other scenarios.
- Energy Efficiency (EE) – Expansion to around 2,750 MW under all scenarios with variation among the scenarios in the timing of the expansion.

- Natural Gas-fired Generation – No new TVA-built CC or CT plants. Under all scenarios, TVA would enter into PPAs for the purchase of power from CT plants, with quantities ranging from 778 MW (i.e., equivalent to one new CT plant) under Scenarios 4 and 5 to 4,668 MW (five new CT plants) under Scenario 3. Varying amounts of power from CT and CC plants would be acquired by short-term market purchases, primarily early in the planning period for CCs and from the early 2020s on for CTs.
- Coal – Strategy C maintains more coal capacity than Strategy A and B. Under Scenarios 1, 2 and 3, additional emission controls are added to the seven Shawnee units in the mid-2020s and no additional idling occurs. Under Scenarios 4 and 5, the seven Shawnee units are retired in the mid-2020s. Under Scenario 4, Kingston is retired in 2020. Coal generating capacity in 2033 totals 5,249 MW for Strategy 4; 6,610 MW for Strategy 5; and 7,506 MW for Strategies 1, 2 and 3.
- Wind – As with Strategies A and B, no wind capacity is added under Scenarios 2 and 5. The additions under Scenarios 3 and 4 are similar to Strategy A and the addition under Scenario 1 is much less at only 500 MW.
- Solar – Solar capacity additions are similar to those for Strategy A and on approximately the same schedule except for modest increases under Scenarios 1 and 2.
- Hydroelectric – Hydroelectric capacity additions are similar to Strategies A and B, except for addition of the 40-MW spill hydro option under Scenario 3 and 4 in 2028 and 2026, respectively.

6.1.5 Strategy D – Maximize Energy Efficiency

Strategy D focuses on increasing energy efficiency by requiring it to be selected first for meeting future energy needs in the least-cost manner. As in Strategies A, B and C, solar capacity expansion is capped at 300 MW/year and a total of 4,000 MW of total capacity. Following is a summary of the five capacity expansion plans developed for Strategy D and illustrated in Figure 6-5 by resource type.

- Demand Response (DR) – Expansion to 500–575 MW in 2033 under all scenarios.
- Energy Efficiency (EE) – Expansion to 4,624 MW in 2033 under all scenarios. The rate of EE expansion is similar to Strategy A over the first decade and then accelerates.
- Natural Gas-fired Generation – No new CT plants are constructed under Scenario 5. New CT plants are constructed under the other scenarios, with one 786-MW plant under Scenario 4, two 786-MW plants under Scenario 2, four 786-MW plants under Scenario 1, and four 786-MW and one 590-MW plant under Scenario 3. No new CC plant is constructed under any scenario. Varying amounts of power from CT and CC plants would be acquired by short-term market purchases, primarily early in the planning period for CCs and from the early 2020s and beyond for CTs.
- Coal – Under all scenarios, seven Shawnee units are retired in 2025 and under Scenarios 4 and 5, all nine Shawnee units are retired in 2025. Kingston is retired in 2018–2020 under Scenarios 4 and 5 and Paradise Unit 3 is retired in 2020 under Scenario 4. 2033 coal capacities are 4,187 MW for Scenario 4, about 5,000 MW for Scenario 5, and 6,610 MW for Scenarios 1–3.

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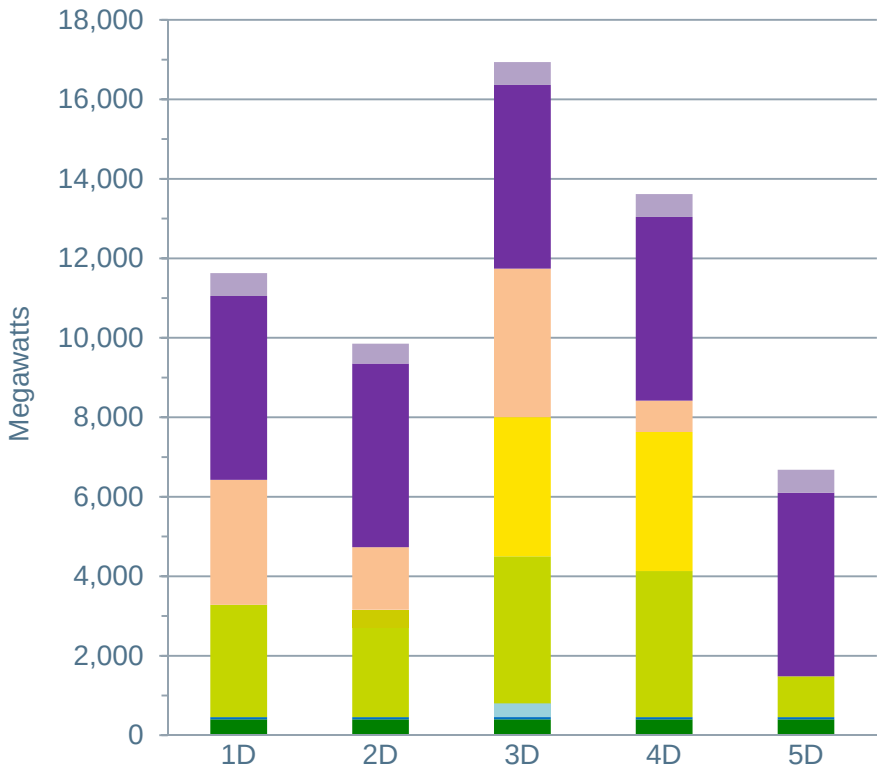

	1D	2D	3D	4D	5D
DR	575	500	575	575	575
EE	4,624	4,624	4,624	4,624	4,624
Gas CT	3,146	1,573	3,736	786	0
Wind HVDC	0	0	3,500	3,500	0
Solar Fixed	0	450	0	0	0
Solar Tracking	2,825	2,250	3,700	3,675	1,025
Hydro PPA	0	0	347	0	0
Hydro	55	55	55	55	55
Nuclear	402	402	402	402	402

Figure 6-5 Strategy D capacity additions through 2033 by resource type for the five scenarios.

- Wind – The only wind additions are 3,500 MW under Scenarios 3 and 4.
- Solar – Compared to Strategy A, the solar capacity addition is somewhat less for Scenarios 1, 3 and 4, considerably less for Scenario 5, and slightly more for Scenario 2.
- Hydroelectric - Hydroelectric capacity additions are similar to Strategies A and B except that Scenario 4 does not include the hydro PPA.

6.1.6 Strategy E – Maximize Renewables

Strategy E focuses on increasing generation by renewable resources by setting specific targets for the contribution from renewables; the mix of renewables that meet the target is selected in a

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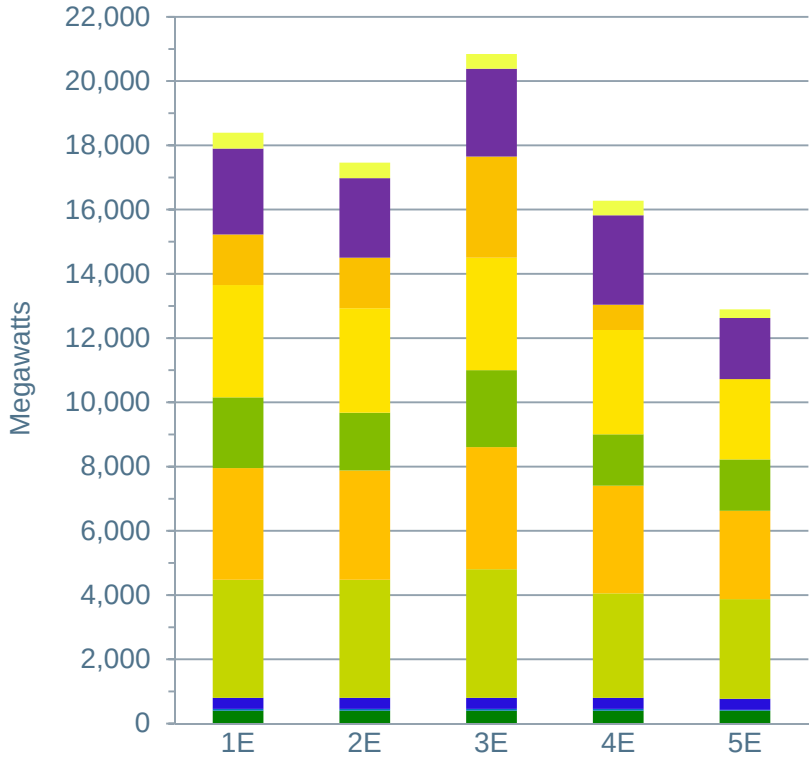
least-cost manner. Generation from TVA's existing hydroelectric system is included in this target. Unlike the other strategies, the allowable solar capacity growth rate is set at 500 MW/year with a maximum total of 8,000 MW. Following is a summary of the five capacity expansion plans developed for Strategy E and illustrated in Figure 6-6 by resource type.

- Demand Response (DR) – DR expansion averages 470 MW for Scenarios 1–4; 273 MW are added under Scenario 5.



	1E	2E	3E	4E	5E
DR	492	481	460	450	273
EE	2,675	2,477	2,735	2,785	1,900
Gas CT	1,573	1,573	3,146	786	0
Wind HVDC	3,500	3,250	3,500	3,250	2,500
Wind MISO	2,200	1,800	2,400	1,600	1,600
Solar Fixed	3,475	3,400	3,800	3,350	2,750
Solar Tracking	3,675	3,675	4,000	3,250	3,100
Hydro PPA	347	347	347	347	347
Hydro	55	55	55	55	25
Nuclear	402	402	402	402	402

Figure 6-6 Strategy E capacity additions through 2033 by resource type for the five scenarios.

- Energy Efficiency (EE) – Expansion averages about 2,700 MW by 2033 in Scenarios 1–4, with a lower amount of 1,900 MW under Scenario 5.

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- Natural Gas-fired Generation – Lower CT plant expansion with one new 786-MW plant under Scenario 4, two new 786-MW plants under Scenarios 1 and 2, and four new CT plants under Scenario 3. No new CT plant is constructed under Scenario 5 and no new CC plant is constructed under any scenario. Varying amounts of power from CT and CC plants would be acquired by short-term market purchases, primarily early in the planning period for CCs and from the early 2020s on for CTs.
- Coal – Strategy E has the greatest overall reduction in coal capacity. The seven Shawnee units without FGD and SCR systems are retired in the mid-2020s under all scenarios. Under Scenario 4 and 5, the two Shawnee units with FGD and SCR systems are also retired in the mid-2020s. Kingston is retired in the early 2020s under Scenarios 2, 4 and 5, as are Bull Run fossil plant under Scenario 5 and Paradise Unit 3 under Scenario 4. Coal capacities range from 4,128 MW under Scenario 5 to 6,610 MW under Scenario 1.
- Wind – Strategy E has the largest wind capacity additions, with large quantities of both HVDC and MISO-area wind under all scenarios. Wind capacity additions start early in the planning period and increase throughout it.
- Solar – As with wind, Strategy E has the largest solar capacity additions, which start early and increase throughout the planning period. It is also the only strategy with large quantities of utility scale, fixed-tilt solar facilities, as the solar additions under the other strategies, excluding those under the RSO and SSI programs and 450 MW of fixed-tilt solar under Strategy D Scenario 2, are utility-scale tracking solar facilities. Total solar additions range from 5,850 MW under Scenario 5 to almost 7,800 MW under Scenario 3.
- Hydroelectric – The hydro PPA and run-of-river options are selected for all scenarios. The existing dam space addition option is added in Scenarios 1–4.

6.2 Comparison of Alternative Strategies

Figure 6-7 summarizes the capacity expansion through 2033 by resource type, strategy, the Target Power Supply (described below in Section 6.4), and scenario. Figure 6-8 show the 2033 resource portfolios by resource type, strategy, the Target Power Supply, and scenario. Strategies A, B and C and the Target Power Supply are similar, with relatively small differences in resource capacities. Strategy C largely replaces TVA-owned natural gas capacity expansion with long-term power purchase agreements for natural gas capacity. Strategies D and E, because of their prioritization of capacity expansion through energy efficiency and renewable generating resources, respectively, both have lower coal capacity and generation and lower natural gas capacity and generation. Figure 6-9 shows the 2033 generation by resource type for the alternative strategies and scenarios. The Target Power Supply would be in the range of Strategies A–C and their associated scenarios.

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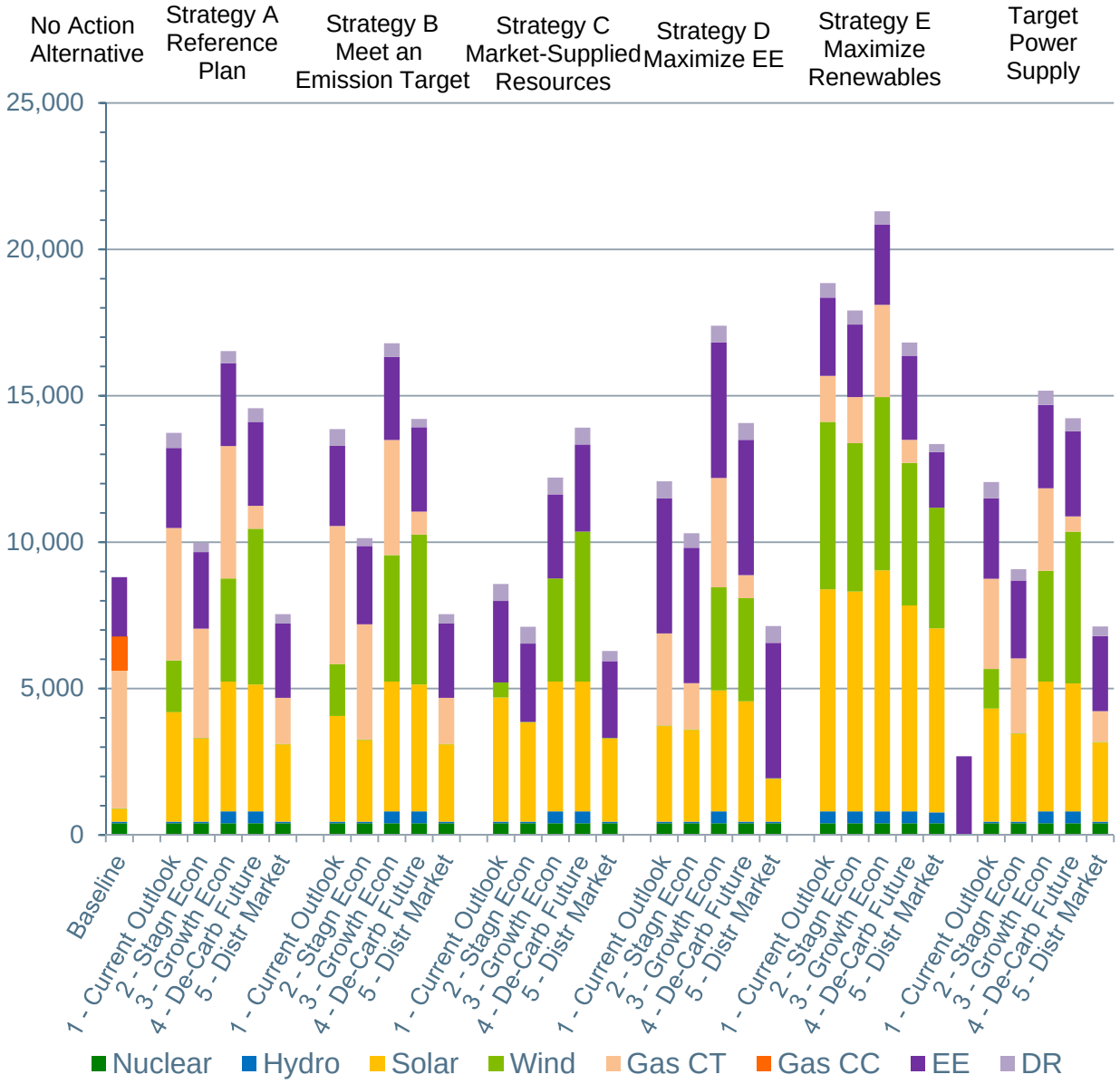

Figure 6-7 Summary of capacity expansion in MW, including power purchase agreements, by resource type through 2033.

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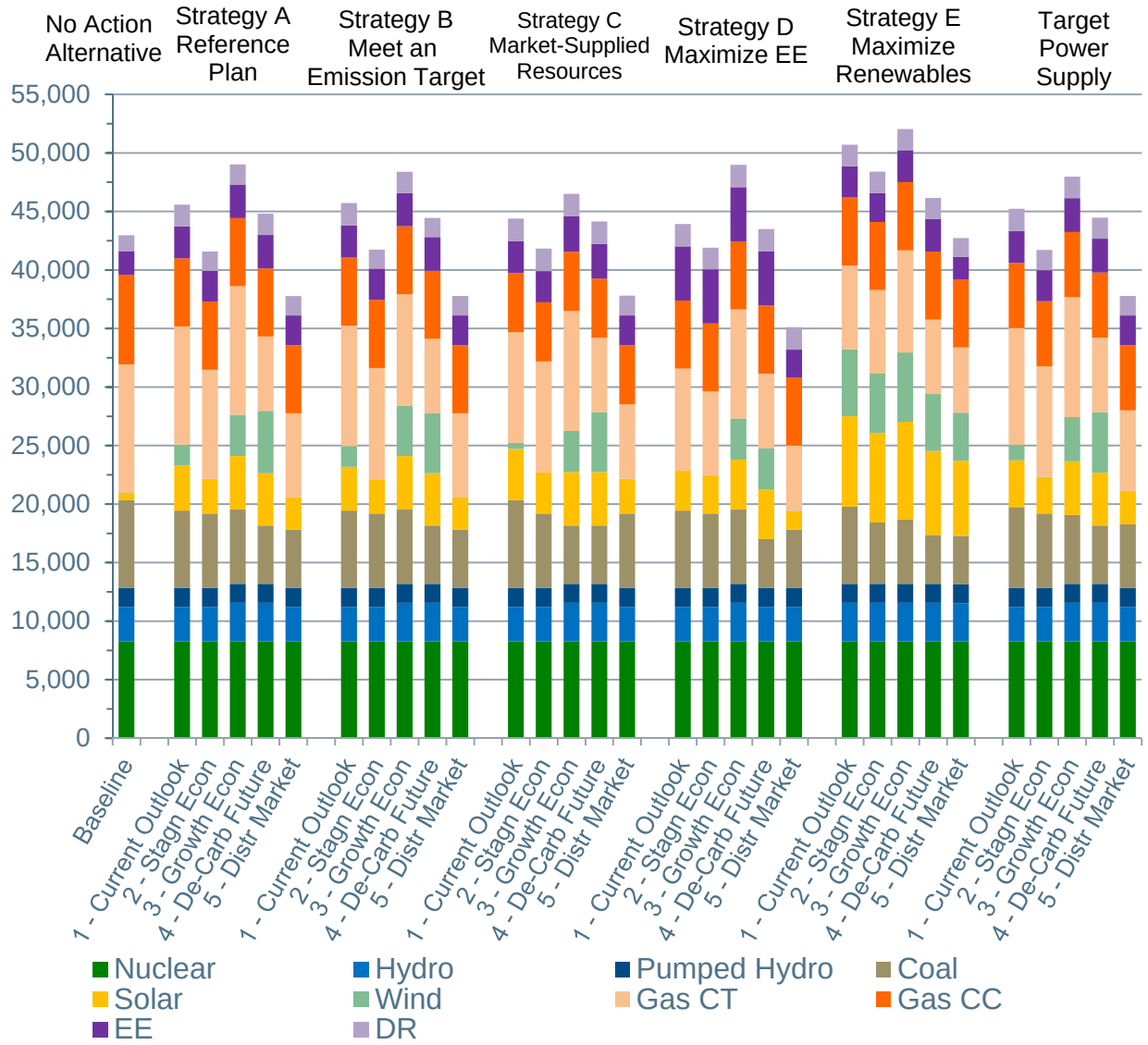

Figure 6-8 2033 resource portfolios by type, strategy, Target Power Supply, and scenario. Capacities are in MW and net summer dependable except for solar and wind, which are nameplate. Biomass- and diesel-fueled generating capacities are not shown because of their small quantities (48 MW for biomass, 9 MW for diesel).

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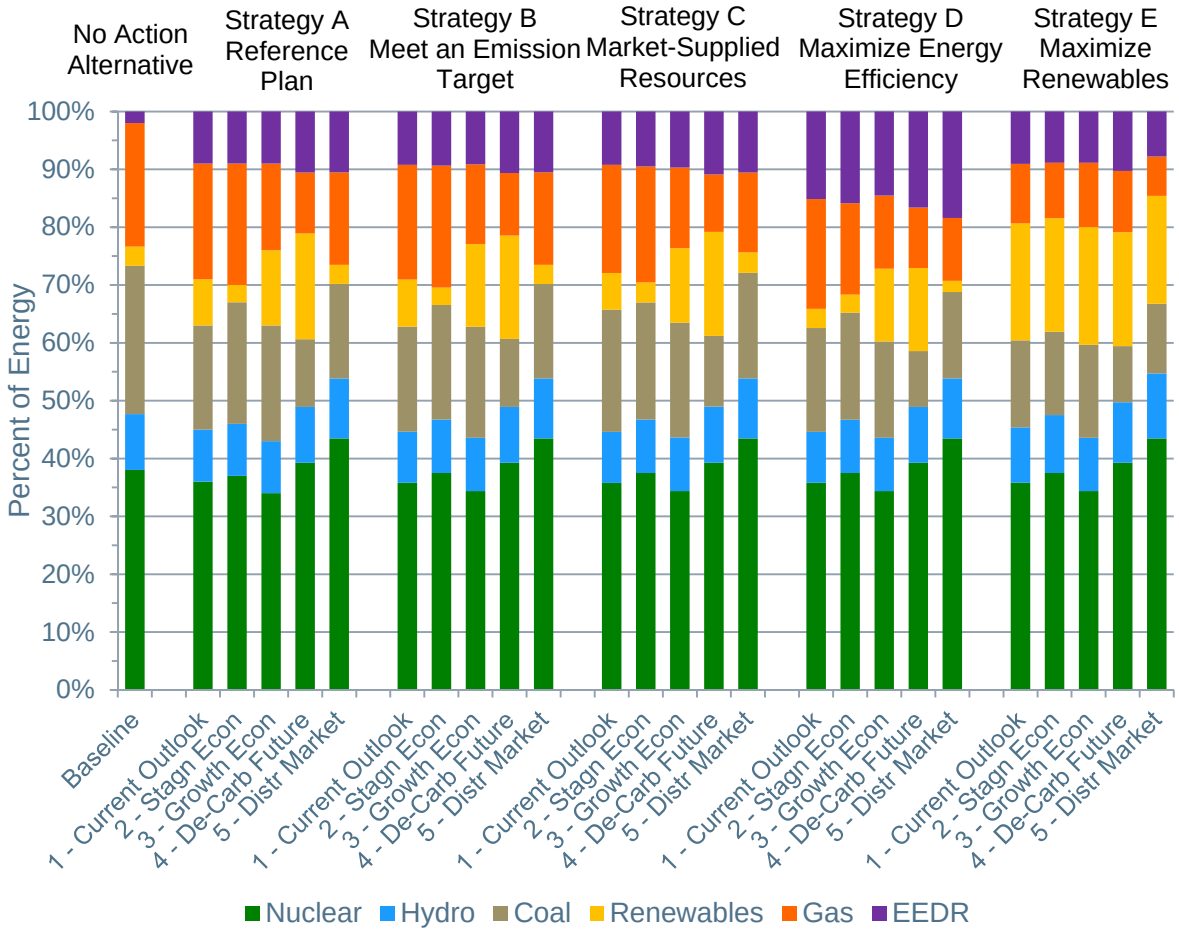

Figure 6-9 2033 energy by resource type, alternative strategy, and scenario.

6.3 Strategy and Portfolio Evaluation

The metrics used to evaluate the cost and financial risk attributes, economic development attributes and a set of environmental attributes are described in Section 2.6 and IRP Chapters 6 and 8. Table 6-1 presents the metrics scores for capacity expansion plans developed for the No Action Alternative and Strategies A–E.

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Table 6-1 Cost, risk, environmental stewardship, flexibility and economic metrics the resource portfolios associated with alternative strategies.

	Alternative Strategy	Scenario 1	2	3	4	5	Average
PVRR ($ billion)	No Action	134.7					134.7
	A	132.7	125.9	139.6	131.7	120.4	130.0
	B	132.7	126.0	139.5	131.7	120.4	130.1
	C	133.4	126.5	140.8	131.9	121.1	130.7
	D	134.4	127.9	141.3	133.6	122.8	132.0
	E	136.2	129.4	140.8	132.8	123.5	132.5
System Average Cost 2014-2023 ($/MWh)	No Action	75.6					75.6
	A	76.7	76.0	77.7	81.0	77.3	77.7
	B	76.7	76.0	77.7	80.9	77.3	77.7
	C	76.4	75.7	77.8	80.6	76.8	77.5
	D	76.9	75.9	77.5	81.1	77.3	77.3
	E	78.4	77.3	78.5	81.3	78.5	78.8
System Average Cost 2024-2033 ($/MWh)	No Action	95.7					95.7
	A	98.7	94.8	100.4	103.0	98.7	99.1
	B	98.6	95.1	100.4	103.4	98.7	99.3
	C	100.5	96.7	104.2	104.6	101.4	101.5
	D	104.5	102.4	106.8	110.0	108.3	106.4
	E	102.0	00.1	100.8	104.6	101.6	101.6
Risk/Benefit Ratio	No Action	0.90					0.90
	A	0.92	0.95	0.91	1.00	0.99	0.95
	B	0.92	0.95	0.92	0.99	0.99	0.95
	C	0.90	0.95	0.91	0.98	0.99	0.95
	D	0.94	0.98	0.93	1.03	1.00	0.98
	E	1.03	1.04	1.04	1.01	1.05	1.03
Risk Exposure ($ billion)	No Action	142.4					142.4
	A	140.4	132.8	147.5	140.3	127.1	137.6
	B	140.4	133.0	147.6	140.3	127.1	137.7
	C	141.2	134.0	149.3	140.7	128.3	138.7
	D	142.4	135.4	149.7	142.7	130.0	140.0
	E	145.1	137.4	149.8	141.7	130.9	141.0
CO_2 Emissions (million tons/year)	No Action	61.4					61.4
	A	57.0	51.8	59.7	44.2	44.2	51.4
	B	57.0	51.8	59.7	44.3	44.2	51.4
	C	58.2	52.9	59.1	44.2	45.2	51.9
	D	56.2	50.7	57.6	41.8	43.5	50.0
	E	52.2	45.6	54.2	41.6	39.9	46.7
Water Consumption (million gallons/year)	No Action	76,259					76,259
	A	72,952	73,429	79,489	65,890	67,536	71,859
	B	72,988	73,438	79,508	66,001	67,533	71,894
	C	74,504	75,042	79,296	66,227	68,840	72,782
	D	72,657	72,827	77,4824	65,696	67,020	71,136
	E	69,019	68,389	74,733	65,4509	63,799	68,278

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	Alternative Strategy	Scenario 1	2	3	4	5	Average
Waste (million tons/year)	No Action	3.56					3.56
	A	3.46	3.50	3.72	3.08	3.21	3.39
	B	3.46	3.50	3.71	3.10	3.21	3.39
	C	3.41	3.46	3.69	3.09	3.25	3.38
	D	3.44	3.44	3.73	2.75	3.17	3.27
	E	3.16	3.13	3.50	2.76	2.93	3.10
System Regulating Capability (2033)	No Action	30.0%					30.0%
	A	28.7%	28.0%	27.1%	18.9%	22.3%	25.0%
	B	29.9%	27.9%	26.2%	19.7%	22.3%	25.2%
	C	28.5%	26.0%	28.6%	20.4%	18.2%	24.4%
	D	27.7%	22.3%	26.4%	20.3%	25.0%	24.3%
	E	20.9%	20.4%	23.5%	18.8%	16.0%	19.9%
Percent Difference in Per Capita Income (Relative to Strategy A)	No Action	-0.03%					-0.03%
	A	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	B	0.00%	0.01%	-0.01%	0.00%	0.00%	0.00%
	C	0.00%	0.01%	0.03%	0.01%	0.00%	0.01%
	D	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
	E	-0.01%	0.00%	0.00%	0.02%	-0.01%	0.00%

Cost and Risk – The No Action Alternative has the highest overall cost (PVRR) of the alternative strategies, although the proportion of its cost occurring during the first half of the planning period (System Average Cost Years 1–10) is the lowest. Strategies A, B and C have the lowest average PVRR, although overall differences among Strategies A–E are less than 2 percent. The system average costs of Strategies A–E are similar for the first 10 years; during the second 10 years Strategy D has the highest cost.

Strategy C has the lowest risk/benefit ratio of the five strategies, indicative of its better performance based on the assumptions about the price and terms of PPAs. Strategy E has the greatest risk/benefit ratio, with an increased likelihood that its cost will exceed the expected value. As shown by the risk exposure metric, Strategies D and E have higher financial risks than Strategies A–C.

Environmental Stewardship – The three environmental metrics, CO_2 emissions, water consumption and waste (coal combustion residuals) generation, have very similar values for Strategies A–C. The environmental metrics values are highest for the No Action Alternative, lower for Strategy D, and lowest for Strategy E. The scores for these metrics are most closely related to the amount of future generation by coal plants, which is highest under the No Action Alternative and lowest under Strategy E.

Flexibility – System regulating capacity is a measure of the ability of the power system to respond to rapid increases in demand. The No Action Alternative, with its heavy dependence on CT plants, scores well for this metric. Strategy D scores well during the first decade but its 2033 score is somewhat lower than Strategies A–C, which have very similar scores. Strategy E, with its heavy reliance on non-dispatchable renewable energy, has the lowest score for this metric.

Valley Economics – All of the alternative strategies have very similar scores for this metric which is described in more detail below in Section 7.5.7.

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6.4 The Recommended Target Power Supply Mix

During and following the public review of the Draft IRP and SEIS, TVA staff began the process of developing the recommended Target Power Supply mix. This process is described in detail in IRP Chapter 9. It was guided by the overall IRP development objectives listed above in Section 1.4 and the goals of identifying a power supply mix that is low cost, reliable, risk-informed, diverse, environmentally responsible, flexible, and consistent with least-cost planning critieria of the TVA Act.

As part of this process, TVA identified questions and findings that warranted further evaluation prior to completing the study. TVA also received many suggestions on key areas that merited further analyses from individuals on the IRP Working Group, the Regional Energy Resource Council advisory group established by TVA, and during the public comment period on the Draft IRP and SEIS. TVA performed additional detailed modeling, termed sensitivity analyses, of several topics related to nuclear generation, energy efficiency, demand response, renewable energy capacity ratings and costs, energy resources not selected in the power supply plans, and key factors in the scenarios. These analyses and their results are described in more detail in IRP Section 8.3.

Based on comparisons of the metrics listed above in Section 6.3, the results of the sensitivity analyses, and stakeholder comments, TVA elected to establish guideline ranges for key resource types (TVA-owned or contracted) that make up the recommended Target Power Supply mix (Figure 6-10). This general planning direction covers the 20-year planning period while providing more specific direction over the first 10-year period. The recommended ranges, shown as the thick solid bars in Figure 6-10, are based on Strategies A, B and C and the Current Outlook Scenario, which TVA considers its best estimation of the future. The thin lines in Figure 6-10 represent the ranges associated with the other scenarios for Strategies A, B and C. The low end of the range for energy efficiency and demand response extends beyond that encompassed by Strategies A, B and C to account for TVA's current trajectories for these programs and uncertainties discussed in IRP Chapter 10.

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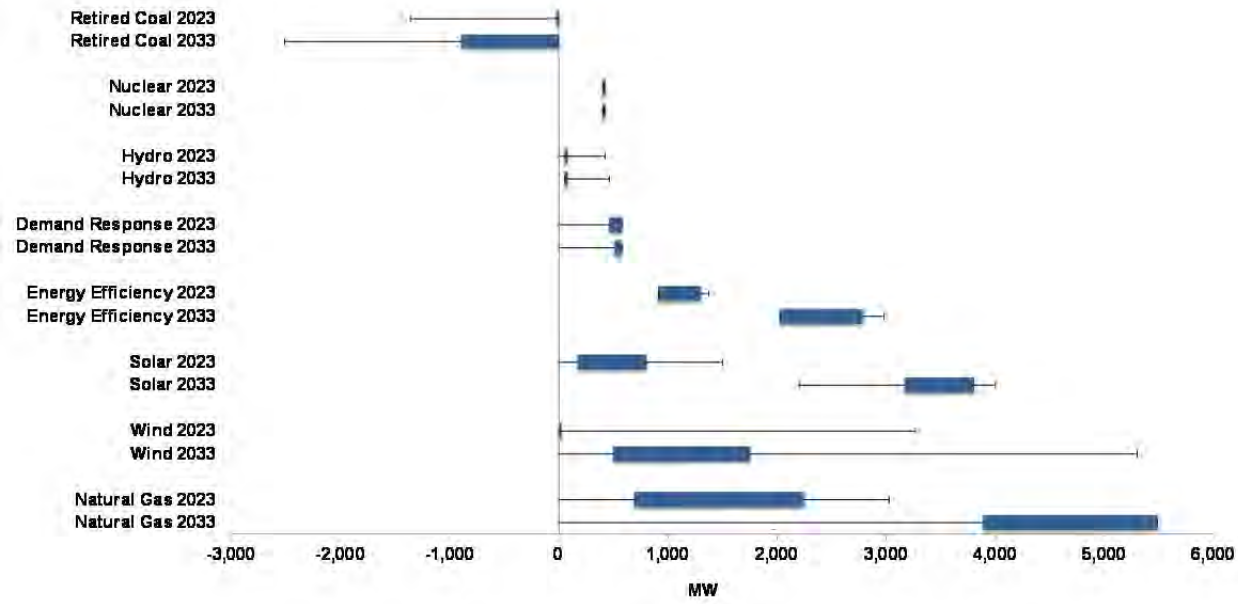

Figure 6-10 Range of resource additions by 2023 and 2033 in the recommended Target Power Supply mix.

The recommended ranges in the Target Power Supply mix are bounded by the full range of the alternative strategies. The implementation of this Target Power Supply mix will result in a diverse portfolio and provide TVA the flexibility to make energy resource decisions, consistent with least-cost planning, that fall within the power supply ranges depicted in Figure 6-10. As the IRP is implemented, TVA will closely monitor key variables including changes in the load forecast, the price of natural gas and other commodities, the pricing and performance of energy efficiency and renewable resources, and impacts from future policy or breakthrough technologies to help determine whether adjustments should be made to the recommended ranges. Following is a summary of the Target Power Supply mix by resource type:

- Coal – Retire units at Allen, Colbert, Johnsonville, Paradise, and Widows Creek as previously announced. Evaluate the potential retirement of Shawnee in the mid-2020s if additional environmental controls are required. Consider retirements of fully controlled units if cost-effective.
- Nuclear – Complete Watts Bar Unit 2 and pursue extended power uprates at all three Browns Ferry units by 2023. Continue work on small modular reactors as part of technology innovation efforts and look for opportunities for cost-sharing to render them more cost-effective.
- Hydro –Pursue an additional 50 MW of hydro capacity at TVA facilities and consider additional hydro opportunities where feasible.
- Demand Response – Add 450–575 MW of demand reduction by 2023 and similar amounts by 2023, dependent on availability and cost of this customer-owned resource.
- Energy Efficiency – Achieve savings of 900–1,300 MW by 2023 and 2,000–2,800 MW by 2033. Work with the local power company partners to refine delivery mechanisms,

program designs, and program efficiencies with the goal of lowering total cost and increasing deliveries of efficiency programs.

- Solar – Add 150–800 MW of large-scale solar by 2023 and 3,150–3,800 of large scale solar by 2033. Solar additions will be highly dependent on pricing, performance, and integration costs.
- Wind – Add 500–1,750 MW by 2033, dependent on pricing, performance, and integration costs. Given the variability of wind expansion in the scenarios, evaluate accelerating wind expansion into the first 10 years if operational characteristics and pricing result in lower cost options.
- Natural Gas (combustion turbine and combined cycle) – Add 700–2,300 MW by 2023 and 3,900–5,500 MW by 2033. The key determinants of future natural gas needs are trajectories on natural gas pricing and the pricing of energy efficiency and renewable generation. The range of natural gas expansion is somewhat larger than that described above for Strategies A, B, and C because it assumes TVA's acquisition of some natural gas facilities from which it is currently purchasing power. The power being generated by these facilities is already factored into TVA's demand forecasts and any TVA acquisitions would not otherwise noticeably affect the environmental impacts of the Target Power Supply.

6.5 Comparison of Environmental Impacts of the Alternatives

All of the alternative strategies, as well as the Target Power Supply, have several common features that affect their anticipated environmental impacts. The only new baseload generation added is the extended power uprate of the three Browns Ferry Nuclear Plant units, a component of all alternative strategies. All alternative strategies result in decreases in coal-fired generation and increases in the reliance on energy efficiency and renewable resources. All alternative strategies also add varying amounts of new natural gas-fueled generation which, with one exception, is by CT plants to meet peak loads.

Emissions of SO_2, NOx, mercury, and CO_2, CO_2 intensity (i.e. emissions rate), and generation of coal combustion residuals all decrease significantly throughout the planning period under all alternative strategies, primarily due to reduced coal-fired generation. These reductions are greatest under Strategy E due to its increased substitution of renewable generation for fossil-fueled generation, and lowest for the No Action Alternative, which maintains the most fossil-fueled generation. Water consumption also decreases, although by smaller proportions. Production of nuclear spent fuel increases at the beginning of the planning period and then remains fairly constant for all alternative strategies. Natural gas consumption would increase by almost 80 percent between 2014 and 2033 under the No Action Alternative, remain about the same under Strategies A and B, and decrease 5-10 percent under Strategies C–E.

Socioeconomic impacts, as quantified by the change to per capita income of TVA service area residents that is attributable to the cost of operating of the TVA power system, are minimal. Relative to Strategy A, it would decrease by 0.03 percent under the No Action Alternative, remain unchanged under Strategies B and E, increase by 0.01 percent under Strategy C, and increase by 0.02 percent under Strategy D. The differences among strategies in regional employment associated with the capacity expansion plans are also small. Relative to Strategy A, the more labor-intensive Strategy D has the largest increase of 0.08 percent. The other

alternative strategies have smaller increases, except for Strategy B, for which employment is the same as Strategy A.

Land requirements for implementing the alternative strategies, and thus the potential for affecting land resources, vary more than other quantified environmental resources. Land required for siting the new generating resources included in the capacity expansion plans range from about 3,625 acres for the No Action Alternative to about 25,000 acres for Strategy D, 29,000 acres for Strategies A–C, and 56,000 acres for Strategy E. These land requirements include the facility footprints, access roads and transmission system infrastructure at the facility site. The largest contributor to the land requirements are solar PV facilities, which occupy large areas of land relative to their generating capacity. Solar facilities do not, however, typically result in long-term impacts to the site, unlike most other types of generation. When the life cycle land requirements (i.e., incorporating the fuel and waste cycles) of nuclear and fossil-fueled generation are considered, the No Action Alternative has the highest land requirements of about 60,000 acres, and the other alternatives have similar land requirements of about 42,000 acres. These life cycle land requirements do not include wind, solar and hydroelectric generation, which do not have comparable fuel and waste cycles.

7.0 Anticipated Environmental Impacts

This chapter describes the anticipated environmental impacts of the alternative strategies and their associated portfolios. It first describes the general process TVA uses to site new power facilities. Then it describes the potential environmental impacts of the continued operation of TVA's generating facilities, facilities from which TVA purchases power through PPAs, and the generating facilities that TVA is likely to own or purchase power from in the future. The chapter then describes the environmental impacts of energy efficiency and demand response (EEDR) programs and the construction and upgrading of the transmission system necessary to support future generating facilities. Finally, this chapter describes potential mitigation measures and commitment of resources.

7.1 Facility Siting and Review Processes

When planning new generating facilities, TVA uses several criteria to screen potential sites. Generating facilities are often needed in specific parts of the TVA power service area in order to support the efficient operation and reliability of the transmission system. Once a general area is identified, sites are screened by numerous engineering, environmental and financial criteria. Specific screening criteria include regional geology and local terrain; proximity to major highways, railroads and barge access; proximity to major natural gas pipelines; proximity to high-voltage transmission lines; land use and land ownership; regional air quality; sources of process water; the presence of floodplains; proximity to parks and recreation areas; potential impacts to endangered and threatened species, wetlands, and historic properties; and potential impacts to minority and low-income populations. Through this systematic process, TVA attempts to minimize the potential environmental impacts of the construction and operation of new generating facilities.

New transmission facilities are typically required to transmit power between two defined points or to improve transmission capacity and/or reliability in a defined area. As with generating facilities, potential transmission line routes, substation locations, and switching station locations are screened by numerous engineering, environmental and financial criteria. Specific screening criteria include slope; the presence of highways, railroads and airports; land use and land ownership patterns; proximity to occupied buildings, parks and recreation areas; and potential impacts to endangered and threatened species, wetlands and historic properties. TVA also provides and encourages participation by potentially affected landowners in this screening process.

TVA is not directly involved in the siting and operation of natural gas pipelines that may have to be built to serve new natural gas plants. Instead, TVA purchases natural gas service from contractors who are responsible for constructing and operating the pipeline. Construction and operation of a natural gas pipeline are subject to various state and federal environmental requirements depending on how and where constructed. If a pipeline is built specifically to serve TVA, TVA would evaluate the potential environmental impacts and take steps to ensure any associated impacts are acceptable.

The results of the site screening process, as well as the potential impacts of the construction and operation of the generating and transmission facilities at the screened alternative locations, are described in comprehensive environmental review documents made available to the public. During this environmental review process, TVA consults with the appropriate State Historic

Preservation Officer on the potential impacts to historic properties and, as necessary, with the USFWS on the potential impacts to endangered and threatened species and their designated critical habitats.

7.2 Environmental Impacts of Supply-Side Resource Options

Because the locations of most future generating facilities are not known, this impact assessment focuses on impact areas that are generally not location-specific. These impact areas are described below.

Air Quality – The potential impacts to air quality are described by the direct emissions of the sulfur dioxide (SO_2), nitrogen oxide (NOx), and mercury (Hg) and are quantified by the amounts emitted per unit of electricity generated and the total amounts emitted under each of the alternative strategies and portfolios.

Greenhouse Gases (GHG) – As recommended by CEQ (2014), GHG emissions are assessed for both the direct emissions of CO_2, from the combustion of non-renewable carbon-based fuels, and for the life cycle GHG emissions, which include direct and indirect emissions of CO_2, methane, nitrous oxide (N_2O), and other greenhouse gases. Life cycle GHG emissions include emissions from the construction, operation, and decommissioning of generating facilities; the extraction or production, processing and transportation of fuels; and the management of spent fuels and other wastes. Because life cycle GHG emissions have not been specifically determined for TVA's generating facilities, the estimates used in this assessment are based on published life cycle assessments (LCAs, e.g., Dolan and Heath 2012, Warner and Heath 2012, NETL 2014). Both direct CO_2 emissions and life cycle GHG emissions are quantified by the amount emitted per unit of electricity generated and the total amount emitted under each of the alternative strategies and portfolios. Where distinguishable and unless otherwise stated, the LCA values described below do not include impacts associated with the transmission and distribution of the electricity generated by the various facilities. Life cycle GHG emissions are standardized to the 100-year global warming potentials adopted by Forster et al. (2007) and given in Table 4-4.

Water Resources – The impacts of water pollutants discharged from a generating facility are highly dependent on site- and facility-specific design features, including measures to control or eliminate the discharge of water pollutants, which are not addressed here. The impacts of the process water used and consumed by a thermal generating facility (primarily for cooling) depend on the characteristics of the source area of water withdrawals and of the water bodies where process water is discharged. The quantities of process water used and consumed are indicators of the magnitude of these impacts. Facilities with open-cycle cooling systems withdraw and discharge large quantities of water. Facilities with closed-cycle cooling systems use less water but consume (typically by evaporation) a large proportion of it. Water use and consumption are quantified by the volumes used and consumed per unit of electricity generated and the total volumes used and consumed under each of the alternative strategies and portfolios.

Solid Waste – The potential for impacts from the generation and disposal of solid wastes are assessed by the quantities of coal ash, scrubber sludge (i.e., synthetic gypsum and related materials produced by flue gas desulfurization systems), and high-level radioactive waste (spent nuclear fuel). These are quantified by the amounts produced per unit of electricity generated and the total amounts under each of the alternative strategies and portfolios.

Fuel Consumption – The amount of fuel consumed relates to the potential impacts of the extraction or production, processing, and transportation of fuels. Fuel consumption is quantified by the amount consumed per unit of electricity generated and the total amount consumed under each of the alternative strategies and portfolios. In addition to coal, coal plants equipped with scrubbers or circulating fluidized bed boilers use limestone ($CaCO_3$) or slaked lime ($Ca(OH)_2$) as a reagent to reduce SO_2 emissions. The quantity of limestone or lime consumed is a function of the quantity of coal consumed. The quarrying, processing and transportation of limestone and lime affects air, water and land resources.

Land Requirements – Land requirements for the alternative strategies and portfolios are quantified by both the facility land requirements and life cycle land requirements. These land requirements are indicators of the potential for impacts to land-based resources such as vegetation, wildlife, many endangered and threatened species, cultural resources such as archaeological sites and historic structures, land use, prime farmland, visual/aesthetic resources, recreation, and to aquatic resources from runoff and sedimentation. While this analysis assumes that the potential for impact increases with the land area affected, the kind of impact and its potential severity will vary depending on site-specific conditions and locations and type of facility.

The facility land requirement is the land area permanently disturbed by the construction of the generating unit. It does not include adjacent lands that are part of the facility site and maintained in a natural or semi-natural state as buffers or exclusion zones. The facility land requirement is the total acreage permanently disturbed by the construction of new generating facilities under each of the alternative strategies and portfolios. Facility land requirements were determined from a variety of sources, including characteristics of TVA facilities, both existing and under development; characteristics of comparable facilities recently constructed or proposed elsewhere in the country; and various published reports on this topic.

The life cycle land requirement is a measure of the land area transformed during the life cycle of a generating facility, expressed in terms of units of area per amount of electricity generated. This land includes the facility site; adjacent buffer areas; lands used for fuel extraction or production, processing, and transportation; and land used for managing spent fuels and other wastes. Some of the land areas, such as the facility site, are transformed for decades while others, such as some minelands, are transformed for shorter time periods. These differing time periods are considered in the assessment. The estimates used in this assessment are based on published LCAs (e.g., Fthenakis and Kim 2009).

Life cycle land requirements can also be expressed with a land-use metric that accounts for the total surface area occupied by the materials and products used by a facility, the time the land is occupied, and the total energy generated over the life of the facility (Spitzley and Keoleian 2005, AEFPERR 2009). The rank order by energy technology reported for a sample of U.S. facilities, from the smallest to the largest land requirements, is natural gas, coal, nuclear, wind, solar PV, conventional hydroelectric, and biomass. The large land requirements for hydroelectric include the reservoirs, which typically have other uses. The biomass land requirements are based on the use of dedicated woody or non-woody crops; the use of forest residues would also result in a large land requirement. Biomass generation using landfill gas, mill residues, or other byproducts has a much smaller life cycle land requirement than biomass generation using other fuel.

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Following is a discussion of the environmental attributes of the generation options. Environmental characteristics of TVA's existing and potential new supply-side resources are listed in Tables 7-1 and 7-2, respectively. A few of the environmental characteristics listed in Table 7-2 are dependent on their siting and on the detailed facility design and are difficult to quantify without more detailed engineering analyses. The various types of generating facilities are described in Sections 3.3 and 5.4. It is important to note there are comprehensive environmental laws and regulations that address almost all activities associated with the construction and operation of new industrial facilities, particularly energy generation facilities. This regulatory umbrella ensures the environmental impacts associated with energy resources are acceptable and in general, public health and the environment are adequately protected.

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Table 7-1 Environmental characteristics of current (2014) and committed supply-side options included in alternative strategies.

	Summer Net Dependable Capacity, MW	Capacity factor, %	Heat rate, Btu/kWh	Fuel consumption	SO_2 emissions, lbs/MWh	NOx emissions, lbs/MWh	Hg emissions, lbs/MWh	CO_2 emissions, tons/GWh	GHG life cycle emissions, tons CO_2-eq/GWh[4]	Process water use, gallons/MWh	Process water consumption, gallons/MWh	Solid waste – coal ash, tons/MWh	Solid waste – coal SO_2 removal byproducts, toms/MWh	High level radwaste, tons uranium/MWh	Facility Land Requirement, permanently disturbed acres
Coal-Fueled															
TVA fleet total	11,296	58	10,298	0.537 tons/MWh	0.4682	0.1708	0.0030	1055.6	1,030	43,765	219.5	0.044	0.0059	0	1,105[3]
PPA lignite	432	92	15,000	1.367 tons/MWh	1.5259	1.2288	0.0348	1630.4	unk	610.5	610.5	0.219	--[2]	0	320
Natural Gas-Fueled															
Combustion turbine – fleet total	5,716	1	10,713	10.451 ft^3/MWh	0	0.1772	0	648.7	>784	0	0	0	0	0	68[3]
Combined cycle - fleet total – TVA and PPA	4,935	47	7,066	6,894 ft^3/MWh	0	0.0129	0	413.4	510	978.7	831.1	0	0	0	80[3]
Diesel-Fueled															
Fleet total – TVA and PPA	121	<1	9,427	68.7 gal/MWh	0.5339	31.474	0	1501.3		0	0	0	0	0	1
Nuclear															
Fleet total	7,895	93	10,346	2.07 kgU/GWh	0	0	0	0	~20	26,674	806	0	0	2.59E-06	890[3]
Hydro															
Fleet total	4,144	68	--	--	0	0	0	0	--	n/a	0	0	0	0	--

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	Summer Net Dependable Capacity, MW	Capacity factor, %	Heat rate, Btu/kWh	Fuel consumption	SO_2 emissions, lbs/MWh	NOx emissions, lbs/MWh	Hg emissions, lbs/MWh	CO_2 emissions, tons/GWh	GHG life cycle emissions, tons CO_2-eq/GWh[4]	Process water use, gallons/MWh	Process water consumption, gallons/MWh	Solid waste – coal ash, tons/MWh	Solid waste – coal SO_2 removal byproducts, toms/MWh	High level radwaste, tons uranium/MWh	Facility Land Requirement, permanently disturbed acres
Storage[1]															
Raccoon Mountain pumped hydro	1,615	20	--	--	0	0	0	see text	see text	386,470	0	0	0	0	1,050
Renewable															
Wind – out of region	300	30	--	--	0	0	0	0	12	0	0	0	0	0	0.8/MW
Wind – in region	6	25	--	--	0	0	0	0	12	0	0	0	0	0	1.0/MW
Landfill gas – fleet total	9.6	83	13,500	27,551 ft^3/MWh	0.024	3.0	0	(2,814)	--	0	0	0	0	0	0.4/MW
Solar		20	n/a	n/a	0	0	0	0	50	0	0	0	0	0	var.

[1]Fuel requirements and emission rates exclude those of the generation used during pumping mode
[2]Combined with ash due to use of circulating fluidized bed boiler
[3]Facility average
[4]Estimate from life cycle literature, see Section 7.2

Table 7-2 Environmental characteristics of new supply-side options included in alternative strategies.

	Net Capacity, MW	Capacity factor, %	Heat rate, Btu/kWh	Fuel concumption	SO_2 emissions, lbs/MWh	NOx emissions, lbs/MWh	Hg emissions, lbs/MWh	CO_2 emissions, tons/GWh	GHG life cycle emissions, tons CO_2-eq/GWh	Process water use, gallons/MWh	Process water consumption, gallons/MWh	Solid waste – ash/slag, tons/GWh	Solid waste – coal SO2 removal byproducts, tons/GWh	High level radwaste, tons uranium/MWh	Facility Land Requirement, permanently disturbed acres
Coal Fueled															
IGCC	500		8,000	0.417 tons/MWh				108.0	1,023	303	303	47.31	0	0	400
SCPC 1x8	800		8,674	0.452 tons/MWh					1,045	540	540			0	725
SCPC 2x8	1,600		8,674	0.452 tons/MWh					1,045	540	540			0	1,100
IGCC with CCS	469	82	10,000	0.521 tons/MWh	0.0898	0.5263	0.0036		242	605	605			0	450
SCPC 1x8 with CCS	600		10,843	0.565 tons/MWh				0.1170	283	920	920			0	775
SCPC 2x8 with CCS	1,200		10,843	0.565 tons/MWh				0.1170	283	920	920			0	1,150
Natural Gas Fueled															
Combustion turbine 3 unit	590	2	10,132	9,845 ft^3/MWh	0	0.2588	0	588.2		0	0	0	0	0	68
Combustion turbine 4 unit	786	2	10,132	9,845 ft^3/MWh	0	0.2588	0	588.2		0	0	0	0	0	68
Combined cycle 2x1	670	40	6,946	6,777 ft^3/MWh	0	0.0120	0	404.7					0	0	80
Combined cycle 3x1	1,005	40	6,598	6,777 ft^3/MWh	0	0.0120	0	404.7	509	978.7	831.1	0	0	0	80

	Net Capacity, MW	Capacity factor, %	Heat rate, Btu/kWh	Fuel concumption	SO_2 emissions, lbs/MWh	NOx emissions, lbs/MWh	Hg emissions, lbs/MWh	CO_2 emissions, tons/GWh	GHG life cycle emissions, tons CO_2-eq/GWh	Process water use, gallons/MWh	Process water consumption, gallons/MWh	Solid waste – ash/slag, tons/GWh	Solid waste – coal SO2 removal byproducts, tons/GWh	High level radwaste, tons uranium/MWh	Facility Land Requirement, permanently disturbed acres
Nuclear															
Browns Ferry extended power uprate	134	93	9,558	1.91 kgU/GWh	0	0	0	0	~20	~ 40,500	~ 1,200	0	0	2.59E-06	0
Pressurized water reactor (cf. BLN 1 or 2)	1,260	92	9,715	1.94 kgU/GWh	0	0	0	0	39*	1,680	576	0	0	2.59E-06	400
Advanced pressurized water reactor (AP1000)	1,117	92	9,716	1.94 kgU/GWh	0	0	0	0	39*	1,289	859	0	0	2.64E-06	450
Small modular reactor	334	92	10,046	2.01 kgU/GWh	0	0	0	0		~ 1,400	~ 1,300	0	0		450
Storage[1]										0	0		0		0
Pumped storage hydro	850	20	n/a	n/a	0	0	0	0				0	0	0	750
Compressed air energy storage	330		4,196	4,094 ft^3 natural gas/MWh	0		0					0	0	0	varies
Renewable															
Hydro expansion – spill addition	40	50	n/a	n/a	0	0	0	0				0	0	0	0
Hydro expansion – space addition	30		n/a	n/a	0	0	0	0				0	0	0	0
Hydro - Run of river	25		n/a	n/a	0	0	0	0				0	0	0	0.5/MW
Wind – MISO	200	40	n/a	n/a	0	0	0	0		0	0	0	0	0	0.8/MW

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	Net Capacity, MW	Capacity factor, %	Heat rate, Btu/kWh	Fuel concumption	SO_2 emissions, lbs/MWh	NOx emissions, lbs/MWh	Hg emissions, lbs/MWh	CO_2 emissions, tons/GWh	GHG life cycle emissions, tons CO_2-eq/GWh	Process water use, gallons/MWh	Process water consumption, gallons/MWh	Solid waste – ash/slag, tons/GWh	Solid waste – coal SO2 removal byproducts, tons/GWh	High level radwaste, tons uranium/MWh	Facility Land Requirement, permanently disturbed acres
Wind – SPP	200	40	n/a	n/a	0	0	0	0		0	0	0	0	0	0.8/MW
Wind – TVA region	120	30	n/a	n/a	0	0	0	0		0	0	0	0	0	1/MW
Wind – HVDC	200	55	n/a	n/a	0	0	0	0		0	0	0	0	0	0.8/MW
Biomass - dedicated facility	115	85	13,500	1.588 tons/MWh[4]	--	0.10	--	0	39			31.78	0	0	100
Biomass - coal boiler conversion	75	85	12,000	see text	0.025	0.10	2.25	0	39			var.	0	0	var.
Solar PV – utility scale one-axis tracking	25	23	n/a	n/a	0	0	0	0	50	0	0	0	0	0	8.5/MW
Solar PV – utility scale fixed-axis	25	20	n/a	n/a	0	0	0	0	50	0	0	0	0	0	7.5/MW
Solar PV – commercial-scale large	25	20	n/a	n/a	0	0	0	0	50	0	0	0	0	0	7.5/MW
Solar PV – commercial scale small	25	20	n/a	n/a	0	0	0	0	50	0	0	0	0	0	7.5/MW

[1]Fuel requirements and emission rates exclude those of the generation used during pumping mode
[3]Varies by facility
[4]Stoker boiler; gasification plant has lower fuel requirement
*See text discussion in Section 7.3.3

7.2.1 Fossil-Fueled Generation

Coal – Existing Facilities

TVA currently operates 40 coal-fired generating units at 10 plant sites (see Section 3.3). Flue gas desulfurization (FGD) systems for SO_2 control have been installed at 16 of these units and selective catalytic reduction (SCR) systems for NOx emissions control have been installed at 16 of these units. The plants with these FGD and SCR systems include TVA's largest coal units and total about 8,000 MW of generating capacity. The remaining coal-fired units currently use other methods to reduce SO_2 and NOx emissions. FGD and SCR systems are currently being installed on the four Gallatin coal units and TVA has committed to installing them on two of the nine Shawnee units. FGD and SCR units may be required for other units that currently lack them in order to comply with anticipated air quality regulations.

While the life cycle GHG emissions for TVA coal plants have not been calculated, several studies have calculated these emissions for comparable coal plants. Spitzley and Keoleian (2004) found an emission rate of 1,060 tons CO_2-eq/GWh[4] for pulverized coal boilers without advanced emissions control systems, comparable to the Allen, Gallatin and Shawnee plants. NETL (2010a) calculated a life cycle GHG emission rate of 1,226 tons CO_2-eq/GWh (1,112 kg/MWh) for a pulverized coal plant equipped with an electrostatic precipitator, SCR, and scrubber, comparable to Kingston. For a supercritical pulverized coal plant (SCPC) equipped with an electrostatic precipitator, FGD and SCR, comparable to Bull Run, Cumberland and Paradise Unit 3, NETL (2010b) calculated a life cycle GHG emission rate of 1,045 tons CO_2-eq/GWh (948 kg/MWh).

The largest source of life cycle GHG emissions at coal plants similar to TVA's is CO_2 from coal combustion, which typically accounts for between 80 and 90 percent of GHG emissions (Kim and Dale 2005, Odeh and Cockerill 2008). The next highest source is methane emissions from coal mining; these emissions are higher for underground than surface mines. Methane emissions from underground mining of Illinois Basin (ILB) coal, which accounts for about half of TVA's current coal supply, are several times those from mining PRB coal (NETL 2014). This difference is attributable to both the higher methane content of bituminous coals (such as ILB coal), and to the greater rate of Powder River Basin (PRB) coal bed methane recovery and utilization as part of the natural gas supply. Coal preparation and transport typically account for less than 1 percent of GHG emissions (NETL 2010b). Other GHG sources include limestone mining and transport, lime processing for FGD systems using slaked lime such as the systems being installed at Gallatin. GHG emissions from plant construction, decommissioning and other processes are relatively small.

All TVA coal plants, except Paradise, use only open-cycle cooling and thus have high water use rates but low water consumption rates (see Section 4.7). Paradise uses closed-cycle cooling much of the year causing lower water use and higher water consumption rates. As a result, the amount of heat discharged to the Green River at Paradise is relatively low.

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[4] Where distinguishable in LCA reports, the transmission and distribution of the generated power is excluded from the LCA metrics.

The Red Hills plant in Mississippi burns lignite coal from an adjacent surface mine. Relative to the average for TVA's coal plants, the Red Hills CO_2 emission rate is high due to the low heat rate of the plant and low fuel energy content. Like the TVA coal plants with FGD systems, Red Hills uses limestone to reduce SO_2 emissions. The plant occupies about 320 acres and its fuel cycle disturbs about 275 acres/year, equivalent to 0.09 acre/GWh of energy generated. It uses groundwater in a closed-cycle cooling system with no discharges to receiving water bodies.

Coal mining has the potential to adversely impact large areas, depending on the mining method and area being mined. The impacts are greatest from surface mining, particularly by mountain-top removal, in Appalachia (USEPA 2005, Palmer et al. 2010). In recent years TVA has greatly reduced its use of coal from Appalachian surface mines and currently uses no coal from this source. Impacts from surface mining include removal of forests and other plant communities, disruption of wildlife habitat, alteration of streams and associated aquatic communities, and long-term alterations of the mine area topography. Impacts from underground mining are typically less than those of surface mining.

Coal plants produce large quantities of ash and, if equipped with FGD systems, calcium-based residues (see Section 4.16). Although some of these coal combustion residuals (CCRs) are recycled for a range of beneficial uses, large quantities are typically permanently stored in impoundments or landfills at or near coal plants. These facilities can occupy tens to hundreds of acres

Coal – New Facilities

The new coal facilities available for selection during the portfolio modeling are an integrated gasification combined cycle (IGCC) plant with and without carbon capture and sequestration (CCS), and two configurations of supercritical pulverized coal (SCPC) plants with and without CCS (see Section 5.3.1). The environmental impacts of constructing and operating an IGCC plant without CCS, the Mesaba Energy Project, are described in USDOE (2009). The environmental impacts of constructing and operating IGCC plants with CCS are described for the FutureGen plant in USDOE (2007) and for the Kemper County, Mississippi, IGCC Project in USDOE (2010a). (Because of funding uncertainties, the FutureGen project is not expected to proceed.) Life cycle impacts of SCPC and IGCC plants with and without CCS are described by Odeh and Cockerill (2008) and NETL (2010b, 2010c, 2014).

Relative to conventional SCPC coal plants, emissions of priority air pollutants from an IGCC plant without CCS are low, especially for SO_2. Projected life cycle GHG emissions for an IGCC plant without CCS are comparable to those of a SCPC plant (NETL 2014). Assuming a 90 percent carbon capture rate, adding CCS to a new SCPC plant would reduce life cycle GHG emissions from approximately 1,045 to 283 tons CO_2-eq/GWh, and adding CCS to an IGCC plant would reduce life cycle GHG emissions to about 242 tons CO_2-eq/GWh (NETL 2014). For both SCPC and IGCC plants, adding CCS increases the proportion of life cycle GHG emissions attributable to coal mining and processing from about 8 percent to 41–43 percent.

New SCPC and IGCC plants are assumed to have closed-cycle cooling systems. Adding CCS to a SCPC plant increases water consumption by the generating facility by about 70 percent to around 920 gallons/MWh (NETL 2010b. For an IGCC plant, CCS raises water consumption by around 50 percent to 605 gallons/MWh (NETL 2010c). Other estimates for IGCC plants with CCS, closed-cycle cooling systems, and zero liquid discharge include 469 gallons/MWh for the Kemper County plant (USDOE 2010a) and 655 gallons/MWh for the FutureGen plant (USDOE

2007). Instead of the fly ash, bottom ash, and scrubber sludge produced by a SCPC plant, IGCC plants produce a glassy, inert slag during the gasification process. The projected slag production rate for the FutureGen plant, using ILB coal, is 47.3 tons/GWh (USDOE 2007).

Projected facility surface land requirements for IGCC plants with CCS include 200 acres for the 275-MW FutureGen plant (USDOE 2007) and 550 acres for the 582-MW Kemper plant (USDOE 2010a). The average land requirement for these two plants is 0.84 acres/MW. The 1,200-MW Mesaba IGCC plant, without CCS, is projected to occupy 300 acres (USDOE 2009). The IGCC plant without CCS option considered in this IRP process is assumed to require 400 acres and the IGCC plant with CCS option is assumed to require 450 acres. The difference is due to the land requirements for CCS components, particularly CO_2 pipelines and injection wells. Published life cycle land requirements are not available and would vary with the type of coal being used, mining method, CCR disposal method, and distance from the generating facility to the carbon sequestration site.

TVA's SCPC plants occupy land areas of 730 to 3,000 acres, with an average of 0.83 acres/MW. Recently constructed SCPC and advanced ultra-supercritical plants in the U.S. (John W. Turk, Jr. in Arkansas, Longview in West Virginia, Sandy Creek in Texas, and Prairie State in Illinois) occupy an average of 0.91 acres/MW. Based on these averages, and because the correlation between plant land area and capacity is weak, a new 800-MW SCPC plant is assumed to occupy 725 acres and a new 1,600-MW SCPC is assumed to occupy 1,100 acres. Due to the land requirements for CCS components, adding CCS to the SCPC plants is assumed to require an additional 50 acres.

Natural Gas – Existing Facilities

The construction and operational impacts of TVA's recently constructed combustion turbine (CT) and combined cycle (CC) plants (e.g., Lagoon Creek CT, John Sevier CC), and CC plants under construction (e.g., Paradise CC) and scheduled to soon begin construction (e.g., Allen CC) are described in several EISs and environmental assessments (e.g., TVA 2000, TVA 2010a, TVA 2013b, TVA 2014d). Natural gas-fired plants do not emit SO_2 or mercury, and direct emissions of NOx (usually controlled by water or steam injection and/or SCR systems) and CO_2 are low relative to other fossil plants. CT plants require minimal amounts of process water. TVA's CC plants use closed-cycle cooling, as do most other CC plants elsewhere. The average land area for TVA CT plants is about 90 acres (0.153 acres/MW). TVA CC plants occupy an average of about 87 acres (0.108 acres/MW).

Life cycle GHG emissions have not been calculated for TVA's gas-fired plants. Published rates for comparable CC plants average about 509 tons CO_2-eq/GWh (Meier and Kulcinski 2000, Spath and Mann 2000, Jaramillo et al. 2007). In a more recent analysis based on advanced F-class combustion turbines, NETL (2014) calculated life cycle GHG emission rates of 510 tons CO_2-eq/GWh for a CC plant and 784 tons CO_2-eq/GWh for a CT plant. Due to the age of many of TVA's CT plants, their life cycle GHG emissions are assumed to be somewhat greater than 784 tons CO_2-eq/GWh.

About 15 percent of the GHG emissions from CC and CT plants reported by NETL (2014) results from the extraction, processing and transport of natural gas. These emissions are dominated by methane. The natural gas supply was based on the 2010 U.S. mix of domestic sources, including 41 percent "conventional" gas sources (54 percent onshore, 30 percent offshore, and 16 percent associated) and 59 percent "unconventional" gas sources (45 percent

tight, 35 percent Barnett shale, 4 percent Marcellus shale, and 16 percent coal bed methane) (NETL 2014). The GHG emission rate during gas production and transport averaged 8.4 grams CO_2-eq/megajoule (MJ, equivalent to 948 BTU) of natural gas. GHG emission rates were somewhat higher for unconventional tight (9.0 grams CO_2-eq/MJ), Barnett shale (9.0 grams CO_2-eq/MJ), and Marcellus shale (9.1 grams CO_2-eq/MJ) gas production than for conventional onshore (8.8 grams CO_2-eq/MJ), offshore (6.1 grams CO_2-eq/MJ), and associated (7.8 grams CO_2-eq/MJ) gas production.

One of several areas of concern over the environmental impacts of shale gas production by hydraulic fracturing has been over fugitive emissions of methane. Hydraulic fracturing involves the injection of pressurized fluids (predominantly water with gels and chemical additives) and sand into the well borehole to fracture the gas-bearing rock formation and increase its permeability. Howarth et al. (2011) suggested that high methane emissions during shale gas production resulted in higher overall GHG emissions than coal. Other studies have shown the life cycle carbon footprint of electricity generation from shale gas is similar to (Weber and Clavin 2012) or somewhat (11 percent) greater than (Hultman et al. 2011) generation from conventional gas. Even when accounting for higher emissions from the use of shale gas, Hultman et al. (2011) and NETL (2014) concluded that electricity generation from shale gas had a much lower GHG emissions than generation from coal.

Several other areas of concern over the environmental impacts of shale gas production have been identified and the risk to water resources is the subject of numerous studies. In a review of this risk, Vengosh et al. (2014) include contamination of shallow aquifers by stray gas from leaking gas wells and subsurface flow, contamination of surface water and shallow groundwater by inadequately treated shale gas wastewater, accumulation of toxic and radioactive elements in soil and stream sediments, and overextraction of water for high-volume fracturing in water-scarce areas. Vengosh et al. (2014) recommend several mitigation measures to reduce these risks, which are also the subject of various regulatory and industry initiatives. Impacts to drinking water can occur from the withdrawal of ground or surface water used for fracturing fluids, from the mixing of chemicals, from the injection of fracturing fluids into wells, from water flowing out of wells (produced waters), and from the treatment and disposal of produced water. The impact to drinking water is the subject of ongoing studies by the USEPA. Other areas of risk include air quality, induced seismicity (earthquakes) from hydraulic fracturing and disposal of fracturing fluids and produced water by deep injection, habitat loss and fragmentation, noise and light pollution, public health, and socioeconomic and community effects. Some of these risk areas are not as well-known as those related to water resources and methane emissions (Small et al. 2014, Souther et al. 2014). Recently published studies have shown an increase in earthquakes in the central U.S. attributable to the deep underground injection of wastewater. Much of this wastewater is saline produced water from oil and gas wells. Relatively few induced earthquakes are directly attributable to hydraulic fracturing (Rubenstein and Mahani 2015, Weingarten et al. 2015).

Natural Gas – New Facilities

The new natural gas facilities available for selection during the portfolio modeling are a 590-MW 3-unit CT plant, a 786-MW 4-unit CT plant, a 670-MW CC plant with two combustion turbines and one steam generator, and a 1,005-MW CC plant with three combustion turbines and one steam generator (see Section 5.3.1). All gas plant configurations are based on advanced F-class combustion turbines. The environmental characteristics of these plants are generally similar to those of existing recent gas plants characterized above by NETL (2014), although the

new F-class turbines are somewhat more efficient and thus have somewhat lower emission rates. Land area requirements are based on those of TVA's newest CT and CC plants, which show little correlation between land area and capacity.

7.2.2 Nuclear Generation

Nuclear – Existing Facilities

The impacts of operating TVA's existing and committed (i.e., Watts Bar Unit 2) nuclear plants are described in previous EISs and other reports (e.g., TVA 2007b). Nuclear power generation does not directly emit regulated air pollutants or GHGs. The largest variable in life cycle GHG emissions of a nuclear plant, aside from the operating lifetime, electrical output, and capacity factor, are related to the uranium fuel cycle and include the uranium concentration in the ore, the type of uranium enrichment process, and the source of power for enrichment facilities. Almost all past uranium enrichment in the U.S. used the energy-intensive gaseous diffusion process largely powered by fossil fuels. No gaseous diffusion enrichment facilities are currently operating or likely to operate in the future in the U.S. Commercial enrichment by the centrifuge process began in the U.S. at a plant in New Mexico in 2010. This process, widely used outside the U.S., can require less than 3 percent the energy of the gaseous diffusion process. Construction of two other U.S. centrifuge process enrichment plants is currently on hold. Laser enrichment processes would further reduce energy requirements; commercial development of this technology in the U.S. has slowed due to the recent low demand for nuclear fuel. The use of highly enriched uranium from dismantled nuclear weapons diluted to commercial reactor fuel also reduces GHG emissions.

The life cycle GHG emissions of TVA's nuclear plants have not been determined. In a recent international survey of nuclear electric generation life cycle studies, Warner and Heath (2012) reported a median GHG emission rate of 13.2 tons CO_2-eq/GWh (12 grams CO_2-eq/kWh) and an interquartile range (the 75th percentile value minus the 25th percentile value) of 18.7 tons CO_2-eq/GWh. Boiling water reactors, such as TVA's Browns Ferry plant, tend to have slightly higher life cycle GHG emissions than pressurized water reactors such as TVA's Sequoyah and Watts Bar plants. Fthenakis and Kim (2007) reported life cycle GHG emissions of 17.6 to 60.6 tons CO_2-eq/GWh for U.S. nuclear plants. Part of the difference in emission rates between the 2012 international survey and the 2007 U.S. study is the greater U.S. reliance on the more energy-intensive gaseous diffusion enrichment process. Fthenakis and Kim (2007) predicted a decrease in life cycle GHG emissions to about 13.2 tons CO_2-eq/GWh with exclusive use of centrifuge enrichment.

TVA's nuclear plants occupy an average of 1,114 acres each and about 80 percent of this area is developed. Life cycle land metrics have not been determined for TVA's nuclear plants. Fthenakis and Kim (2009) estimated a life cycle land transformation of 0.023 acres/GWh for nuclear power. About half of this transformed land is the power plant site. Due to the evolving approach to the long-term disposal of spent fuel, the land required for offsite spent fuel disposal is excluded from this estimate.

Nuclear – New Facilities

The new nuclear generation options available for selection during the portfolio modeling are a 1,260-MW pressurized water reactor (completion of one or both Bellefonte units), an advanced pressurized water reactor (characterized by the AP1000 design), a 334-MW two-unit small modular reactor, and the Browns Ferry nuclear plant extended power uprates (see Section 5.3.2). The impacts of constructing and operating a one- or two-unit pressurized water reactor

nuclear plant at the Bellefonte site are described in a 1974 EIS (TVA 1974). A 2010 EIS (TVA 2010c) described the impacts of completing one of the partially constructed units. The main environmental impacts of the extended power uprate of one or more units at the Browns Ferry plant are associated with the increased fuel consumption and increased cooling requirements.

In 2008, TVA completed an environmental report (TVA 2008b) for a combined license application to the Nuclear Regulatory Commission for the construction and operation of a two-unit AP1000 nuclear plant on the Bellefonte site. Because this site contains a partially built, two-unit nuclear plant, the impacts of construction of one or two AP1000 nuclear units would likely not be significant. Most operational impacts would be comparable to those of TVA's existing nuclear plants with the exception of water use and water consumption. An AP1000 plant at Bellefonte would primarily operate with closed cycle cooling and water use would be relatively low and water consumption relatively high compared to TVA's other thermoelectric plants. The impacts of constructing and operating one or more AP1000 reactors at an undeveloped site would be greater than at Bellefonte.

The impacts of constructing and operating a small modular reactor (SMR) plant would be generally similar to those of TVA's existing nuclear plants and the other new nuclear generation options, but proportionately less due to the lower capacity of the small modular reactor plant. A new SMR plant would operate with closed cycle cooling, with relatively low water use rates and relatively high water consumption rates. The land requirement for a new SMR plant is based on the potential design of an SMR plant at TVA's Clinch River Site.

7.2.3 Renewable Generation

TVA's current renewable energy portfolio is dominated by the hydroelectric facilities at its dams and power purchase agreements for wind energy. Power purchase agreements for solar generation are a small but rapidly growing component of the portfolio (see Sections 3.3 and 3.4). Following is an overview of the environmental impacts of renewable generation from hydroelectric, wind, solar, and biomass facilities.

Hydroelectric – Existing Facilities

Impacts of the operation of TVA's hydroelectric facilities are described in the *Reservoir Operations Study* (TVA 2004). Hydropower generation does not directly emit CO_2 and its life cycle GHG emissions are among the lowest of the various types of generation. Although not studied for TVA facilities, reported life cycle GHG emissions from other hydroelectric facilities vary greatly, primarily due to uncertainties over methane emissions from the decomposition of flooded biomass, mostly after the reservoir is initially filled (AEFPERR 2009). These methane emissions are site-specific and are poorly known for reservoirs in areas with temperate climates such as the TVA region. Excluding methane emissions, reported life cycle emissions include 12.1 tons CO_2/GWh for a temperate zone 10-MW run-of-river plant (Hondo 2005), and 28.8 tons CO_2/GWh for the much larger Glen Canyon plant (Spitzley and Keolieian 2005). Emissions from hydroelectric reservoirs are also offset by the multi-purpose use of the reservoirs.

Hydroelectric – New Facilities

Under all the alternatives, TVA would continue to modernize its hydroelectric units as part of its normal maintenance activities. The impacts of these upgrades have been described in environmental assessments for many facilities (e.g., TVA 2005a). While the upgrades generally do not change the volume of water used on a daily cycle, they can increase the rate of water passing through the turbines and result in small, periodic increases in downstream velocities. A

potential consequence of the increased velocity is increased downstream bank erosion, which TVA mitigates as necessary by protecting streambanks with riprap or other techniques. Other environmental impacts of hydro modernization are minimal and there is typically no additional long-term conversion of land.

Two options for new hydroelectric generation involve adding turbines to existing TVA hydroelectric dams. One option is adding a 40-MW turbine to a main-stem dam where water is regularly spilled (passed over the dam through floodgates during high flow periods) to utilize the energy potential in the spilled water. The other option is adding a 30-MW turbine where there is adequate existing space for the turbine. Both of these would be relatively major construction projects, although most construction activities would occur on the dam reservations.

An additional option for new hydroelectric generation is the development of run-of-river generating facilities. Run-of-river facilities could include the addition of turbines to existing, non-power dams and in-stream turbines not requiring a dam. One type of run-of-river generating facility is adding turbines to existing run-of-river dams, such as old mill dams. The construction of the generating facilities could result in major modifications to the dams and transmission upgrades, and at some sites would require additional land. The dams would continue to operate in a run-of-river mode, which would lessen some potential environmental impacts. Provisions for fish passage, however, could be required at some dams. See Section 4.17.3 for descriptions of potential sites. Other run-of-river projects would use very small or no reservoirs. One class of these would divert part of the streamflow into a raceway to a downstream generator without totally blocking the stream channel. Potential environmental impacts include alterations of the streambed and streambanks, removal of riparian vegetation, and, for at least a short stretch of the stream, reduction of streamflow (EPRI 2010). Another type of run-of-river facility is in-stream generators mounted on the streambed or suspended from a barge or other structure. These could interfere with boating and other recreational uses of the stream. At this time, their potential impacts on fish and other aquatic life are poorly known, although a few studies have suggested they are not significant. Land requirements vary with the type of run-of-river facility and for this analysis are assumed to be 0.5 acres/MW.

Wind – Existing Facilities

A significant portion of TVA's generation portfolio is wind generation from the Cumberland Mountains of Tennessee, the upper Midwest, and the Great Plains (Table 3-6). TVA currently purchases power from nine wind farms with a total of 907 turbines. The hub heights of these turbines range from 78–100 m and the rotor diameters range from 77–100 m. TVA completed environmental assessments for wind farms in Tennessee (TVA 2002) and Kansas (TVA 2011e, 2011f).

Impacts of wind farm construction include the clearing and grading of access roads and turbine sites and excavation for turbine foundations and electrical connections. Denholm et al. (2009) reported an average direct permanent impact area of 0.74 acres/MW, and a direct average temporary impact area of 1.73 acres/MW. These impact areas average somewhat smaller in mid-western croplands and somewhat larger in Great Plains grasslands/herbaceous areas and forested Appalachian ridges. A review of wind farms supplying TVA purchased power (Table 3-6) showed that their average direct impact area is close to that of Denholm et al. (2009).

The total wind farm area tends to be much larger than the direct impact areas and nationwide averages 84 acres/MW or a capacity density of 1 MW/82 acres (Denholm et al. 2009). This

density, while low relative to most other types of electrical generation, varies greatly due to different leasing practices by wind farm developers. A very small proportion of this area is directly disturbed and most land use practices can continue on the remainder of the wind farm area. Land clearing and road and transmission line development for wind farms can, however, result in habitat fragmentation.

Operational impacts include turbine noise, which can be audible for distances of a quarter mile or more, and the visual impacts of the turbines which can dominate the skyline. Operating turbines can also cause shadow flicker, the flickering effect caused when rotating wind turbine blades periodically cast shadows through constrained openings such as the windows on neighboring properties. The scale of the problem depends on a number of factors such as turbine height, wind speed and direction, position of the sun, distance from the turbine, local terrain and amount of cloud cover; modeling tools have been developed to quantify shadow flicker associated with existing and proposed windfarms. Shadow flicker has been reported to cause headaches and increase stress for some individuals.

Impacts to biological resources include habitat fragmentation, displacement of wildlife that avoid tall structures, and mortality of birds and bats from collision with turbines. Bats can also die from trauma induced by air pressure changes caused by the rotating turbines (BLM 2005, Baerwald et al. 2008). Loss et al. (2013) and Erickson et al. (2014) recently analyzed bird collision mortality at wind farms across North America. Loss et al. (2013) estimated mean annual mortality rates of 6.86 birds/turbine (3.86 birds/MW) for the eastern U.S. (including Tennessee and Illinois) and 2.92 birds/turbine (1.81 birds/MW) for the Great Plains (including Iowa and Kansas). This study also found an increase in mortality rate with turbine hub height. Erickson et al. (2014) estimated annual mortality rates for songbirds (passerines) of 2.58–3.83 birds/MW for the eastern U.S. (including Tennessee) and 2.15–3.96 birds/MW for the Plains region (including Illinois, Iowa, and Kansas). In comparing total estimated wind farm mortality of individual species of songbirds with their estimated continent-wide populations, Erickson et al. (2014) concluded less than 0.045 percent of the entire population of each species suffered mortality from collisions with turbines.

While the impacts of bird mortality are probably not significant in most areas, the impacts of bat mortality have a greater potential for concern. The highest annual bat mortality rates, 20.8–69.6 bats/turbine (14.9–53.3 bats/MW) have been reported at wind farms on forested ridges in the eastern U.S. (Arnett et al. 2008, Hayes 2013). Annual rates at Midwest wind farms (i.e., much of the potential MISO area) are lower, between 2.0 and 7.8 bats/turbine (2.7–8.7 bats/MW). Very limited bat mortality information is available from wind farms in the southern Great Plains (i.e., much of the potential SPP and HVDC wind resource areas), where one study found a mortality rate of 1.2 bats/turbine/year (0.8/MW) (Arnett et al. 2008, USDOE 2014a). Common patterns detected in bat mortality studies include the following: 1) most fatalities occur in later summer and early fall; 2) most fatalities are of migratory, foliage- and tree-roosting species; and 3) most fatalities occur on nights with low wind speed (<6 meters/second) and 4) fatalities increase immediately before and after the passage of storm fronts (Arnett et al. 2008).

The U.S. Fish and Wildlife Service has developed guidelines (USFWS 2012) for the siting, development, and operation of wind farms. These voluntary guidelines include preliminary site screening, detailed site characterization studies, post-construction studies, and potential impact reduction and mitigation measures. Reducing the operation of wind turbines during periods of low wind speeds at night during seasons when bats are most active has been shown to be an

effective measure for reducing bat mortality while having minimal effect on power generation (Arnett et al. 2011).

Wind turbines produce no direct emissions of air pollutants or GHGs. In a recent international survey of land-based, utility-scale wind power generation life cycle studies, Dolan and Heath (2012) found a median GHG emission rate of 12 tons CO_2-eq/GWh (11 grams CO_2-eq/KWh) and an interquartile range (the 75th percentile value minus the 25th percentile value) of 11 tons CO_2-eq/GWh. The largest contributor to variation in the life cycle GHG emission rate was the turbine capacity factor.

Wind – New Facilities
The draft EIS for the Plains & Eastern Clean Line Transmission Project (USDOE 2014) describes the potential impacts of constructing and operating this HVDC transmission line (see Section 5.3.3). TVA is a cooperating agency in the development of this draft EIS, which also programmatically describes the potential impacts of constructing and operating wind farms in the Oklahoma and Texas Panhandle area from which TVA could purchase power. Most of the potential HVDC wind farm area is rangeland. Potential wind farm sites in other portions of the SPP service area are dominated by rangeland. Potential wind farm sites in the MISO area are primarily agricultural land with an increasing proportion of rangeland in the Dakotas.

TVA anticipates the developers of wind farms will follow USFWS guidelines on windfarms (USFWS 2012). Land area requirements, based on the direct permanent impact area, are conservatively assumed to be 1 acre/MW for wind farms in the TVA service area and 0.8 acre/MW for wind farms elsewhere. Larger areas are affected by the noise and visual impacts of wind turbines, as well as shadow flicker.

Solar – Existing Facilities
TVA operates 15 small PV installations. The environmental impacts of constructing and operating these have been negligible (TVA 2001). TVA also purchases energy generated from numerous PV facilities up to 20 MW in size (see Section 3.4).

TVA recently assessed the potential impacts of small PV facilities in a programmatic environmental assessment (TVA 2014f). Most completed ground-mounted PV facilities have been constructed on previously cleared areas, frequently pasture, hayfield, or crop land, and most have required little grading to smooth or level the site. Several have been constructed on land classified under the Farmland Protection Policy Act as prime farmland. Although the construction and operation of the PV facility eliminates agricultural production on the area, it typically does not adversely affect soil productivity or the ability to resume agricultural production once the PV facilities are removed. The construction of the PV facility frequently affects local scenery, but this affect is often minor because of the low profile of the PV components and vegetative screening, either existing or planted as part of the PV facility development.

PV facilities produce no direct emissions of air pollutants or GHGs. In a recent international survey of crystalline silicon power generation life cycle studies, Hsu et al. (2012) found a median GHG emission rate of 50 tons CO_2-eq/GWh (45 grams CO_2-eq/KWh) and an interquartile range (the 75th percentile value minus the 25th percentile value) of 11 tons CO_2-eq/GWh (10 g/kWh). These rates are based an annual solar insolation of 1,700 kWh/m^2/year, within the range of 1,460–1,825 kWh/m^2/year (4–5 kWh/m^2/day) found across most of the TVA region (see Figure

4-47, Section 4.17.2). The largest contributor to variation in the life cycle GHG emission rate was the insolation level. Facilities using thin-film PV panels based on cadmium-telluride (CdTe), which are often used in large utility-scale PV facilities, have a life cycle GHG emission rate of 22 tons CO_2-eq/GWh (20 grams CO_2-eq/kWh; Kim et al. 2012). Very few, if any, existing or proposed PV facilities in the TVA service area use thin-film PV panels.

Land requirements for PV facilities vary greatly and depend on the type of installation. Building-mounted systems require no additional land. Ground-mounted systems may be on canopies that provide shelter and thus, do not negatively impact land use. Land requirements for stand-alone ground-mounted systems vary with the type of mounting system. Fixed systems (with panels that do not move to track the movement of the sum) require less land than those with 1- or 2-axis tracking (Denholm and Margolis 2007). The generation by tracking systems, however, is greater than from fixed systems. Ong et al. (2013) surveyed land requirements of U.S. PV projects between 1 and 20 MW capacity. Fixed-tilt systems required an average of 5.5 acres/MW_{AC} and 1-axis tracking systems required an average of 6.3 acres/MW_{AC}. Ground-mounted PV facilities with a capacity of at least 50 kWdc constructed and under development in the TVA service area have an average land requirement of 7.3 acres/MW_{DC} (ca. 8.6 acres/MW_{AC}). More recent facilities have reduced land requirements. Based on the analysis of Ong et al. (2013) and experience in the TVA service area, new ground-mounted PV facilities are assumed to require 7.5 acres/MW_{AC} for fixed-tilt systems and 8.5 acres/MW_{AC} for 1-axis tracking systems.

Solar – New Facilities
The impacts of new solar generating facilities are expected to be similar to those described above for existing facilities. An emphasis on power purchases from larger utility-scale projects would result in more large solar facilities (i.e., $\geq$20 MW) being constructed.

Biomass – Existing Facilities
TVA generates electricity from biomass by co-firing methane from a sewage treatment plant at Allen Fossil Plant and by co-firing wood waste at Colbert Fossil Plant. The relative amounts of this generation are small and adverse environmental impacts are minimal. A beneficial impact is the avoidance of methane emissions and the small reduction of emissions from the displaced coal generation.

TVA also purchases electricity generated from landfill gas and wood waste. The environmental impacts of this generation are, overall, beneficial due to the avoidance of methane emissions and utilization of residues at wood and grain processing plants. The generating facilities have typically been built on heavily disturbed landfill or other industrial sites and occupy small land areas.

Biomass – New Generation
The alternative strategies include the two options for new biomass generation, a 115-MW dedicated biomass facility, and a 75-MW repowered coal unit. Under the repowered coal unit option, TVA would convert one or more of its existing smaller coal-fired units, such as at the Shawnee Fossil Plant, to exclusively burn biomass. The conversion would require changes to the boilers, changes to or replacement of the boiler coal feed system, and construction of a biomass fuel receiving and processing facility. The land requirements for these vary and are plant-specific. Most of the components could likely be sited on the existing plant reservations on areas previously disturbed by other plant operations. Life cycle land requirements would

increase over those of a coal facility if there are multiple, dispersed fuel sourcing areas. Emission rates would likely be similar to those of a new dedicated biomass facility described below. Water use and consumption rates would be somewhat less than those of the coal unit.

Potential fuels for the biomass-fueled generating facilities include forest wood (trees harvested for use as biomass feedstock), forest residues, mill residues, wood waste, and dedicated biomass crops. These fuels and their availability in the TVA region are described in Section 4.17.4.

A dedicated biomass facility could be constructed at one of TVA's existing plant sites or at a greenfield site. Plant capacity for biomass generating facilities can be limited due to fuel delivery constraints and plants larger than 50 MW are uncommon (AEFPERR 2009, EPRI 2014). A few larger plants have been proposed or begun construction in recent years. The amount of fuel consumed per unit of generation varies with the type of biomass, its moisture content, and the plant technology (e.g., stoker boiler, circulating fluidized bed boiler, or gasification). Fuel consumption rates reported at several dedicated facilities range from 2–5 tons/MWh (Wiltsee 2000, EPRI 2014). Facility land requirements vary; reported values include 17 acres for a 36-MW plant, 31 acres for a 40-MW plant, 39 acres for a 50-MW plant, and 200 acres for a 100-MW plant (Wiltsee 2000, EPRI 2010). This impact analysis assumes 100 acres are required for a 115-MW plant. Life cycle land requirements vary greatly with the fuel feedstock. They are relatively small for mill residues and waste wood. For biomass fuel crops, land requirements would be high and likely among the highest of any of the any of the resource options under consideration.

Biomass-fueled generating plants emit no mercury and only minimal amounts of SO_2; NOx emissions vary with the type of facility and NOx emission reduction systems are typically required. Biomass-fueled generating plants are frequently described as being carbon neutral because the CO_2 they emit is not of fossil origin. Plants used as biomass fuel feedstock take up (sequester) CO_2 from the atmosphere during photosynthesis; this CO_2 is then emitted to the atmosphere when they are burned. The CO_2 emission rate from the combustion of biomass for generating electricity is typically higher than for fossil fuels (EPRI 2014) due to the low energy content of biomass fuels and the low efficiency (high heat rate) of biomass generating plants. The issue of whether biomass-fueled power generation is carbon neutral, however, is controversial as the combustion of forest-derived biomass emits large quantities of CO_2 that can require decades to be sequestered by growing trees (Walker et al. 2010). Important factors for assessing CO_2 emissions from biomass-fueled power plants include 1) feedstock growth and harvest; 2) processing, transport, storage and use of the feedstock; and 3) the alternative fate of the feedstock if not use for energy production (USEPA 2014d).

Aside from direct CO_2 emissions, GHGs are emitted during several process steps of biomass-fueled power generation. Many published studies of life cycle GHG emissions from electrical generation with biomass fuels assume that combustion of biomass does not result in the direct emission of CO_2 and therefore, some studies have concluded that life cycle GHG emissions are negative. Spath and Mann (2004), for example, calculated a life cycle GHG emission rate of -452 tons CO_2-eq/GWh for a 60-MW direct-fired boiler using wood waste. Spitzley and Keoleian (2005) reported rates of 58 tons CO_2-eq/GWh for a 50-MW direct-fired boiler and 44 tons CO_2-eq/GWh for a 75-MW IGCC plant; both of these facilities were fueled with willow grown as an energy crop. In a survey of published LCAs, EPRI (2013) found a median GHG emission rate of 39 tons CO_2-eq/GWh (35 grams CO_2-eq/KWh) and an interquartile range (the

75th percentile value minus the 25th percentile value) of 33 tons CO_2-eq/GWh (30 g/kWh) for direct combustion biomass generating facilities. Gasification biomass generating facilities had a median GHG emission rate of 52 tons CO_2-eq/GWh (47 g/kWh) and an interquartile range of 40 tons CO_2-eq/GWh (36 g/kWh). Facilities burning mill and forest residues had lower life cycle GHG emission rates than those burning dedicated woody and herbaceous crops. These differences are largely attributable to increased energy inputs for crop production, including fertilizer applications (EPRI 2013). These life cycle GHG emission estimates do not include emissions resulting from any land use conversion associated with fuel acquisition.

The harvesting and transportation of trees for use as fuel can result in adverse environmental impacts. These impacts are similar to those that can result from harvesting trees for other purposes, such as for wood chips for the manufacture of pulp or other forest products (TVA 1993). Potential impacts include the modification or loss of wildlife habitat, sedimentation, reduction in soil fertility, loss of old growth forest, change in forest type and understory vegetation, altered scenery, and competition with other wood-using industries. The severity of these impacts varies with the use of appropriate best management practices, the proportion or quantity of trees harvested from a stand, whether the harvested stand is a plantation, post-harvest site treatment and other factors.

7.2.4 Energy Storage

Existing Facilities

Operational impacts of the Raccoon Mountain facility are summarized in Table 7-1. Denholm and Kulcinski (2004) analyzed life cycle GHG emissions of pumped storage facilities. The construction, operation (excluding pumping), and decommissioning of the facility produce life cycle GHG emissions of approximately 5.5 tons of CO_2-eq/GWh of storage capacity, a small proportion of the total life cycle GHG emissions. GHG emissions from generation are a function of the GHG intensity of the electricity used in the pumping mode. Assuming 78 percent efficiency of energy conversion (slightly lower than the 80 percent efficiency of Raccoon Mountain) and 5 percent transmission loss factor (a function of distance from the energy source and load center), GHG emissions are approximately 1.35 times the energy source emissions. At TVA's 2014 CO_2 intensity of 550 tons/GWh, the operation of Raccoon Mountain, as well as that of a future pumped storage facility, would emit about 743 tons of CO_2/GWh. This emission rate will decrease with the reduction in CO_2 intensity occurring under the action alternatives. Although Raccoon Mountain uses a large volume of water, none of this water is consumed.

New Facilities

The operational impacts of a new 850-MW pumped storage plant are expected to be similar to those of the Raccoon Mountain plant. Construction impacts would include the construction of the upper reservoir, excavation of the powerhouse and the tunnel connecting the upper and lower reservoirs, and construction of the discharge structure in the lower reservoir. If the lower reservoir is an existing reservoir, dredging of the discharge area and construction of an enclosure around the discharge structure would likely be required. If a new lower reservoir is required, additional impacts would result from the construction of the dam and reservoir and diversion of existing streams around or into the reservoirs. These impacts could be substantial. A new pumped storage plant is assumed to operate with an efficiency of 81 percent.

Because there are few operating compressed air energy storage (CAES) plants, information on their environmental impacts is limited. Based on a TVA study of potential CAES facility configurations in northeast Mississippi during the 1990s, a 330-MW CAES facility would require

about 80 acres for the air injection/withdrawal wells, connecting pipelines, and the CAES plant. Operation of the plant would require about 2,300 gallons per minute of water to operate the plant cooling system. A portion of this water would likely be provided by well air/water separators. The plant is assumed to operate with an efficiency of 70 percent.

7.3 Environmental Impacts of Energy Efficiency and Demand Response Programs

The sources of environmental impacts from the proposed expansion of TVA's EEDR programs under the alternative strategies include the following:

- The reduction in or avoidance of generation (collectively "reduction") resulting from energy efficiency measures. This reduction is incorporated into the alternative strategies and portfolios assessed in Section 7.5.
- The change in the type of generation due to changes from on-peak to off-peak energy use resulting from demand response programs. This change in load shape, and the resulting change in peak demand, is incorporated into the alternative strategies and portfolios assessed in Section 7.5. Historically, most demand response has been in emergency situations and shifted the time of electrical use with little net change in use and little environmental impact. More widespread employment of demand response is likely to result in a small net reduction in electrical use and the associated impacts from its generation (Huber et al. 2011).
- The impacts of the generation of renewable electricity by end users participating in the Green Power Providers, biodiesel generation, and non-renewable clean generation programs. The impacts of this generation are included in the discussion Section 7.5.
- The generation of solid waste resulting from building retrofits and the replacement of appliances, heating and air conditioning (HVAC) equipment, and other equipment to reduce energy use.
- Adverse impacts to historic buildings from building retrofits that result in changes in their external appearance and associated historic integrity.

Building retrofits to reduce energy use, such as replacing windows and doors, produce solid wastes which are often disposed of in landfills. The disposition of old appliances, HVAC equipment, water heaters, and other equipment varies across the region with the local availability of recycling facilities. Old refrigerators and HVAC equipment may also contain hydro chloroflourocarbon refrigerants ("freon") whose use and disposal is regulated due to their harmful effects on stratospheric ozone ("the ozone layer") and because of their high global warming potential. To reduce these harmful effects, HVAC contractors are required to reclaim and recycle these refrigerants from HVAC equipment being replaced.

The activities associated with building retrofits and other residential, commercial, and industrial measures EE are unlikely to have disproportionately high adverse impacts on low income and minority populations. Household energy efficiency efforts can result in reductions of cold-related illnesses and associated stress by making it easier for residents to heat their homes. Reduced ventilation rates, can, however, adversely affect indoor air quality. In a recent review of this topic, Maidment et al. (2014) concluded that household EE measures have a net positive impact on health and the benefits are greatest for low income populations. Due to the structure of the EE programs, however, low-income residents frequently have less ability to participate in them. Most EE programs require that participating individuals and organizations pay a portion of the

costs of their energy efficiency measures. Low-income residents typically have a reduced ability to pay these costs. In addition, many low-income residents live in rental housing and there are few EE programs targeting rental single-family and multi-family housing.

Programmatic environmental reviews of EE programs have been conducted by USDOE (2014b) for the Hawai'i Clean Energy Program and by the Rural Utilities Service (USDA 2012) for their Energy Efficiency and Conservation loan program. USDOE (2014b) concluded that EE programs would result in beneficial impacts from reduction of GHG emissions and the potential for adverse impacts from EE actions is low with adherence to applicable regulations and best management practices. The Rural Utility Service (USDA 2012) identified a few areas of concern including the potential presence of lead-based paint and asbestos containing material which would be mitigated with adherence to applicable regulations. The potential for adverse impacts to historic properties was low but some EE activities resulting in the modification of the exterior of buildings would require additional project-specific reviews.

7.4 Environmental Impacts of Transmission Facility Construction and Operation

As described in Chapter 6, all of the alternatives would require the construction of new or upgraded transmission facilities. Following is a listing of generic impacts of these construction activities (Table 7-3). This listing was compiled by reviewing the EISs (e.g., TVA 2005b), environmental assessments (e.g., TVA 2013d), and other project planning documents for TVA transmission construction activities completed since 2005. A total of 149 projects were included in this review. Thirty-two projects involved construction or expansion of a new or existing substation or switching station. One-hundred two projects, including some of the substation/switching station projects, involved the construction of new transmission lines totaling about 410 miles in length. Sixty projects involved modifications to existing transmission lines.

The anticipated amount of construction of new or upgraded transmission facilities varies among the alternative strategies. All new generating facilities would require connections to the transmission system; the length of connecting transmission lines and the need for new substations and switching stations depend on the location and capacity of the facilities. The retirement of generating facilities, such as coal plants, can also result in the need for new or upgraded transmission facilities in order to maintain adequate power supply and reliability. The importation of wind energy from outside the TVA region, a component of a majority of the capacity expansion plans, would likely require transmission facility construction. Potential impacts of transmission facility construction associated with the HVDC wind resource option are described in a recent programmatic draft EIS (USDOE 2014a).

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Table 7-3 Generic impacts of transmission system construction activities.

	Transmission Lines	Substations and Switching Stations
Land Use Impacts		
Land requirements	Average of 12.2 acres/line mile, range 3.5 – 36.4	Average of 11.8 acres, range 1 – 73 Median for 500 kV: 49.5 Median for <500 kV: 5.1
Floodplain fill	0	Average of 0.1 acres, range 0 – 4 6% affected floodplains
Prime farmland converted	0	Average of 6.9 acres, range 0 – 29.1 64% affected prime farmland
Land Cover Impacts		
Forest cleared	Average of 5.6 acres/line mile for new lines, range 0 – 30.5	Average of 4.2 acres, range 0 – 50 33% cleared forest
Wetland Impacts		
Area affected	Average of 0.7 acres/line mile for new line, range 0 – 8.5 63% affected wetlands Average of 1.2 acres/line mile of existing line, range 0 – 18.3 78% affected wetlands	Average of 0.1 acres, range 0 – 1.8 14% affected wetlands
Forested wetland area cleared	Average of 0.4 acres/line mile of new line, range 0 – 6.3 43% affected forested wetlands Average of 0.03 acres/line mile of existing line, range 0 – 0.5 31% affected forest wetlands	-
Stream Impacts		
Stream crossings	Average of 3.4 per mile of new line, range 0 – 50 78% crossed streams Average of 1.5 per mile of existing line, range 0 – 5.6	n/a
Forested stream crossings	Average of 1.2 per mile of new line, range 0 – 17.6 54% crossed forested streams Average of 0.1 per mile of existing line, range 0 – 1.6 17% crossed forested streams	n/a
Endangered and Threatened Species	26 (18%) of 145 projects affected federally listed endangered or threatened species, or species proposed or candidates for listing	
	44 (30%) of 146 projects affected state-listed endangered, threatened, or special concern species	
Historic Properties	35 (28%) of 146 projects affected historic properties	

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7.5 Environmental Impacts of Alternative Strategies and Portfolios

While the total amount of energy generated during the 2014-2033 planning period is, by design, similar across the alternative strategies for each scenario, the manner in which this energy is generated varies greatly across strategies (Figures 6-7, 6-8, 6-9). This is a result of the differences between the alternative strategies in emphasis and constraints on different energy resources and targets as described in Sections 2.4 and 6.1. The resource portfolios and their associated environmental impacts for alternative strategies A, B and C, as well as the Target Power Supply, are relatively similar for the same scenarios while those for strategies D and E, as well as the No Action Alternative Baseline Plan, show greater differences.

Alternative Strategies:

- Baseline Plan (No Action)
- A – The Reference Plan
- B – Meet an Emission Target
- C – Focus on Long-Term, Market-Supplied Resources
- D – Maximize Energy Efficiency
- E – Maximize Renewables

Scenarios:

- 1 – Current Outlook
- 2 – Stagnant Economy
- 3 – Growth Economy
- 4 – De-Carbonized Future
- 5 – Distributed Marketplace

Following is a discussion of the impacts of each alternative strategy on air quality, greenhouse gas emissions and climate change, water withdrawals and water use, waste generation, and land requirements over the 20-year planning period. The bar charts and time-series graphs illustrate the average of the values for the five scenarios for each alternative strategy. The whisker bars on the bar charts show the range of the values of the five scenarios. The values for the Target Power Supply in the bar charts are based on the average of the values for the five scenarios for Strategies A, B and C. The whicker bars on the bar charts show the range of these scenario values. Because the Target Power Supply is largely based on the Current Outlook scenario, the time-series charts comparing it and the alternative strategies only show results for the Current Outlook scenario.

7.5.1 Air Quality

All alternative strategies and the Target Power Supply will result in significant long-term reductions in total emissions and emission rates of sulfur dioxide (SO_2), nitrogen oxides (NOx), and mercury (Table 7-4, Figures 7-1, 7-2, 7-3). A large portion of these reductions, especially for SO_2 and mercury, result from the scheduled coal plant and unit retirements occurring through 2020 and the installation of additional air emission controls at the Gallatin and Shawnee coal plants. This accounts for the rapid, similar decreases in annual emissions illustrated in the figures. A further decrease occurs during the mid-2020s as the seven Shawnee coal units without FGD and SCR systems are retired in most resource portfolios. The overall reductions are greatest for Strategies D and E, where larger amounts of energy are provided by non-emitting energy efficiency and renewable energy sources, and the least for the No Action alternative which has less fossil-fueled generation replaced by non-emitting energy sources than the other alternative strategies. Strategies D and E also have the lowest total emissions and lowest annual emissions during the planning period (Table 7-4, Figures 7-4, 7-5, 7-6). The emissions for the Target Power Supply are within the range of Strategies A-C.

Table 7-4 Average total, annual, and 2014-2033 percent reduction of emissions of SO_2, NOx, and mercury by alternative strategy and the Target Power Supply (TPS).

	Alternative Strategy						
	No Action	A	B	C	D	E	TPS
SO_2							
Total Emissions 2014-2033, tons	882,408	861,109	861,503	864,956	849,818	809,121	859,209
Annual Emissions, tons	44,120	43,055	43,078	43,248	42,291	40,456	42,960
Percent Reduction 2014–2033	84.1	85.8	85.8	85.1	90.5	88.2	86.7
NOx							
Total Emissions 2014-2033, tons	601,520	535,655	535,996	541,424	519,349	489,231	538,715
Annual Emissions, tons	30,076	26,783	26,800	27,071	25,967	24,462	26,936
Percent Reduction 2014–2033	54.8	67.6	67.8	65.6	71.3	74.4	66.7
Mercury							
Total Emissions 2014-2033, tons	5,369	5,019	5,023	5,055	4,922	4,576	5,028
Annual Emissions, tons	268	251	251	253	246	229	251
Percent Reduction 2014–2033	70.0	75.9	76.0	74.8	77.6	80.6	75.6

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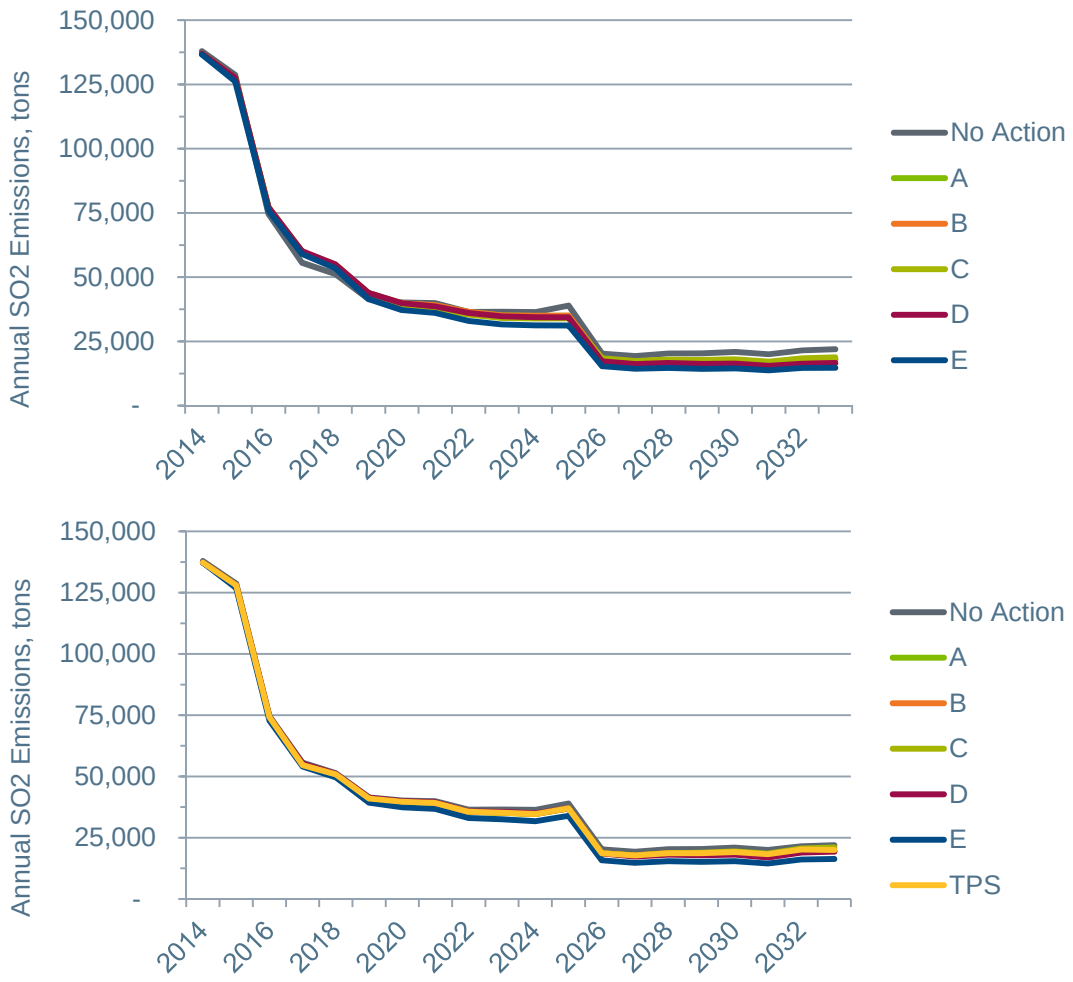

Figure 7-1 Trends in emissions of sulfur dioxide (SOx) by alternative strategy based on average of the five scenarios (top) and by alternative strategy and the Target Power Supply for the Current Outlook scenario (bottom).

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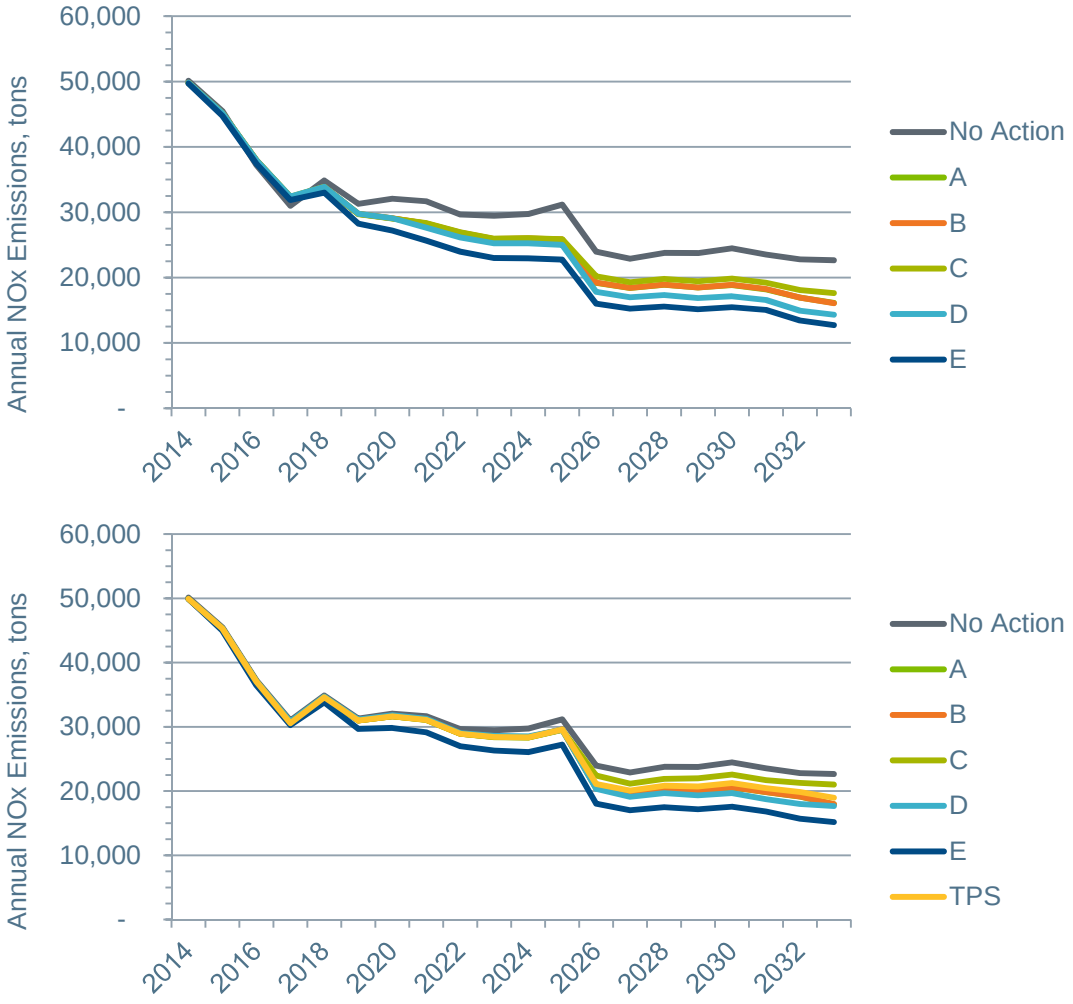

Figure 7-2 Trends in emissions of nitrogen oxides (NOx) by alternative strategy based on average of the five scenarios (top) and by alternative strategy and the Target Power Supply for the Current Outlook scenario (bottom).

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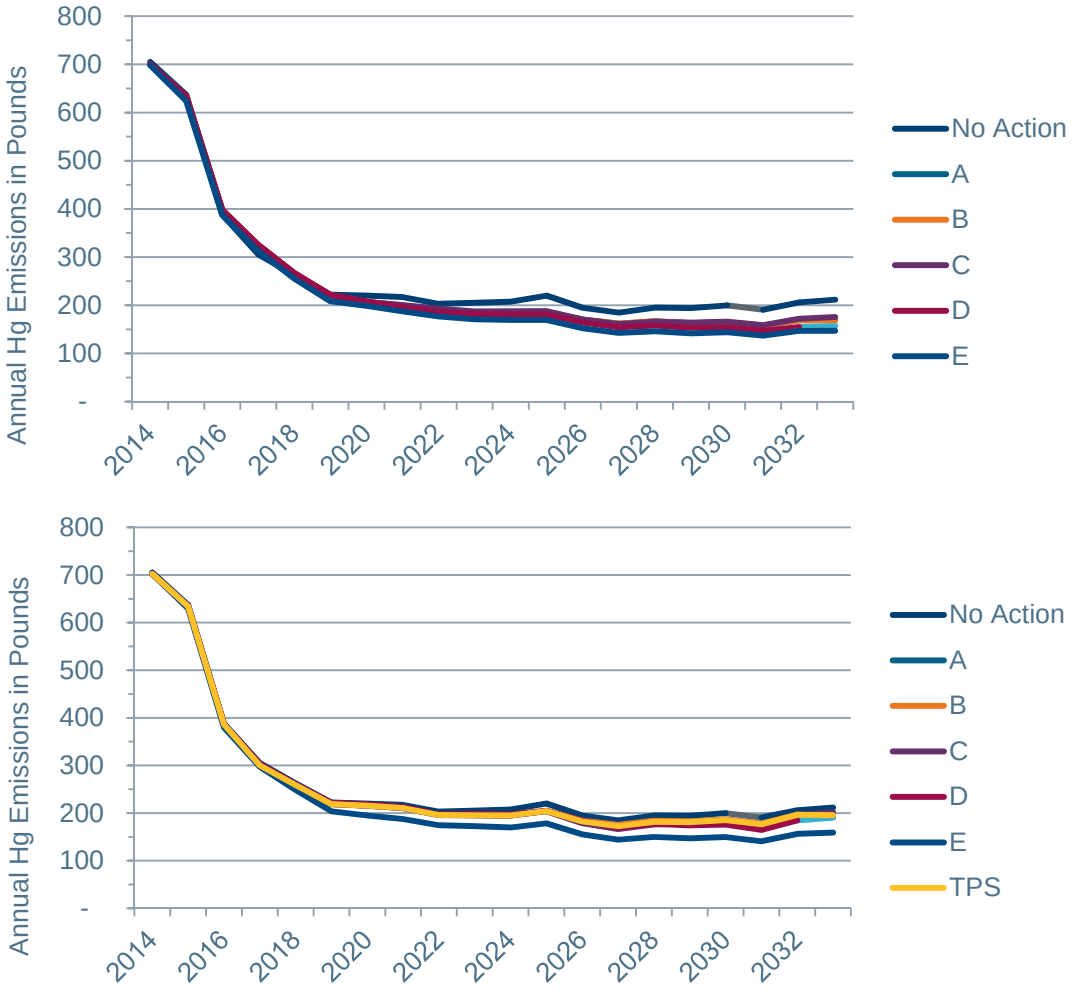

Figure 7-3 Trends in emissions of mercury by alternative strategy based on average of the five scenarios (top) and by alternative strategy and the Target Power Supply for the Current Outlook scenario (bottom).

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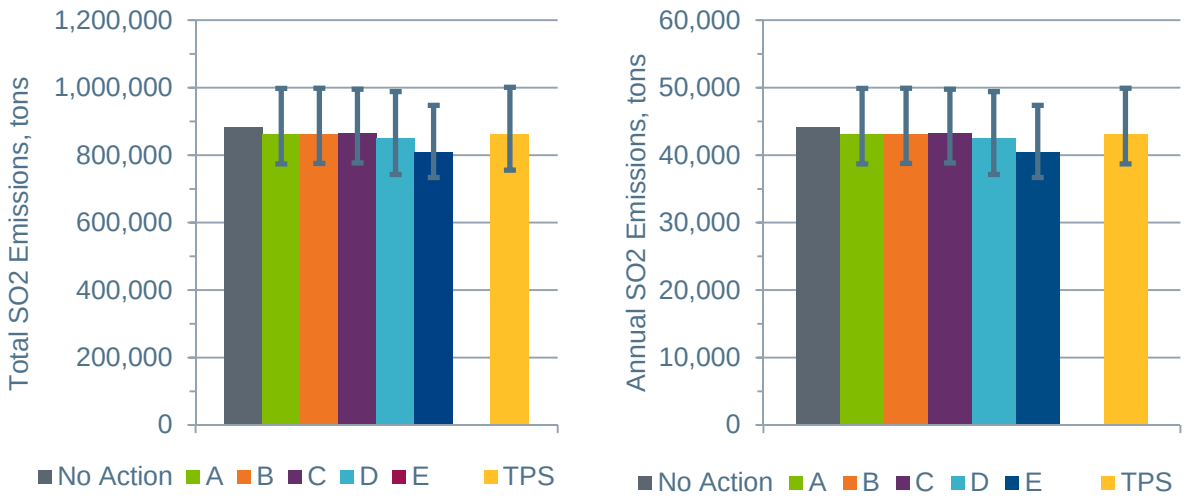

Figure 7-4 Average 2014–2033 total emissions (left) and 2014–2033 annual average emissions (right) of sulfur dioxide (SO_2) by alternative strategy and the Target Power Supply (TPS). The error bars indicate the maximum and minimum values for the scenarios associated with each alternative strategy and the TPS.

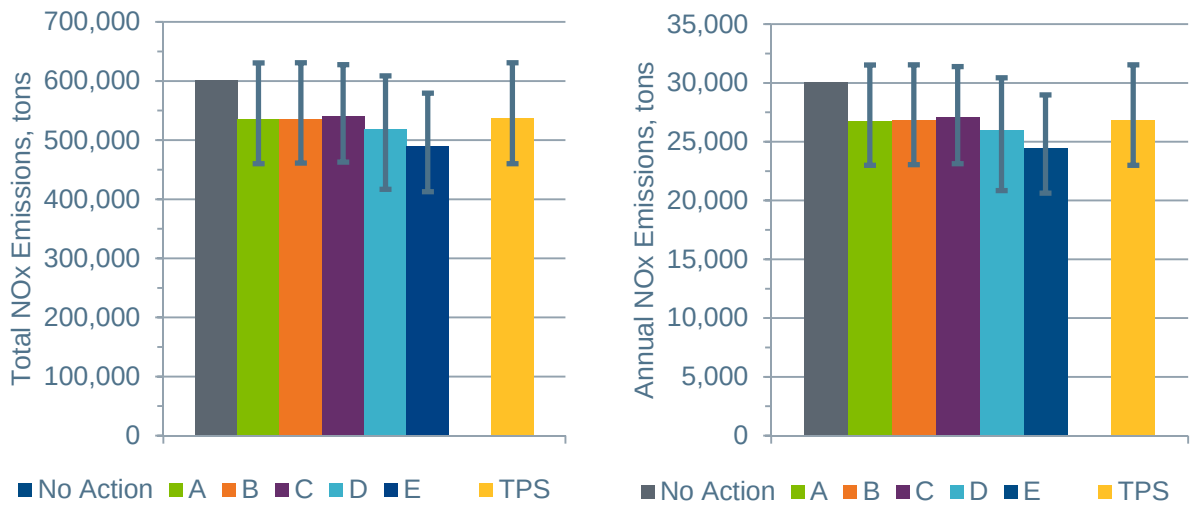

Figure 7-5 Average 2014–2033 total emissions (left) and 2014–2033 annual average emissions (right) of nitrogen oxides (NOx) by alternative strategy and the Target Power Supply (TPS). The error bars indicate the maximum and minimum values for the scenarios associated with each alternative strategy and the TPS.

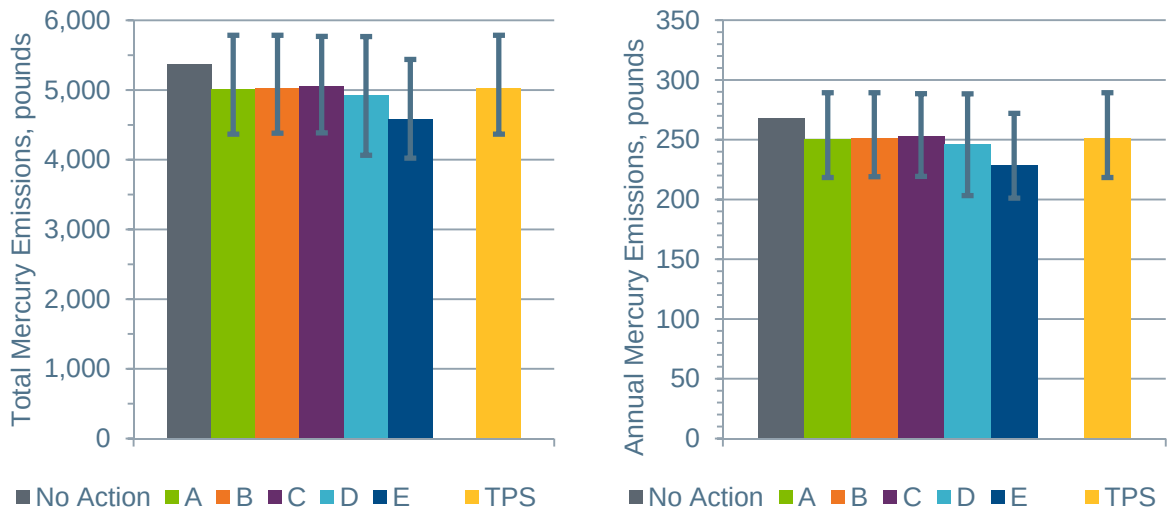

Figure 7-6 Average 2014–2033 total emissions (left) and 2014–2033 annual average emissions (right) of mercury by alternative strategy and the Target Power Supply (TPS). The error bars indicate the maximum and minimum values for the scenarios associated with each alternative strategy and the TPS.

By 2020, all of TVA's operating coal generating units will operate advanced air emissions controls including FGD and SCR systems except for seven units at Shawnee with a total capacity of about 900 MW. The trends in emissions of these three air pollutants for each alternative strategy and the Target Power Supply are very similar until about 2018-2020. During these first few years, the changes are driven almost entirely by coal retirements and there is little difference in the alternative strategies. After 2020 they begin diverging, although the overall divergence by the end of the planning period is small. The No Action alternative consistently has the smallest reductions and Strategy E consistently has the largest reductions. Under all alternative strategies and the Target Power Supply, there would be a substantial beneficial cumulative impact on regional air quality.

The reductions in SO_2, NOx and mercury emissions will continue recent trends in emissions of these air pollutants. By 2033, TVA emissions of SO_2 will have decreased since 1995 by at least about 98 percent under all alternative strategies and the Target Power Supply. This is expected to result in further decreases in regional concentrations of SO_2 and sulfate (a component of acid deposition), regional haze, and fine particulates. TVA emissions of NOx will have decreased since 1995 by between 95.8 percent under the No Action alternative and 97.6 percent under Strategy E. Although this continued reduction will likely result in reductions in regional NOx and ozone concentrations, the air quality effect may be small as TVA emissions make up an increasingly small proportion (11 percent in 2013) of regional NOx emissions (Figure 4-24).

7.5.2 Greenhouse Gas Emissions and Climate Change

Total and annual direct emissions of CO_2, as well as CO_2 emission rates, decrease under all alternative strategies and the Target Power Supply (Table 7-5; Figures 7-7, 7-8, 7-9, 7-10). The reductions are consistently the greatest across scenarios for Strategies D and E at 50–55 percent and least for the No Action alternative at 20 percent. Most of the reductions occur early

in the planning period as a result of coal plant/unit retirements and the replacement of this capacity with lower emitting generation by natural gas-fueled and nuclear generation. From about 2020 through 2030, further reductions are relatively modest for the similar Strategies A, B and C and the Target Power Supply. Reductions during this period are greater for Strategies D and E as increasing amounts of energy are provided by energy efficiency and renewable resources, as well as the additional coal retirements under some scenarios. Further reductions occur late in the period with the expiration of the PPA with the Red Hills lignite-fueled plant, which has a high CO_2 emissions rate.

Table 7-5 Average CO_2 emissions, percent emissions reductions, and percent emission rate reduction by alternative strategy.

	Alternative Strategy						
	No Action	A	B	C	D	E	TPS
Total Emissions 2014-2033, million tons	1,229	1,027	1,023	1,033	999	947	1,030
Annual Emissions, thousand tons	61,444	51,371	51,410	51,647	49,971	47,336	51,476
Percent Emission Reduction 2014–2033	19.6	44.9	45.1	41.9	49.9	55.0	44.0
Percent Emission Rate Reduction 2014-2020	24.4	24.3	24.3	24.3	24.3	30.1	25.7
Percent Emission Rate Reduction 2014-2030	30.6	41.9	41.8	35.9	35.9	50.9	41.6

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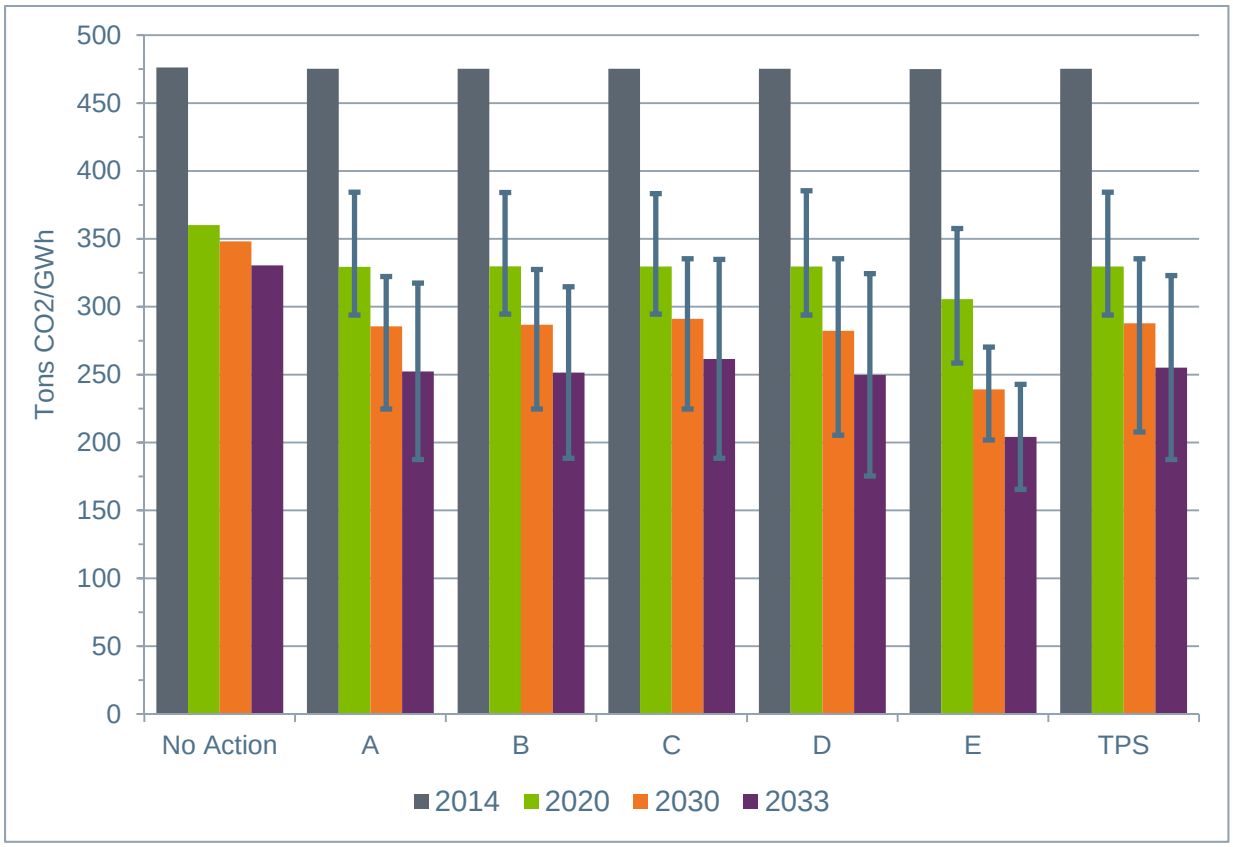

Figure 7-7 CO_2 emission rates (tons CO_2/GWh) in 2014, 2020, 2030, and 2033 by alternative strategy and for the Target Power Supply (TPS). The error bars indicate the maximum and minimum values for the scenarios associated with each alternative strategy and the TPS.

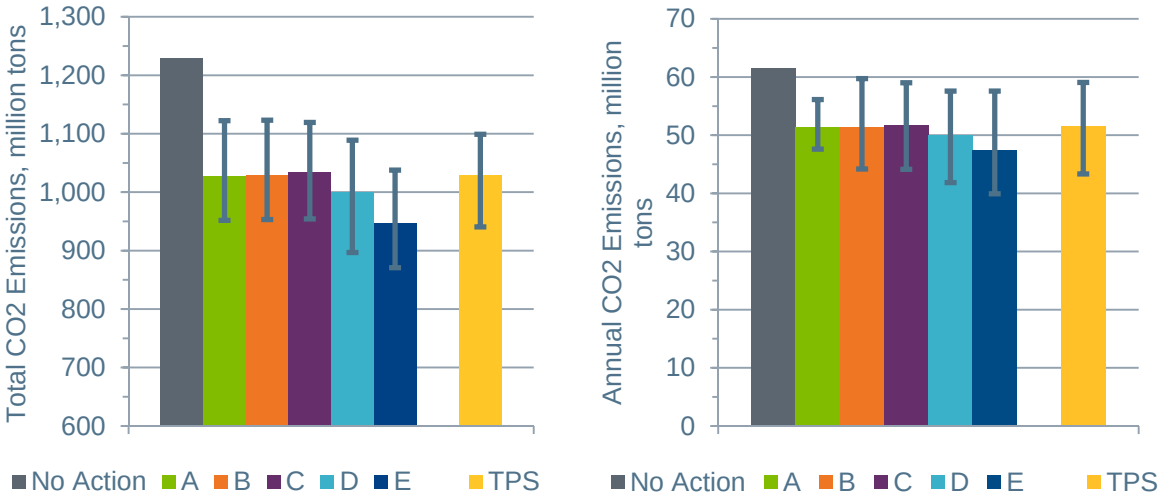

Figure 7-8 Average 2014–2033 total emissions (left) and 2014–2033 annual average emissions (right) of CO_2 by alternative strategy and for the Target Power Supply (TPS). The error bars indicate the maximum and minimum values for the scenarios associated with each alternative strategy and the TPS.

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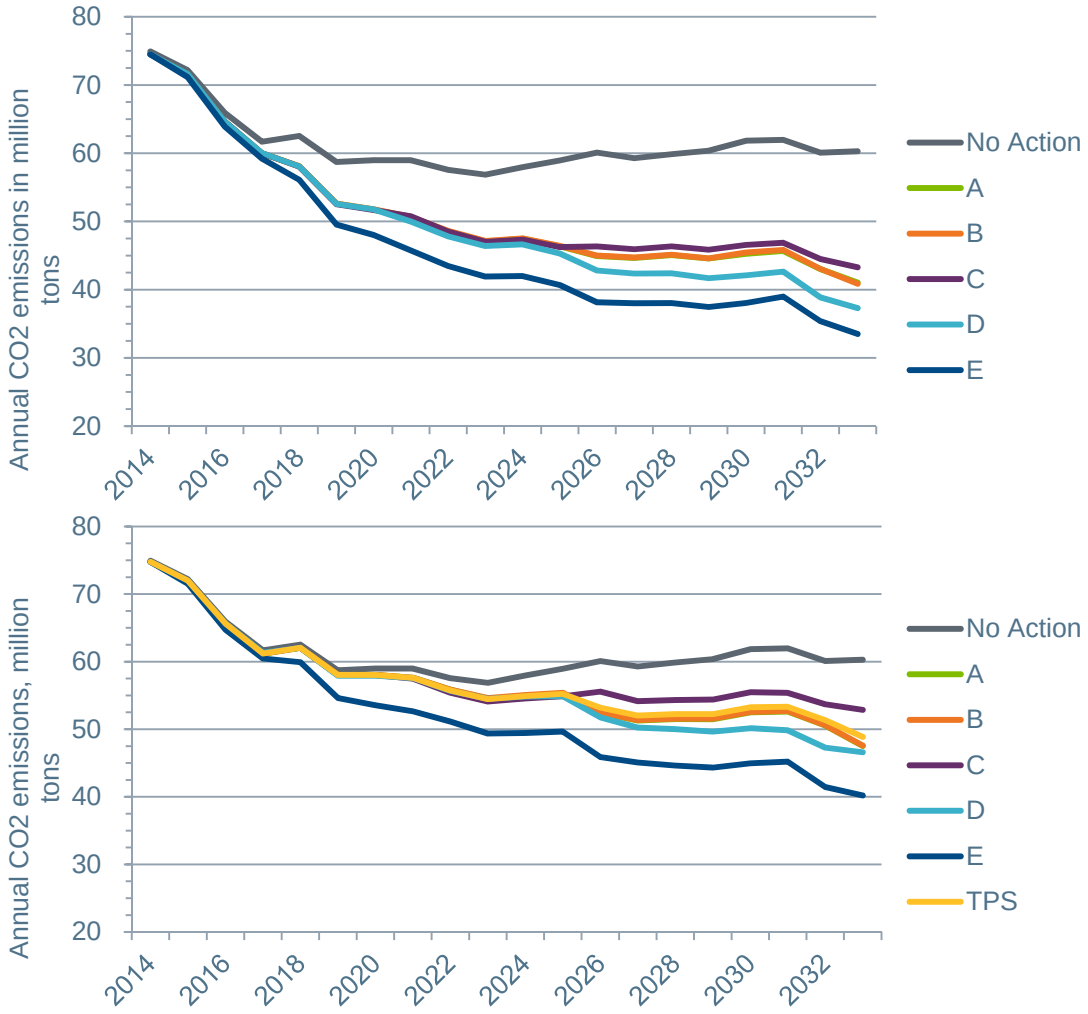

Figure 7-9 Trends in emissions of CO_2 by alternative strategy based on average of the five scenarios (top) and by alternative strategy and the Target Power Supply for the Current Outlook scenario (bottom).

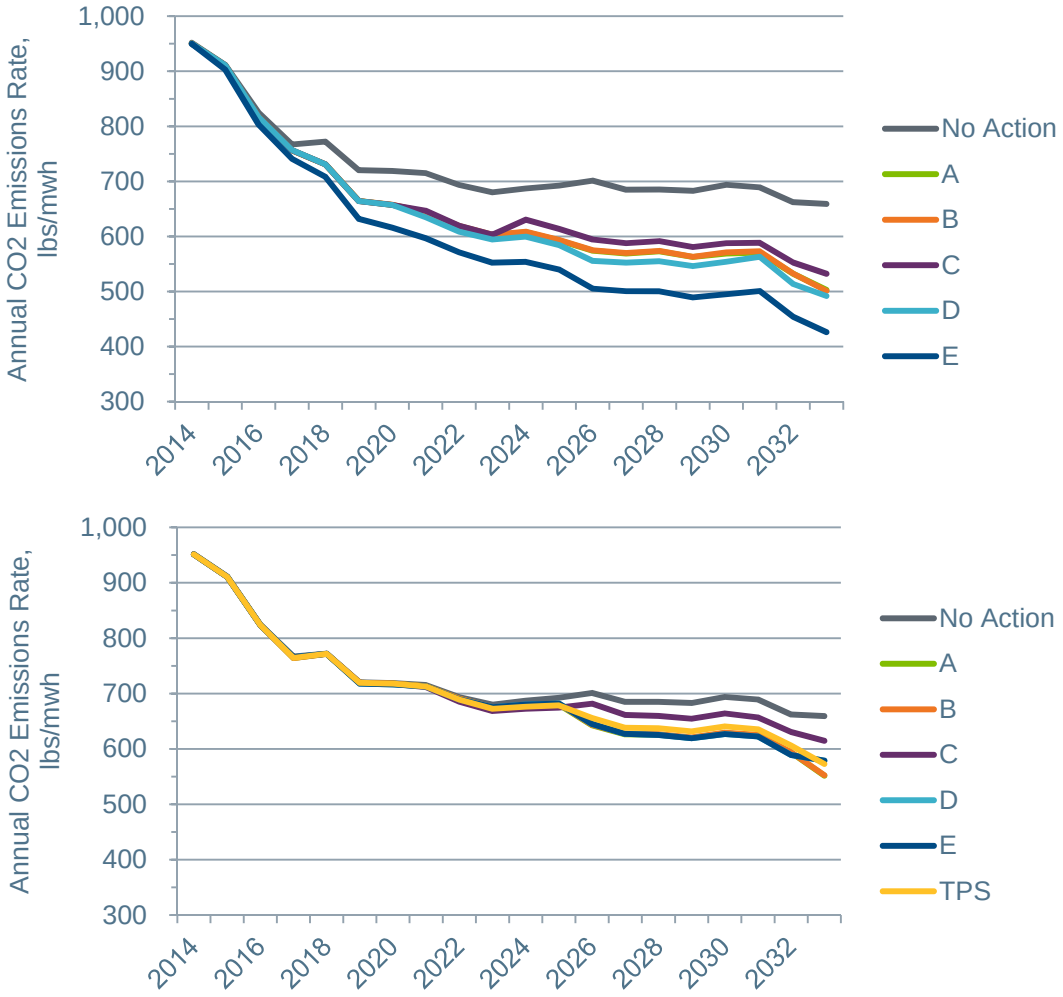

Figure 7-10 Trends in CO_2 emissions rate by alternative strategy based on average of the five scenarios (top) and by alternative strategy and the Target Power Supply for the Current Outlook scenario (bottom).

In addition to the forecast reductions in GHG emissions from power generation, TVA has specific targets related to GHG emissions associated with its other activities under E.O. 13514. These include a 17 percent reduction in Scope 1 and Scope 2 GHG emissions by 2020 and a 21 percent reduction in Scope 3 GHG emissions by 2020. Scope 1 GHG emissions are direct emissions from applicable sources owned or controlled by TVA, including vehicles. Scope 2 GHG emissions are indirect emissions from the generation of power used by TVA. Scope 3 GHG emissions are from sources not owned or controlled by TVA but related to TVA activities and include, among other things, business travel, employee commuting and contracted waste disposal. Additional TVA targets include reducing the energy intensity of subject facilities by 30 percent from 2003 to 2015 and using electricity from renewable sources for at least 7.5 percent of facility electricity use. TVA is on track to meet all of these targets except for the Scope 3 emissions target (TVA 2014g).

All alternative strategies and the Target Power Supply, and especially action alternatives Strategies D and E, will result in significant reductions in GHG emissions and small but beneficial impacts on the potential for associated climate change. The actual effects on climate in the TVA region and elsewhere would be small and difficult to quantify. In its Climate Adaptation Plan (TVA 2014h) TVA identified the following climate change risks relevant to the TVA power system:

- Increased demand for power due to increased cooling-season temperatures
- Altered reservoir operations and hydropower generation due to altered precipitation patterns and increased demands for water
- Effects of changing runoff and water temperatures
- Increased frequency of extreme weather events and drought
- Increased geographic variation in temperature and precipitation
- Increased ozone and particulate matter concentrations

Recent and projected trends in temperature and precipitation in the TVA region are described in Section 4.2. Projected trends from climate change models include increases in average temperature and number of days over 95°F and decreases in number of days below 32°F. Predicted trends in precipitation have greater uncertainty and include increases in winter, spring and fall precipitation, and an increase in the frequency of heavy precipitation events.

The EPRI and TVA (2009) report described the effects of the forecast climate change based on the 2007 IPCC report in the TVA region. The effects are likely to be relatively modest over the next decade and increase in magnitude by mid-century. Potential effects on water resources include increased water temperatures, increased stratification of reservoirs, reduced dissolved oxygen levels, and increased water demand for crop irrigation. Potential effects on agriculture include increased plant evapotranspiration, altered pest and pathogen regimes, changes in the types of crops grown, and increased demand for electricity by confined livestock and poultry operations.

Potential effects on forest resources include increased tree growth, altered disturbance regimes, changes in forest community composition with declines in species currently at the southern limit of their ranges, and expansion of the oak-hickory and oak-pine forest types. Potential effects on fish and wildlife include range retractions and expansions, altered community composition, loss of cool to cold aquatic habitats and associated species such as brook trout, and increased threats to many endangered and threatened species.

The modeled higher air temperatures, the associated higher water temperatures, and the altered precipitation patterns that could result from climate change likely would affect the operation of TVA generating facilities. One likely effect is an increase in the demand for electricity. Warmer summer temperatures would result in more electricity used for air conditioning; this increase would likely be greater than the reduction in electricity used for space heating resulting from warmer winter temperatures. TVA's coal and nuclear plants currently use open-cycle cooling and discharge heated water to the river system. NPDES permits, required for the discharge of cooling water into rivers and reservoirs, prescribe the maximum temperature of discharged water. Warmer gross river and reservoir temperatures would make meeting thermal discharge limits more difficult. The NRC also sets safety limits at nuclear plants

on the maximum temperature of intake water used in essential auxiliary and emergency cooling systems. When cooling water intake temperatures are high, power plants must reduce power production (derate) or use cooling towers (if available) to reduce the temperature of the discharged water and avoid non-compliance with thermal limits. If intake temperatures reach their limits, NRC requires the plants to shut down. Consequently, elevated water temperatures can reduce thermal generation by causing forced deratings, additional use of cooling towers (which reduces net generation), and/or nuclear plant shutdown.

Increased air and water temperatures also influence the operation of thermal power plants with cooling towers. Increased condenser cooling water temperatures reduce the efficiency of power generation. Hotter, more humid air also reduces evaporation potential and the performance of cooling towers. A 1993 TVA study (Miller et al. 1993) analyzed the relationships between extreme air and water temperatures and power plant operations based on historical meteorological and operational data.

In the upper Tennessee River drainage, for each 1°F increase in air temperature (April through October), water temperatures increased by 0.25°F to almost 0.5°F, depending upon year and location in the TVA reservoir system. In general, air temperature effects cascade down the reservoir system. In the Tennessee River system, for both closed- and open-cycle plants in Tennessee (on or upstream of Chickamauga Reservoir) and in Alabama (on Wheeler Reservoir), this study found that the incremental impacts to operations from increased temperature were greatest during hot-dry years. Operation of most thermal power plants in the TVA power system was resilient to temperature increases during cold-wet and average meteorological years. The dominant meteorological variables affecting thermal plant performance were water temperature, and, for plants using cooling towers, humidity.

Changes in the operation of the Tennessee River system implemented in the ROS (TVA 2004) provide TVA flexibility to adapt to some climate change impacts while minimizing the effects on thermal generation. The analyses in the ROS were based on historical conditions and assume unusually high air temperatures and/or changes in precipitation last a relatively short time and are not long-term changes (cf. Milly et al. 2008). Further adaptation, such as the installation of increased cooling capacity at thermal plants, may be necessary in the future given the forecast long-term increases in temperature.

While water resources are relatively abundant in the TVA service area, climate stressors could change that abundance, either locally or region-wide, leading to impacts and the need for adaptive measures by other sectors of the economy, as well as other aspects of the energy system (EPRI and TVA 2009). Increased precipitation during storms will increase flood risk, expand flood hazard areas, increase the variability of stream flows (i.e., higher high flows and lower low flows) and increase the velocity of water during high flow periods, thereby increasing erosion. These changes will have adverse effects on water quality and aquatic ecosystem health. Climate change also has the potential to affect outdoor recreation, including reservoir and stream-based recreation.

A recent Government Accountability Office report (USGAO 2014) described a number of measures to help reduce climate-related risks and adapt the nation's energy systems to weather and climate-related impacts. These measures generally fall into two categories—hardening and resiliency. Hardening involves making physical changes that improve the durability and stability of specific pieces of infrastructure—for example, elevating and sealing water-sensitive

equipment—making it less susceptible to damage. In contrast, resiliency measures allow energy systems to continue operating after damage and allows them to recover more quickly; for example, installing back-up generators to restore electricity more quickly after severe weather events. TVA is continually evaluating the need for, and where necessary, implanting measures to increase the hardening and resiliency of its power system.

7.5.3 Water Resources

The coal-fired, nuclear, and natural gas-fired CC plants comprising most of TVA's energy supply require water to operate plant cooling systems and, particularly for coal plants, other plant processes. For each of these generating plants, the required quantity of water is directly proportional to the amount of power they generate. CT plants have very low water requirements and wind and solar generating facilities do not require water to operate. Potential impacts to water resources, with the exception of discharges of cooling water, are generally greater from coal-fired generation than from other types of generation due to the various liquid waste streams from coal-fired plants and the potentially adverse water quality impacts from coal mining and processing. Under all alternative strategies, TVA would continue to meet water quality standards through compliance with NPDES permit requirements.

The volume of water used by thermal generating facilities, (i.e., nuclear, coal-fired and natural gas-fired facilities) decreases between 2014 and 2033 under all alternative strategies and the Target Power Supply (Figure 7-11). The decreases range from 8 percent for the No Action Alternative to 22–27 percent for Strategies A–C and the Target Power Supply, to 38 percent for Strategy E. Figure 7-12 shows the annual average water use by alternative strategy and the Target Power Supply; the greatest difference, between the No Action Alternative and Strategy E, is 11 percent. The differences in water use are a function of the amount of energy generated by coal and nuclear plants. Almost all of the water is used by open-cycle condenser cooling systems in coal and nuclear plants; these systems withdraw water from an adjacent reservoir or river, circulate it through condensers, and discharge the warmer water to the water body. With the exception of Paradise Fossil Plant and Watts Bar Nuclear Plant, all of TVA's coal and nuclear plants operate exclusively or primarily with open-cycle cooling (see Section 4.7). Both Paradise and Watts Bar supplement open-cycle cooling with closed-cycle cooling, in which water is evaporated instead of being discharged to a water body. Although the start-up of Watts Bar Unit 2 and the Paradise and Allen CC plants increases water use early in the planning period, this increase is more than offset by the reductions in water use from coal retirements. The reductions in water use would result in localized beneficial impacts to aquatic ecosystems. The volume of water used by hydroelectric facilities is not included in Figures 7-11 and 7-12.

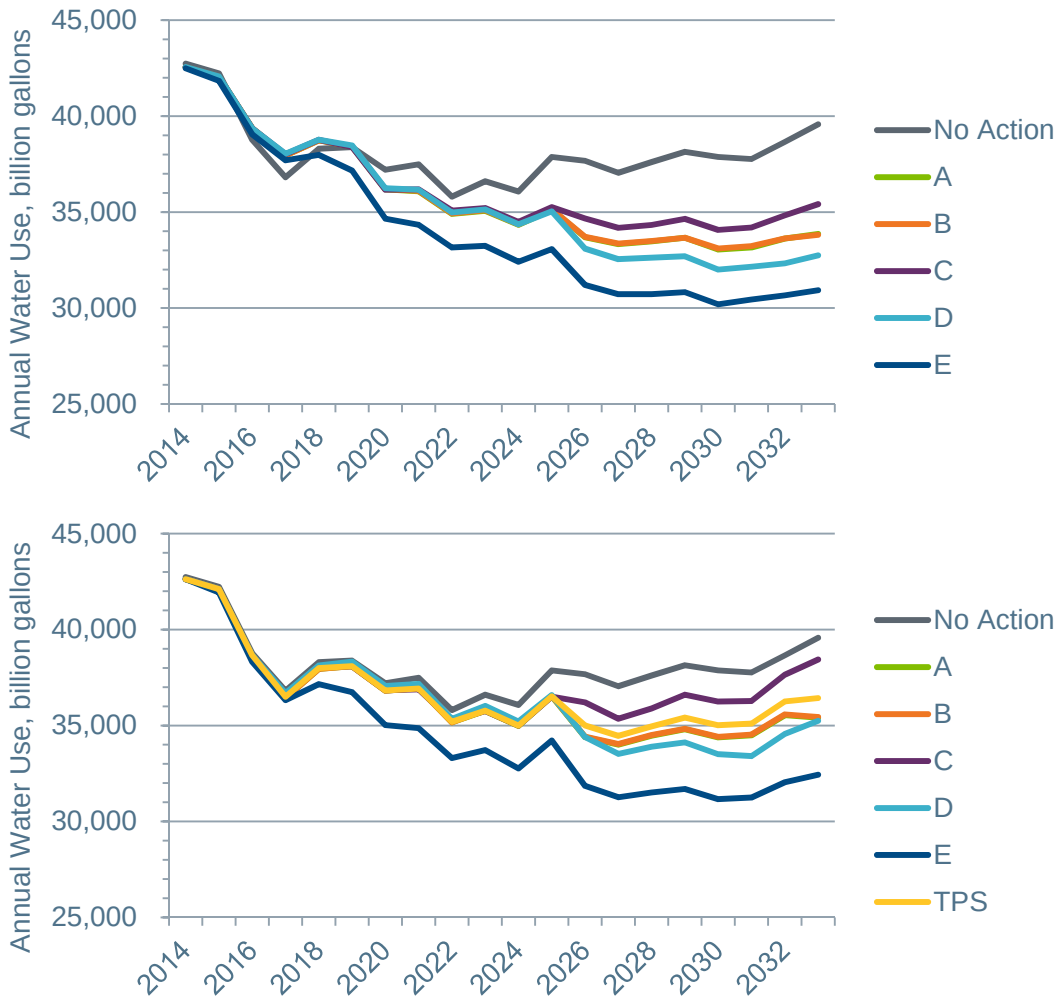

Figure 7-11 Trends in water use by alternative strategy based on average of the five scenarios (top) and by alternative strategy and the Target Power Supply for the Current Outlook scenario (bottom).

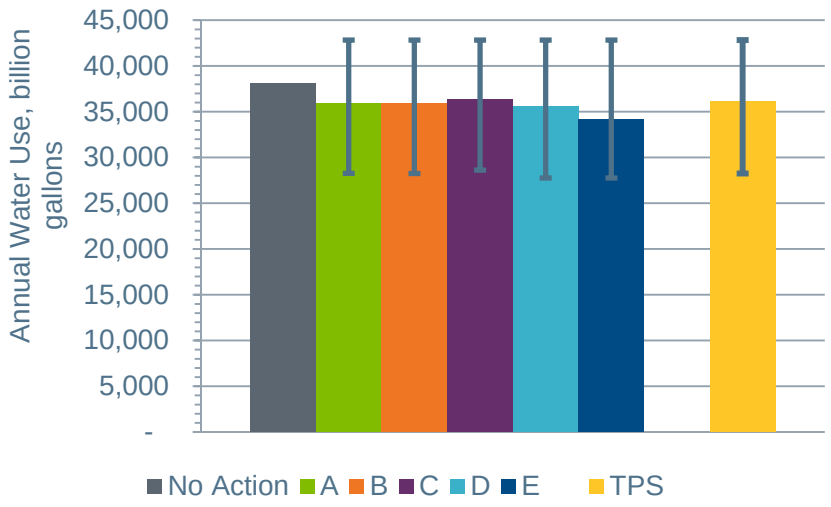

Figure 7-12 Average annual 2014–2033 water use by the alternative strategies and the Target Power Supply (TPS). The error bars indicate the maximum and minimum values for the scenarios associated with each alternative strategy and the TPS.

Figures 7-13 and 7-14 show the 2014–2033 trends and annual averages of water consumption by alternative strategy and the Target Power Supply. The volume of water consumed is the quantity of water withdrawn from a water body and evaporated in the closed-cycle cooling systems of thermal generating facilities instead of being discharged to a water body. This volume is typically less than 2 percent of the total quantity of water used under each alternative strategy. The No Action Alternative would result in a 4 percent increase in water consumption, due to the high continued high reliance on thermal generating plants. Water consumption decreases under Alternatives A–E and the Target Power Supply, with decreases (averaged across all scenarios) ranging from about 6.7 percent under Strategy C to 13 percent under Strategy E. Strategy E displaces the largest amount of thermal generation with renewable generation. Average water consumption by Strategies A, B, and C and the Target Power Supply is essentially the same and consumption by Strategy D is only 1.3 percent less. The reductions in water consumption would have beneficial impacts; these impacts would generally be small and vary with the characteristics of the source area of the water withdrawal.

Chapter 7 – Anticipated Environmental Impacts

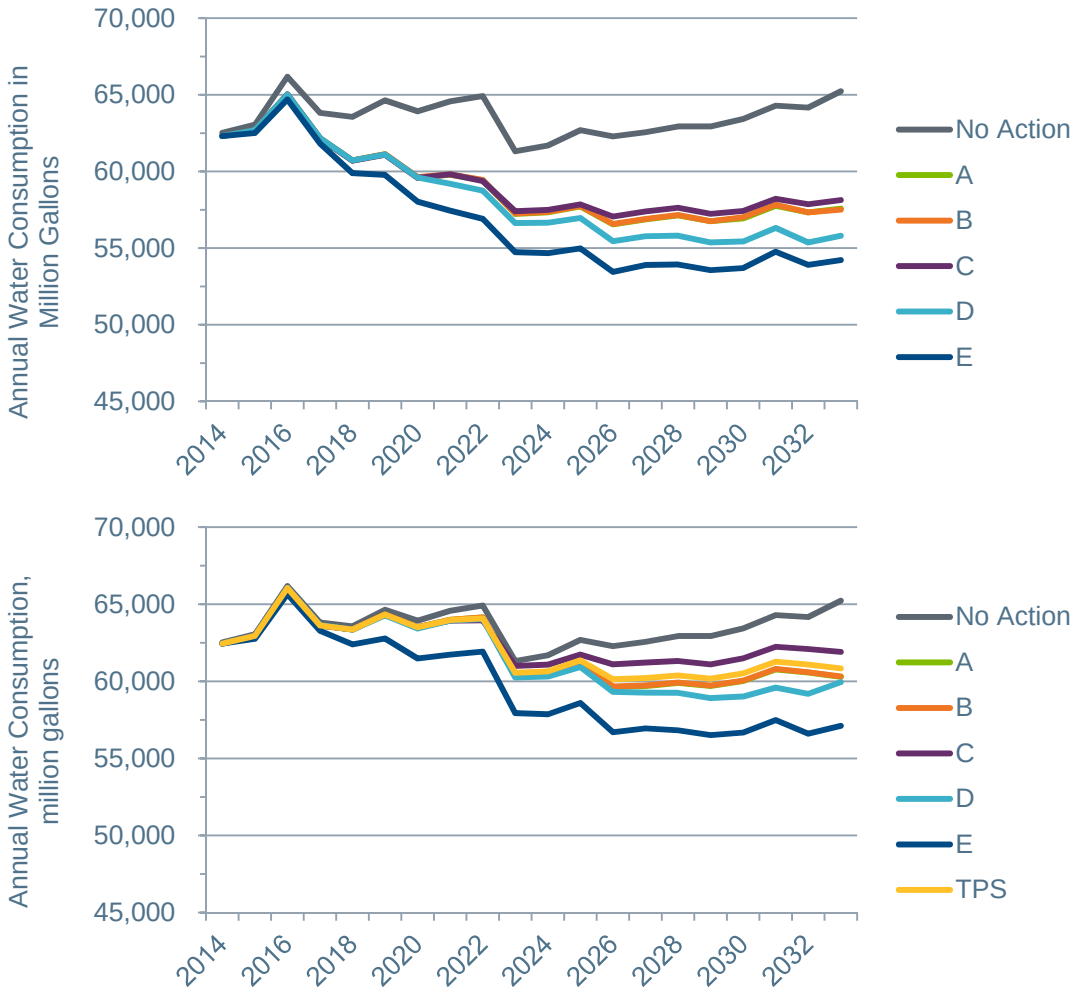

Figure 7-13 Trends in average annual water consumption by coal, nuclear, and natural gas generating facilities by alternative strategy based on average of the five scenarios (top) and by strategy and the Target Power Supply (TPS) for the Current Outlook scenario (bottom).

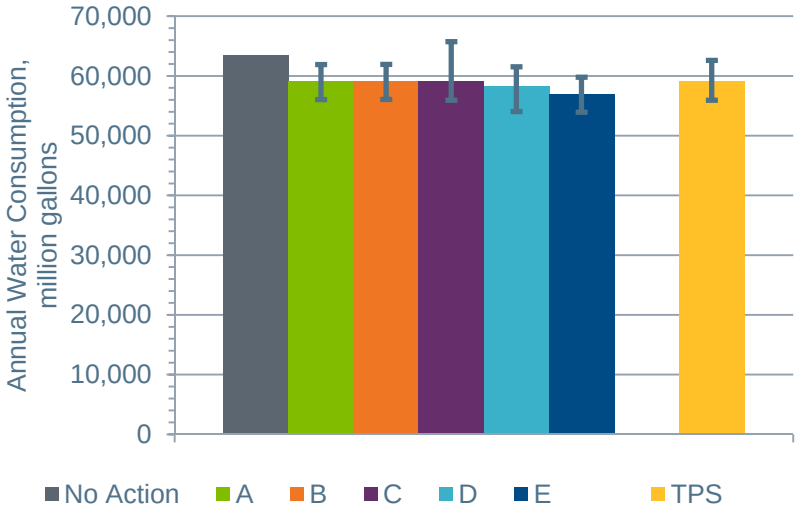

Figure 7-14 Average annual 2014–2033 water consumption by alternative strategy and the Target Power Supply (TPS). The error bars indicate the maximum and minimum values for the scenarios associated with each alternative strategy and the TPS.

7.5.4 Fuel Consumption

The major fuels used for generating electricity would continue to be coal, enriched uranium and natural gas in all of the alternative strategies and the Target Power Supply. The proportion of generation from coal and the quantity of coal consumed decreases sharply into the early 2020s as coal plants/units are retired. Coal generation then remains relatively stable until decreasing again in the mid-2020s under some combinations of strategies and scenarios as additional retirements occur. No additional coal plants are built under any strategy or the Target Power Supply. Coal consumption by TVA coal plants during the 2014–2033 planning period ranges from about 442 million tons (22.1 million tons/year) under the no action alternative to 349 million tons (17.5 million tons/year) under Strategy C (Figure 7-15). The decreases in coal consumption range from about 34 percent under the No Action Alternative to 71 percent under Strategy C. Although the future sources of coal purchased by TVA cannot be accurately predicted, the anticipated decrease in coal consumption would reduce the adverse impacts associated with coal mining.

Lignite consumption by the Red Hills plant in Mississippi, from which TVA acquires all of the power generated, is assumed to remain constant at about 4.5 million tons/year until 3032 when TVA's PPA expires.

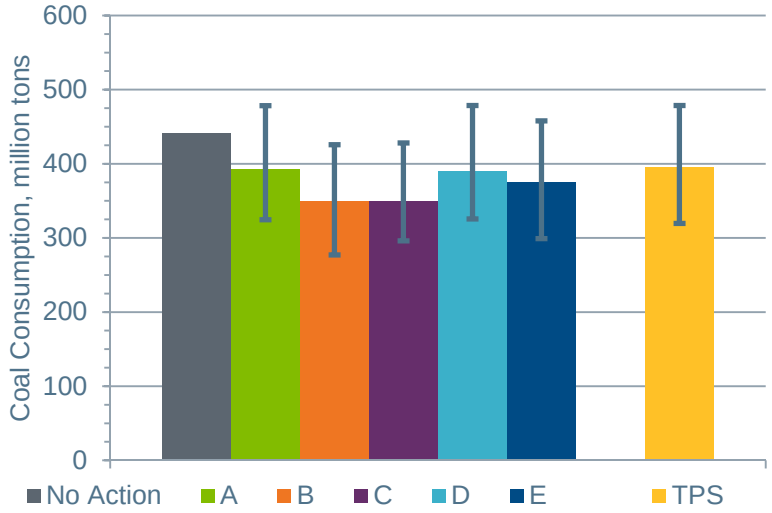

Figure 7-15 Average total 2014–2033 coal consumption by TVA plants by alternative strategy and the Target Power Supply (TPS). The error bars indicate the maximum and minimum values for the scenarios associated with each alternative strategy and the TPS.

TVA presently uses about 121 tons/year of enriched uranium in its nuclear plants.This quantity will increase to about 154 tons/year by 2020 with the startup of Watts Bar Nuclear Plant Unit 2 and the extended power uprates at Browns Ferry Nuclear Plant under all of the alternative strategies. Use of enriched uranium then remains relatively constant throughout the planning period; total enriched uranium consumption from 2014–2033 is approximately 3,000 tons. Potential impacts from producing the nuclear fuel include land disturbance, air emissions (including the release of radioactive materials), and discharge of water pollutants from uranium mining, processing, tailings disposal, and fuel fabrication. The magnitude of these impacts is difficult to predict with certainty due to the great variability in potential sources for nuclear fuel. The environmental impacts of uranium enrichment are expected to greatly decrease in the future as more energy-efficient enrichment processes become widely used in the U.S. Any future use of surplus highly enriched uranium would also reduce overall uranium fuel cycle impacts as it would reduce the need for uranium mining and enrichment.

About 146,600 billion standard cubic feet (scf) of natural gas were used in 2014 by TVA gas-fueled generating facilities and by gas facilities from which TVA purchases power under PPAs. Natural gas consumption increases by about 79 percent between 2014 and 2033 under the No Action Alternative. During the same time period gas consumption increases by about 1 percent under Strategies A and B and the Target Power Supply, decreases by about 10 percent under Strategy C, and decreases by about 5 percent under Strategies D and E. Figure 7-16 illustrates the average total gas consumption between 2014 and 2033 for each alternative strategy.

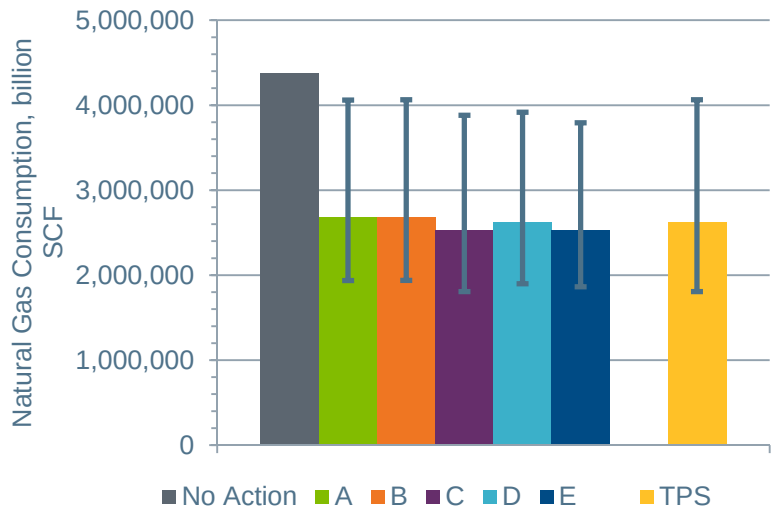

Figure 7-16 2014–2033 natural gas consumption by alternative strategy and the Target Power Supply (TPS). The error bars indicate the maximum and minimum values for the scenarios associated with each alternative strategy and the TPS. The volume is based on the heat content of 1,025 Btu/cubic foot of natural gas used by the electric power sector in 2013 (EIA 2014).

7.5.5 Solid Waste

Coal Combustion Solid Wastes

All alternative strategies will result in long-term reductions in the production of CCRs due to the retirement of coal plants/units (Figure 7-17). Most of the reductions occur early in the planning period; additional reductions occur at the end of the planning period as the PPA with the Red Hills lignite plant expires. These reductions range from 43 percent for the No Action Alternative to about 51 percent for Strategies A–C and the Target Power Supply, to 55 percent for Strategy D and 61 percent for Strategy E. Total CCR production during the planning period ranges from about 62 million tons under Strategy E to 71 million tons under the No Action Alternative (Figure 7-18).

In recent years, TVA has marketed 18–29 percent of the annual production of CCRs for beneficial reuse (see Section 4-16). The remaining CCRs are stored in landfills and impoundments at or near coal plants. TVA is in the process of converting the wet CCR collection/storage systems at six coal plants to dry storage and disposal facilities in order to reduce the potential environmental risk. TVA is also committed to increasing the beneficial reuse of CCRs. Even with an increase in beneficial reuse, TVA will likely need additional storage areas for CCRs produced at some of its coal plants.

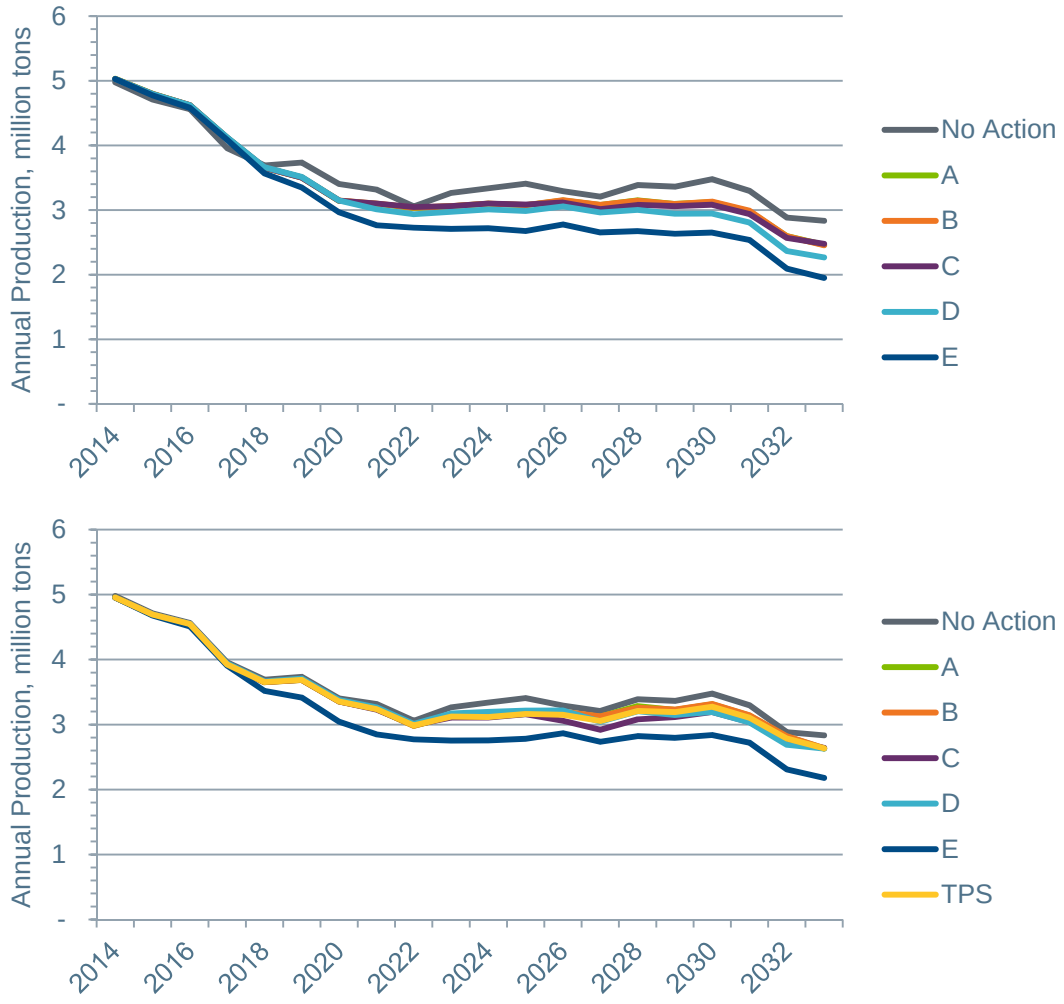

Figure 7-17 Trends in production of coal combustion residuals (combined ash and FGD residue) by alternative strategy (top) and by strategy and the Target Power Supply (TPS) for the Current Outlook scenario (bottom).

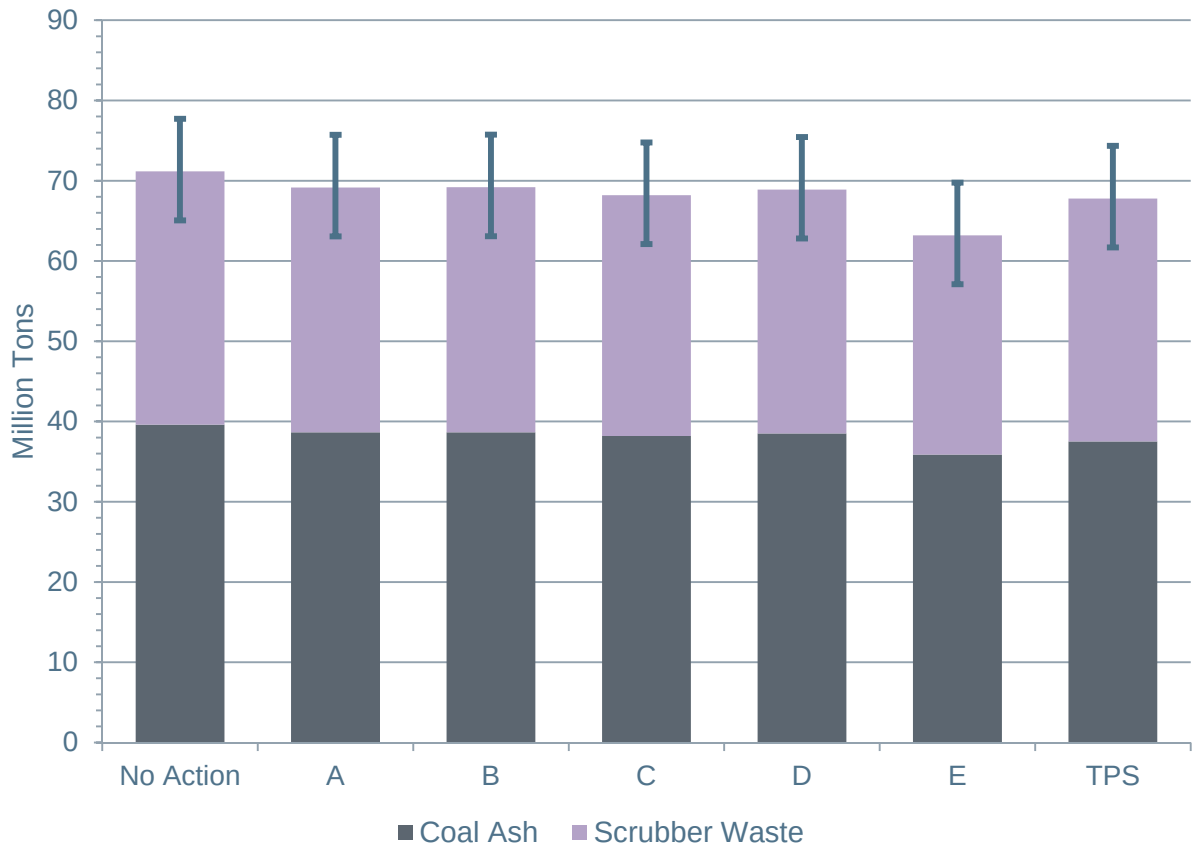

Figure 7-18 2014–2033 coal combustion residue by alternative strategy and the Target Power Supply. The error bars indicate the maximum and minimum values for the scenarios associated with each alternative strategy and the TPS.

EPA determined that the criteria it established in its April 2015 CCR rule will ensure that CCR management facilities and practices will not pose a reasonable probability of adverse effects on the health or the environment. EPA's analyses indicate that one of the most important actions that affected utilities can take, including TVA, is drying out their CCR impoundments. Removing the water from impoundments reduces the hydrological head and thereby reduces the risk of structural failure, which occurred at TVA's Kingston ash impoundment, and groundwater contamination. TVA's ongoing effort to convert its wet-storage CCR facilities to dry is consistent with EPA's direction. This combined with the reduction in the generation of CCRs under all of the IRP strategies is expected to reduce any CCR impacts and risks to health and the environment.

Nuclear Waste

The trends in the production of high-level waste, which is primarily spent nuclear fuel and other fuel assembly components, parallel those of nuclear fuel requirements and are the same for all alternative strategies and the Target Power Supply. High-level waste production will increase by about 21 percent by 2020 once Watts Bar Unit 2 is operating and the Browns Ferry extended power uprates are completed. TVA anticipates continuing to store spent fuel on the nuclear plant sites until a centralized facility for long-term disposal and/or reprocessing are operating. TVA is currently constructing additional dry cask storage capacity to store more spent fuel on its

nuclear plant sites. The proportional increase in production of low-level waste would be somewhat less than for high-level waste and would be similar for all alternative strategies.

7.5.6 Land Area

TVA's existing power plant reservations have a total area of about 24,500 acres. This total does not include conventional hydroelectric plants, most of which are closely associated with multi-purpose dams and reservoirs, or the 1,761-acre Bellefonte site. Many of the power plant reservations have large, relatively undisturbed areas and the actual area disturbed by facility construction and operation (the "facility footprint") totals about 17,500 acres. The existing generating facilities from which TVA purchases power under PPAs (excluding hydroelectric plants) have a total area of about 2,400 acres.

Land requirements for new generating facilities were determined from the capacity expansion plans and the resource type- and facility-specific land requirements given in Section 7.2. For long-term natural gas PPAs, half of the facilities were assumed to be existing and half new. Where the indicated capacities translated to fractional facilities, the number of facilities was rounded up to the nearest whole number.

Land requirements for new generating facilities range from about 3,625 acres for the No Action Alternative to 60,210 acres for Strategy E (Figure 7-19). Average land requirements for Strategies A, B and C and the Target Power Supply are similar at around 32,500 acres; Strategy D is somewhat less at 27,200 acres. Under each alternative strategy and the Target Power Supply, "traditional" central station power plants (i.e., CC and CT plants) comprise a small proportion of the land requirements, about 14 percent for the No Action Alternative and less than 2 percent for the other alternative strategies and the Target Power Supply (Figure 7-20). The land requirements for Strategies A–E and the Target Power Supply are dominated by solar PV facilities which, relative to other types of generation, have a high land requirement in relation to their generating capacity. Solar facility land requirements are based on the assumption that the new utility-scale tracking and fixed-tilt PV facilities are ground-mounted, as are existing utility-scale solar facilities. An increase in the proportion of building mounted (e.g., rooftop) solar facilities would reduce land requirements.

Despite the large land requirements of utility-scale solar facilities, which typically displace agricultural operations or other land use activities, the impacts of solar facilities on the land are low relative to other types of generating facilities. The construction of solar facilities typically does not require extensive excavation and solar facilities have little associated permanent or semi-permanent infrastructure that hinders restoration of the site after the facility is dismantled. While 27,200–62,200 acres is a large land area, it comprises 0.05–0.13 percent of the TVA service area. In addition, the additional land area required for the Target Power Supply is only about 30 percent more than the area occupied by existing TVA generating facilities. Based on recent patterns in the siting of large (i.e., at least 20 MW), much of the solar facility development would likely occur in west Tennessee, northwest Alabama, and Mississippi. The solar resource is somewhat better in this region than the rest of the TVA (see Section 4.17.2).

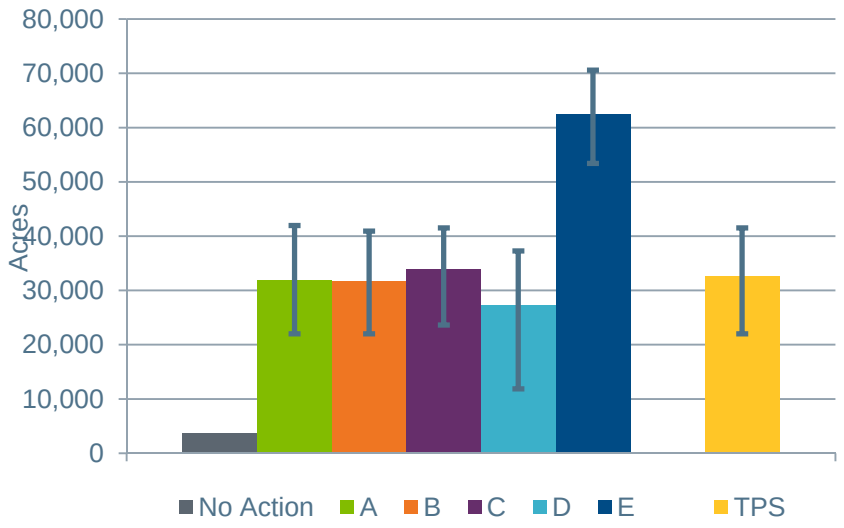

Figure 7-19 Average total land area for all new generating facilities by alternative strategy and the Target Power Supply (TPS). The error bars indicate the maximum and minimum values for the scenarios associated with each alternative strategy and the TPS.

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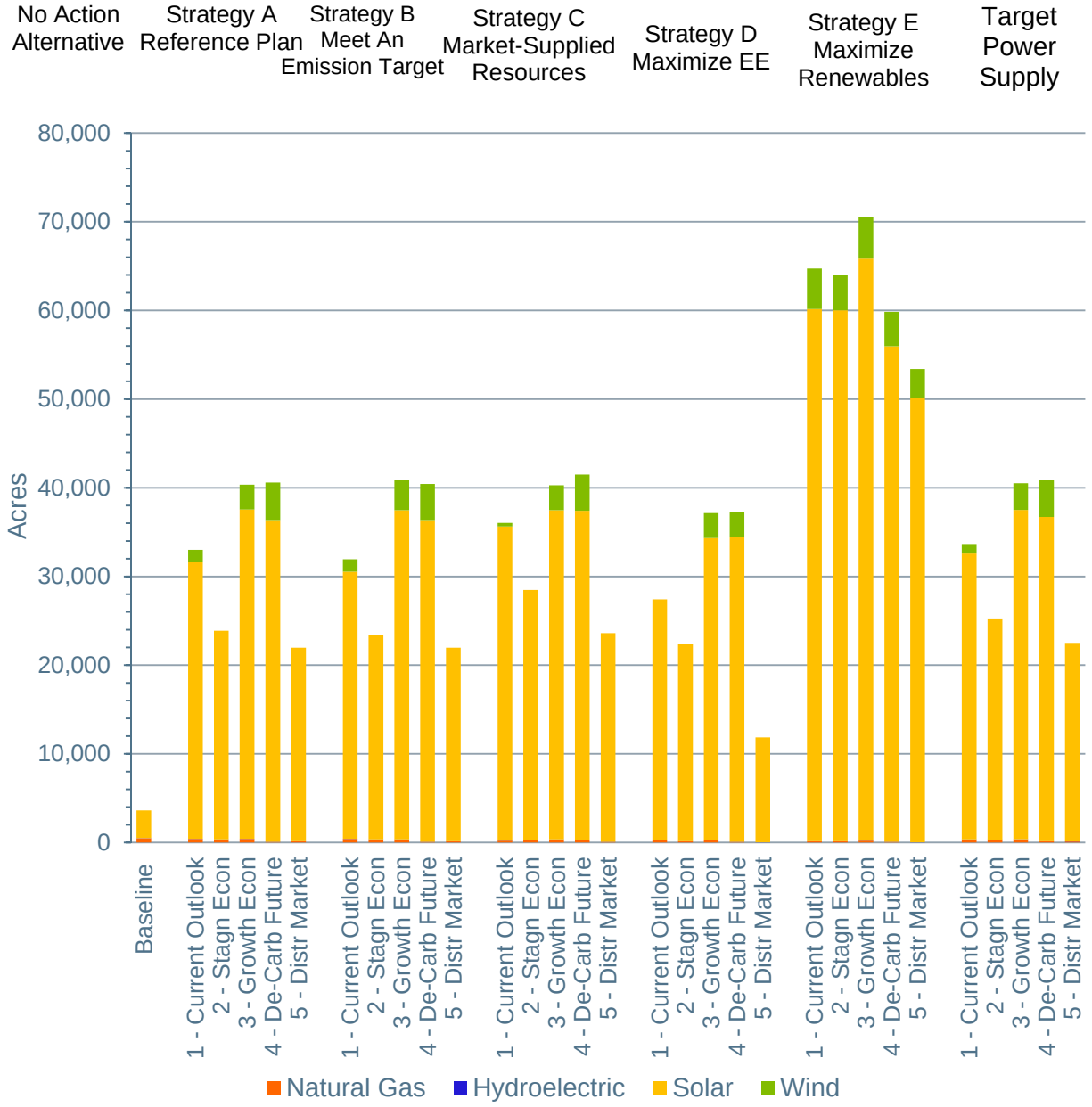

Figure 7-20 Land requirements for new generating facilities by type of generation, alternative strategy, and scenario.

The land requirements illustrated in Figures 7-19 and 7-20 only include those for the generating facility footprints and associated access roads. They do not include undisturbed portions of the power plant reservations or the land area needed for extraction (e.g., mining), processing, and transportation of fuels or long-term disposal of ash and other wastes. The land requirements for windfarms also do not include lands near the turbines where certain land uses may be restricted or affected by turbine noise or shadows.

Figure 7-21 shows the life cycle land requirements for the nuclear and fossil-fueled generation components of the alternative strategies and the Target Power Supply. These strategies have similar amounts of nuclear generation. Despite their differences in coal- and natural gas-fueled generation, the different life cycle land requirements for coal generation (0.014 m^2/MWh) and gas generation (0.12 m^2/MWh for CC, 0.19 m^2/MWh for CT) ultimately result in very similar total life cycle land requirements for Strategies A–E and the Target Power Supply. The life cycle land requirements are based on metrics in Fthenakis and Kim (2009) and NETL (2010a, 2010b, 2014) and include land directly transformed by facility life cycle processes including construction, fuel extraction, processing, and transportation, and waste handling and disposal. They do not include land required for disposal of waste from nuclear plants, given the uncertainties over long-term nuclear waste disposal. Inclusion of land requirements for the disposal of spent nuclear fuel at Yucca Mountain would have increased the life cycle land requirements for nuclear generation by about 27 percent (Fthenakis and Kim 2009). Solar and wind generation are not included in this analysis; the differences between their facility land requirements and life cycle land requirements are relatively small because they do not have associated fuel supply and waste disposal processes,. Hydroelectric generation is not included because of the multipurpose nature of the dams and reservoirs.

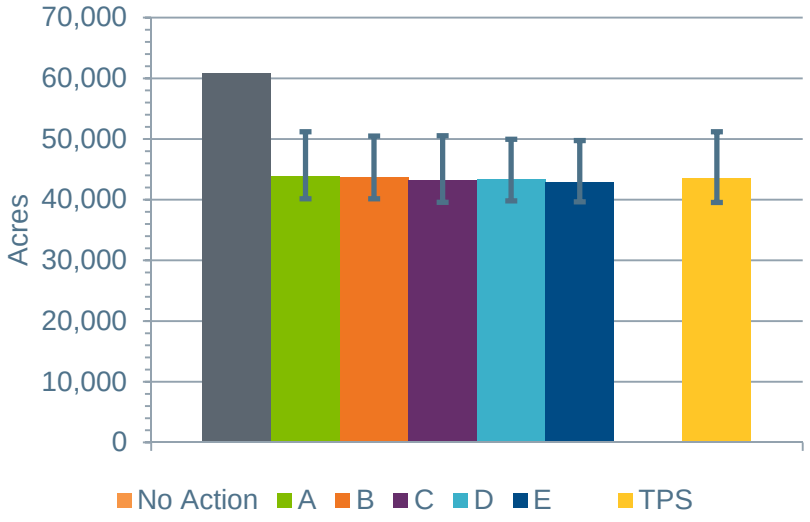

Figure 7-21 Average life cycle land requirements for nuclear and fossil-fueled generation by alternative strategy and the Target Power Supply (TPS). The error bars indicate the maximum and minimum values for the scenarios associated with each alternative strategy and the TPS.

7.5.7 Socioeconomics

Potential socioeconomic impacts of the alternative strategies were assessed by the per-capita income and employment metrics described in Sections 2.6. These metrics were calculated using the PI+ Model by Regional Economic Models, Inc. This model is described in detail in IRP Appendix G. The numerous inputs to the model include employment, wage, income,and population data, costs associated with the energy resource options, and labor and capital requirements. Per-capita income reflects the general economic well-being of area residents and reflects the net effect of each strategy's, and the Target Power Supply's, change in expenditures and electricity bills. Increases in TVA expenditures to operate the power system stimulate the

area economy but can also increase customers' electricity bills and reduce their disposable income. These impacts tend to be offsetting.

Changes in per-capita income and employment are described for the TVA service area. Because the IRP is programmatic and does not address the future siting and construction of generating facilities, site-specific analyses of socioeconomic impacts, including potential site-specific disproportionate impacts to minority and low income populations, are not possible at this time. TVA acknowledges that any future rate increases could affect low income populations more than other populations. Low income populations also have limited ability to participate in energy efficiency programs that could reduce their future power bills and is working with the local power companies to develop programs benefiting low income homeowners and renters.

For the No Action Alternative and Strategies B through E, the differences in annual per capita income of residents of the TVA service area were compared to Strategy A for each scenario (Table 7-6). The differences are small, with a slight reduction under the No Action Alternative, no change under the Strategies B and E averages, and slight increases under the Strategies C and D averages. The small changes are due in large part to the small proportion of the TVA region's economy (about $430 billion in 2015) comprised by TVA revenues ($11 billion). The per capita income metric does not reflect the effects of TVA expenditures outside its service area for fuels, which would be highest under the No Action Alternative and relatively similar for the other strategies, or for energy imported into the TVA service area. Strategies A through E and the Target Poser Supply have significant quantities of wind energy generated in the southern Great Plains and imported into the TVA region. This quantity is greatest for Strategy E, which also has significant quantity of wind energy generated in the Midwest and/or northern Great Plains. Strategies A through E would have small positive effects on per capita income in the wind energy sourcing areas. Although the change in per capita income was not calculated for the Target Power Supply, its performance would be in the range of Strategies A, B and C since it is based on these strategies.

Table 7-6 Comparison of changes in annual per capita income under alternative strategies relative to Alternative Strategy A – The Reference Case.

	Scenario					
Strategy	Current Outlook	Stagnant Economy	Growth Economy	De-Carbonized Future	Distributed Market Place	Strategy Average
No Action	-0.03%					-0.03%
B – Meet an Emission Target	0.00%	0.01%	-0.01%	0.00%	0.00%	0.00%
C – Focus on Long-Term Market-Supplied Resources	0.00%	0.01%	0.03%	0.01%	0.00%	0.01%
D - Maximize Energy Efficiency	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
E – Maximize Renewables	-0.01%	0.00%	0.00%	0.02%	-0.01%	0.00%

The differences in non-farm employment in the TVA service area attributable to the No Action Alternative and to Strategies B through E were compared to Strategy A for each scenario (Table 7-7). As with changes in per capita income, the magnitude of changes in employment in the TVA service area directly resulting from implementing the alternative strategies is small. Relative to other energy resources, investments in energy efficiency programs have high labor requirements. Consequently, Strategy D – Maximize Energy Efficiency, with its larger amounts of energy efficiency, would result in the largest increase in employment in the TVA service area. Strategy E, with its large amount of imported wind energy, would probably result in the largest increase in employment outside the TVA service area. Although the change in non-farm employment was not calculated for the Target Power Supply, its performance would be in the range of Strategies A, B and C since it is based on these strategies.

Table 7-7 Comparison of changes in employment under alternative strategies relative to Alternative Strategy A – The Reference Case.

	Scenario					
Strategy	Current Outlook	Stagnant Economy	Growth Economy	De-Carbonized Future	Distributed Market Place	Strategy Average
No Action	-0.05%					
B – Meet an Emission Target	0.00%	0.03%	-0.01%	0.00%	0.00%	0.00%
C – Focus on Long-Term Market-Supplied Resources	0.00%	0.04%	0.05%	0.02%	0.00%	0.02%
D - Maximize Energy Efficiency	0.06%	0.11%	0.06%	0.07%	0.08%	0.08%
E – Maximize Renewables	-0.02%	0.02%	-0.01%	0.00%	-0.02%	0.01

Before implementing a specific resource option, TVA will conduct a review of its potential socioeconomic impacts. This review will, as appropriate, focus on resource- and/or site-specific socioeconomic issues such as impacts on employment rates, housing, schools, emergency services, water supply and wastewater treatment capacity, and local government revenues including TVA tax equivalent payments, as well as the potential for disproportionate impacts on minority and low-income populations.

7.6 Potential Mitigation Measures

As previously described, TVA's siting processes for generation and transmission facilities, as well as practices for modifying these facilities, are designed to avoid and/or minimize potential adverse environmental impacts. Potential impacts are also reduced through pollution prevention measures and environmental controls such as air pollution control systems, wastewater treatment systems, and thermal generating plant cooling systems. Other potentially adverse impacts can be mitigated by measures such as compensatory wetlands mitigation, payments to in-lieu stream mitigation programs and related conservation initiatives, enhanced management of other properties, documentation and recovery of cultural resources, and infrastructure improvement assistance to local communities.

Chapter 7 – Anticipated Environmental Impacts

7.7 Unavoidable Adverse Environmental Impacts

The adoption of an alternative strategy for meeting the long-term electrical needs of the TVA region has no direct environmental impacts. The implementation of the strategy, however, would have adverse environmental impacts. The nature and potential significance of the impacts will depend on the energy resource options eventually implemented under the strategy. Resource options in each strategy have associated adverse impacts that cannot be realistically avoided but which can often be minimized.

Under every alternative strategy, TVA would continue to operate most of its existing generating units for the duration of the 20-year planning period. The exceptions are the coal plants/units that would be retired. The operation of the generating units would continue to result in the release of various air and/or water pollutants, depending on the kind of unit, and to generate wastes.

The construction and operation of new generating facilities would unavoidably result in changes in land use unless new facilities are located at existing plant sites. The conversion of land from a non-industrial use to an industrial use would unavoidably affect land resources such as farmland, wildlife habitat and scenery.

7.8 Relationship Between Short-Term Uses and Long-Term Productivity of the Human Environment

The adoption and implementation of a long-term energy resource strategy would have various short- and long-term consequences. These depend, in part, on the actual energy resource options implemented. Option-specific and/or site-specific environmental reviews will be conducted before final implementation decisions are made to use certain energy resources and will examine potential environmental consequences in more detail.

In both the short and long term, TVA would continue to generate electrical energy to serve its customers and the public. As described in Chapter 2, the demand for electricity is forecast under most scenarios to grow in the future. The availability of adequate, reliable, low-priced electricity will continue to sustain and increase the economic well-being of the TVA region. The availability of electricity also has been recognized as enhancing public health and welfare.

The generation of electricity has both short- and long-term environmental impacts. Short-term impacts include those associated with facility construction and operational impacts, such as the consequences of exposure to the emission of air pollutants and consequences of thermal discharges. Potential long-term impacts include land alterations for facility construction and fuel extraction, and the generation of nuclear waste that requires safe storage for an indefinite period.

7.9 Irreversible and Irretrievable Commitments of Resources

The continued generation of electricity by TVA will irreversibly consume various amounts of non-renewable fuels (coal, natural gas, diesel, fuel oil, and uranium). The continued maintenance of TVA's existing generating facilities and the construction of new generating facilities will irreversibly consume energy and materials. The siting of most new energy facilities, except for wind and PV facilities, will irretrievably commit the sites to industrial use because of the substantial alterations of the sites and the relative permanence of the structures. The continued generation of nuclear power will produce nuclear wastes; therefore, a site or sites will

have to be devoted to the safe storage of these wastes. Any such site would essentially be irretrievably committed to long-term storage of nuclear waste.

The alternative strategies contain varying amounts of EEDR and renewable generation. Reliance on these resources lessens the irreversible commitment of non-renewable fuel resources, but would still involve the irreversible commitment of energy and materials and, depending on the type of renewable generation, the irreversible commitment of generating sites.

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8.0 Literature Cited

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Chapter 9 – List of Preparers

9.0 List of Preparers

Tyler F. Baker
Education: M.S., Ecology; B.S., Wildlife and Fisheries Science
Experience: 26 years in aquatic resources monitoring and assessment
Role: Water Quality

John T. Baxter
Education: M.S. and B.S., Zoology
Experience: 24 years in protected aquatic species monitoring, habitat assessment, and recovery; 13 years in environmental review
Role: Aquatic ecology, threatened and endangered species

J. Markus Boggs (retired)
Education: M.S., Hydrology; B.S., Geophysics
Experience: 41 years in hydrologic investigation and analysis for environmental and engineering applications
Role:Groundwater

Charles E. Bohac, P.E. (retired)
Education: Ph.D., M.S., and B.S., Civil Engineering
Experience: 40 years in water resource investigations, water quality analysis, waste treatment and disposal system design, groundwater supply and contamination analysis, and hydro and fossil power plant engineering
Role: Water supply

Amanda K. Bowen
Education: M.S., Environmental Engineering; B.S., Civil Engineering
Experience:5 years in water supply investigations, watershed hydrology, and surface water quality analysis
Role: Water supply

Gary S. Brinkworth, P.E.
Education: M.S. and B.S., Electrical Engineering
Experience: 32 years of electric utility experience in system planning, DSM analysis, forecasting, and rate analysis
Role: Integrated Resource Plan project manager

Cathy Ann Coffey
Education: B.A., Journalism; B.A., French
Experience: 35 years in environmental and crisis communications
Role: IRP project communications

Edward L. Colston, P.E.
Education: B.S., Mechanical Engineering
Experience: 35 years in demonstration, design, implementation, and measurement of energy efficiency and demand response programs
Role: Energy efficiency and demand response program accomplishments, current programs, and program plans

Chanda K. Cooper
Education: B.S. Chemistry, A.S. Environmental Protection & Safety Technology
Experience: 14 years in clean air environmental policy and planning, clean and renewable energy policy and planning, capacity resource planning, and economic analysis
Role: Capacity expansion modeling, strategy and scenario development, IRP report preparation

Adam Datillo
Education: M.S., Forestry
Experience: 10 years botany, restoration ecology, ESA compliance.
Role: Vegetation, threatened and endangered species

Chapter 9 – List of Preparers

Heather M. Hart
Education: M.S., Environmental Science and Soils; B.S., Plant and Soil Science
Experience: 12 years in natural areas management, surface water quality and soil and groundwater investigations;
Role: Parks, managed areas, and ecologically significant sites

Samuel W. Hixson
Education: M.S., Environmental Engineering
Experience: 32 years environmental engineering experience, NPDES and RCRA permitting, water quality, solid waste, groundwater monitoring, and environmental compliance
Role: Solid and hazardous waste

Andrew Henderson
Education: M.S., Fisheries (Conservation), B.S. Fisheries
Experience: 10 years in aquatic monitoring, rare aquatic species surveys
Role: Aquatic ecology, endangered and threatened species

Scott C. Jones, PE
Education: BS, Electrical Engineering, Professional Engineer in Tennessee
Experience: 28 years TVA experience in nuclear systems engineering, resource planning, price forecasting, and financial analysis
Role: Integrated expansion, production cost, and financial modeling. Application of stochastic and risk analysis.

Holly G. LeGrand
Education: M.S., Wildlife, B.S., Biology
Experience 17 years field biology, 12 years technical writing, 8 years ESA compliance
Role: Wildlife, endangered and threatened species

Tanya Mathur
Education: B.S., Electrical Engineering, B.S., Neuroscience
Experience: 14 years in reliability engineering and operations, energy management systems, advanced power applications, transmission reliability and engineering controls, resource planning and fleet strategy
Role: Capacity planning, financial modeling, expansion modeling and analysis; document preparation

Randy McAdams (ScottMadden)
Education: B.S., Management Science; M.B.A.
Experience: 32 years as management consultant; the last 23 in the electric utility industry with consulting to over 50 utilities
Role: IRP team member and subject matter expert on integrated resource planning, strategy development, and scenario planning.

Charles P. Nicholson
Education: PhD, Ecology and Evolutionary Biology; MS, Wildlife Management; BS, Wildlife and Fisheries Science
Experience: 20 years in NEPA compliance, 17 years in wildlife and endangered species management
Role: NEPA compliance and EIS preparation

R. Wesley Nimon
Education: Ph.D., Economics
Experience: 15 years of economic and statistical modeling
Role: Economic and load forecasting economic impact analysis,

Jack W. O'Grady
Education: MS, Management (Natural Resources); BS, Biology
Experience: 35 years environmental management (chemical, pulp & paper, utility)
Role: IRP report preparation

Chapter 9 – List of Preparers

Kim Pilarski-Hall
Education: M.S., Geography, Minor Ecology
Experience: 20 years in wetlands assessment, delineation, mititation
Role: Wetlands

Erin E. Pritchard
Education: M.A., Anthropology
Experience: 17 years in archaeology and cultural resource management
Role: Cultural resources

Thomas C. Rice
Education: M.B.A., B.A., Economics and Finance
Experience: 13 years utility experience in rates, power trading/commercial operations, and resource planning
Role: Integrated resource plan analysis and modeling team leader

Jose Salas (ScottMadden)
Education: M.S. Chemical Engineering; M.B.A.
Experience: 24 years as executive and management consultant in the utility industry
Role: IRP team member and subject matter expert on integrated resource planning, strategy development, and scenario planning

Timothy D. Sorrell
Education: M.S., Mechanical Engineering; B.S., Nuclear Engineering; M.B.A.
Experience: 24 years utility experience in forecasting, system planning, commodity trading, nuclear fuel
Role: Economic impact, load forecasting, commodity price forecasting

Michael B. Stiefel, P.E.
Education: B.S. Civil Engineering (Environmental Emphasis)
Experience: 38 years in environmental and civil engineering
Role Water quality

Karen R. Utt
Education: B.A., Biology; J.D.
Experience: 21 years of experience with environmental compliance, specializing in carbon risk management and climate change adaptation planning
Role: Greenhouse gas and climate change analyses

Daniel A. Woolley
Education: B.S., Finance
Experience: 11 years of experience in financial and risk analysis and modeling, and resource planning
Role: Capacity expansion and financial modeling

Cassandra L. Wylie
Education: M.S., Forestry and Statistics; B.S., Forestry
Experience: 26 years in air quality analyses and studying the effects of air pollution on forests
Role: Air quality

W. Richard Yarnell
Education: B.S., Environmental Health
Experience: 38 years cultural resource management
Role: Cultural resources

Peden Young (ScottMadden)
Education: B.S., Radio/TV/Film; M.B.A.
Experience: Six years in the energy industry; the last three years as a management consultant in the electric utility industry
Role: IRP development with focus on stakeholder engagement process

Chapter 10 – EIS Recipients

10.0 EIS Recipients

Following is a list of the agencies, organizations, and persons who have received copies of the draft supplemental EIS or notices of its availability with instructions on how to access the EIS on the IRP project webpage.

Federal Agencies
USDA Forest Service, Region 8, Atlanta, GA
U.S. Environmental Protection Agency, Washington, DC
U.S. Environmental Protection Agency, Region 4, Atlanta, GA
Department of Interior, Atlanta, GA
U.S. Fish and Wildlife Service, Southeast Region Office, Atlanta, GA
U.S. Fish and Wildlife Service, Frankfort, KY
U.S. Fish and Wildlife Service, Asheville, NC
U.S. Fish and Wildlife Service, Abingdon, VA
U.S. Fish and Wildlife Service, Cookeville, TN
U.S. Fish and Wildlife Service, Gloucester, VA
U.S. Fish and Wildlife Service, Daphne, AL
U.S. Fish and Wildlife Service, Athens, GA
U.S. Army Corps of Engineers, Savannah District
U.S. Army Corps of Engineers, Nashville District
U.S. Army Corps of Engineers, Memphis District
U.S. Army Corps of Engineers, Wilmington District
U.S. Army Corps of Engineers, Vicksburg District
U.S. Army Corps of Engineers, Mobile District
Economic Development Administration, Atlanta, GA
Advisory Council on Historic Preservation

State Agencies
Alabama
Department of Agriculture and Industries
Department of Conservation and Natural Resources
Department of Economic and Community Affairs
Department of Environmental Management
Department of Transportation
Alabama Historic Commission
Top of Alabama Regional Council of Governments
North-Central Alabama Regional Council of Governments
Northwest Alabama Council of Local Governments

Georgia
Georgia State Clearinghouse
Historic Preservation Division

Kentucky
Department for Local Government
Department for Environmental Protection
Energy and Environment Cabinet
Department for Energy Development and Independence
Department for Natural Resources
Kentucky Heritage Council

Mississippi
Northeast Mississippi Planning and Development District
Department of Finance and Administration
Department of Environmental Quality
Department of Wildlife, Fisheries, and Parks
Historic Preservation Division

North Carolina
North Carolina State Clearinghouse
Office of Archives and History

Tennessee
Department of Environment and Conservation
Office of Policy and Planning
Tennessee Historical Commission
Tennessee Wildlife Resources Agency
First Tennessee Development District
East Tennessee Development District
Southeast Tennessee Development District
Upper Cumberland Development District
South Central Tennessee Development District
Greater Nashville Regional Council
Southwest Tennessee Development District
Memphis Area Association of Governments
Northwest Tennessee Development District

Virginia
Office of Environmental Review
Department of Historic Resources

Federally Recognized Tribes
Cherokee Nation
Eastern Band of Cherokee Indians

Chapter 10 – EIS Recipients

United Keetoowah Band of Cherokee Indians in Oklahoma
The Chickasaw Nation
Muscogee (Creek) Nation of Oklahoma
Poarch Band of Creek Indians
Alabama-Coushatta Tribe of Texas
Alabama-Quassarte Tribal Town
Kialegee Tribal Town
Thlopthlocco Tribal Town
Choctaw Nation of Oklahoma
Jena Band of Choctaw
Mississippi Band of Choctaw
Seminole Tribe of Florida
Seminole Nation of Oklahoma
Absentee Shawnee Tribe of Oklahoma
Eastern Shawnee Tribe of Oklahoma
Shawnee Tribe

Individuals

Abde Naima, Johnson City, TN
Abdullah-Zaimah Sondra, Summertown, TN
Abkowitz Kendra, Nashville, TN
Absar Patricia, Nashville, TN
Abu Ruth, TN
Adam Ralph, TN
Adamo Helen, Saulsbury, TN
Adams Debbie, Liberty Fuels Co., Collinsville, MS
Adams Donnie, Gates, TN
Adams James, Memphis, TN
Adams Jason, Nashville, TN
Adams Lavia, Memphis, TN
Adkins Robert H., Collinsville, MS
Ainsworth Paul, Knoxville, TN
Akers Emma, TN
Akin Angela, Humboldt, TN
Albertson Tess, Nashville, TN
Alcott Russell, Huntsville, AL
Aldering Ron, Nashville, TN
Alderman Lisa, Alexandria, TN
Alegria Raul, Franklin, TN
Alexander Bob, Nashville, TN
Algahtani Mohammed, Nashville, TN
Al-Haddad Sharon, Winchester, TN
Allen Daniel, Springfield, TN
Allen Diana, TN
Allen Katie & Mary, Nashville, TN
Allen Sheela, Lebanon, TN
Allison Chaz, Franklin, TN
Almesallimy Shrief
Alntz Z., Nashville, TN
Alvey Shane, TN
Alvis Shane, Hendersonville, TN
Ames David, Johns Creek, GA
Ammons Wayne, Brandon, MS
Anderson Betty, Bowling Green, KY
Anderson Caroline, Nashville, TN
Anderson Christopher, Brentwood, TN
Anderson Emily, Cookeville, TN
Anderson, Hunter
Anderson JB, Nashville, TN
Anderson Robert, Murfreesboro, TN
Anderson Sara, Nashville, TN
Andes Heather, Johnson City, TN
Andes John, Mount Juliet, TN
Andresen Cynthia, Knoxville, TN
Andrews Geneva, Dayton, TN
Andrys Sandra, Allardt, TN
Angel Jerry, McCaysville, GA
Apple Becky, Piqua, OH
Apple Jeana, Piqua, OH
Aquino Virginia, Dungannon, VA
Aragon Mary, Nashville, TN
Araujo Kimberley, Johnson City, TN
Armistead Heather, Clarksville, TN
Armstrong Laura, Central City, KY
Armstrong Ronda, Antioch, TN
Armstrong Wanda F., Seminole, FL
Armstrong, III J. Hord, Armstrong Coal Co., St. Louis, MO
Arnold Brittany, Johnson City, TN
Arnold Dwight, La Follette, TN
Arnold Sandra, New Tazewell, TN
Arwood Hazel, TN
Aryell Eddie, Nashville, TN
Asbell Michael, Nashville, TN
Ashayeoi Loren, Johnson City, TN
Askew Bill, Fayetteville, TN
August Leila, Gallatin, TN
Aurednik Erin, Lexington, SC
Aust Ken, Scooba, MS
Aust Mindy, Scooba, MS
Aust Sheila, Scooba, MS
Authony Jessica, Nashville, TN
Avery-Quinn Rebecca, Knoxville, TN
Avila Maria K., Johnson City, TN
Avorsano Marlin, TN
Ayers Ginny, TN Interfaith Power and Light, Maryville, TN
Bach Liza, Sevierville, TN
Bachman Maria K., Knoxville, TN
Backstrom Charles, Boardwalk Pipeline Partners, Owensboro, KY
Baer Leah, Memphis, TN
Baez George, Smyrna, TN
Bague Angelica, Chicago, IL
Baier Michele, Nashville, TN
Bailey Bill, Kingston Springs, TN
Bailey Brent, Catnon, MS
Bailey Catie, Miller & Martin PLLC, Nashville, TN
Bailey Javier,Javier Bailey Capital Group, Memphis, TN
Bailey Savannah C., Woodbury, TN
Bain Patricia, TN
Baker Haley, Centre, AL
Baker Michael, College Grove, TN
Baker Wilton, Calhoun, GA
Balcar Andrew, Murray Energy Corp., St. Clairsville, OH
Baldeirn Claire, Nashville, TN
Baldwin Charles, Jackson, TN
Baldwin Pat, Cross Plains, TN
Balentine Dewayne, Somerville, TN
Bales Willis, TN
Ballentine Anne, Memphis, TN
Bamford Joe, Lutz, FL
Banach Deb, Munster, IN
Banbury Scott, Sierra Club, Memphis, TN
Banker Jeremia S., Johnson City, TN
Bankston Patricia, Nashville, TN
Barber Shelley, Morristown, TN
Bargery Donald, Ridgely, TN
Barhfield, Billy, Goodlettsville, TN
Barkenbus Jack, Nashville, TN
Barker Bob and Ellen, Kingsport, TN
Barker Shawn, White House, TN
Barnes David, Moscow, TN
Barnes Janis, Nashville, TN
Barnes Michael, McMinnville, TN
Barnes Tanny, Murray, KY
Barnett Frances, Pinson, TN
Barnett Jamie, Memphis, TN
Barnett Judith, Crossville, TN
Barnfield Rachel, Goodlettsville, TN
Barr Hubert, Sparta, TN
Barr T.A., Bristol, VA
Barrie Jeff, Kilowatt Ours, Sierra Club, Nashville, TN
Barrie Jennifer, Nashville, TN
Barritt Jim, Shelbyville, TN
Barry Cecilea, TN
Bartels Kevin, Nashville, TN
Bartlett Angela, Knoxville, TN
Bartley Lucille, TN
Barton Amy, Oxford, MS
Baser Steve, Memphis, TN
Baskin Rory, Watertown, TN
Bass Doris Holiday, Nashville, TN
Bass Nichole
Bates Beth, Jackson, TN
Bates Daniel, Centerville, TN
Batson Alicia, Whites Creek, TN
Battles D. Philip, Nashville, TN
Baty Debra, Huntsville, AL
Bauch Jerold, Nashville, TN
Bauer Dakota, Johnson City, TN
Baumeyer Jack, Memphis, TN
Baurice Margaret M., Lutz, FL
Baz Darlene, TN
Beacham Nancy, Luray, TN
Beaird Wanda, Nashville, TN
Beard Jason, New Johnsonville, TN
Beaudry Heather, Johnson City, TN
Becker Dan, Christiana, TN
Becker Laura, Nashville, TN

Chapter 10 – EIS Recipients

Beech Carol, Springfield, TN
Belan Paula, TN
Belcher Kristin, Chattanooga, TN
Belcher Lynden F., Bartlett, TN
Bell Jonathan, Knoxville, TN
Bell Linda, Nashville, TN
Bell Max, Rock Island, TN
Beltramo Dana, Chattanooga, TN
Benn Doretha, Johnson City, TN
Bennell Mona, Kingston Springs, TN
Bennett Anne, Fulton, MS
Bensen Tiffany, Oxford, MS
Benson Diane, Memphis, TN
Benson William, Maryville, TN
Bergman Carol, TN
Berkheimer Nicole, Knoxville, TN
Bernhardt Cheryl, Gladeville, TN
Berry Connie, Corryton, TN
Berry Donald, Knoxville, TN
Berryhill, James, Atoka, TN
Besind William, Nashville, TN
Best Stanley, Maryville, TN
Bethurem Tanya, Jellico, TN
Beyer Alissa, Nashville, TN
Beyer Donald, Lubbock, TX
Bhattacharjer Biplab, Nashville, TN
Bien Russell, Muscle Shoals, AL
Bilyeu Josh, Tennessee Tech University, Cookeville, TN
Bingham Emelyne, Nashville, TN
Bird Cathie, Pioneer, TN
Bird, Toni, Hoover, AL
Bishop Ben, Nashville, TN
Bishop Leslie, Hernando, MS
Bishop Leta, Mosheim, TN
Bissett Bill,Kentucky Coal Assoc., Lexington, KY
Blackaby Jo, Springfield, TN
Blackwell Anessa, Centerville, TN
Blalock Lauren, Murfreesboro, TN
Blalock Thomas, Murfreesboro, TN
Blanchard Biani, Mt. Juliet, TN
Blanchard Emile, Memphis, TN
Blanchard John, TN
Bland Misty, Rogersville, TN
Blankenship Evan, Bristol, TN
Blanks Jeff, Cave Ridge, TN
Blaylock Frankie, Jackson, TN
Blomstrom Keith, Franklin, TN
Bloodworth Michelle, America's Natural Gas Alliance, Washington, DC
Bloomer Douglas, TN
Blumbeah, Jay, Nashville, TN
Blumberg Victory
Blurton William, Humboldt, TN
Bobo Laura, TN
Bohac Chuck, Hixson, TN
Bolden Lareace, Somerville, TN
Bolding Kathy, Memphis, TN
Boldman Lane, KY Environmental Foundation, Berea, KY
Bolin Luke, Nashville, TN
Bollenbacher Don, Huntsville, AL
Bolt Linda, Knoxville, TN
Booher David, Elizabethton, TN
Booher Sam, Augusta, GA
Booth Carolie, Fountain Run, KY
Booth Edwin, Tazewell, TN
Boozer Deborah, Chattanooga, TN
Bordenkircher David, Nashville, TN
Bosela Alicia, Columbia, KY
Boughan Tom, Decherd, TN
Boule Wilder, Nashville, TN
Bouska Diane, Nashville, TN
Bowen Nigel, Lakeland, TN
Bowers Gary, Nashville, TN
Bowers Jack, Warner Robins, GA
Bowers John, Ramer, TN
Bowman Heather, Centerville, TN
Bowsky Leon, Vestavia, AL
Boyce Fred, Memphis, TN
Boyce Marty, Murfreesboro, TN
Boyd Barbara, Hendersonville, TN
Boyd Madison, Chattanooga, TN
Boyd Raymona, Nashville, TN
Boyd Stanley, Pleasant View, TN
Boyd Thomas, Caryville, TN
Boydstun Martha, Louisville, MS
Boykin Barbara, Oakland, TN
Boyre Charlie, Murfreesboro, TN
Brackett Karen, Maryville, TN
Bradley Braxton, Nashville, TN
Bradshaw Kaye, Covington, TN
Brandt Patricia, Dunlap, TN
Brasfield Jim, Burns, TN
Braski David, Kingston, TN
Brasnier Raven, Murfreesboro, TN
Breeds Tina, Dover, TN
Brendel Sandy, Jamestown, TN
Brewer Brandon, Johnson City, TN
Brewer Christopher, Chattanooga, TN
Brewer Rob, Mountain Brk, AL
Brewster T. A., Robbins, TN
Brian Jordan, Mt. Juliet, TN
Brill Rob, Nashville, TN
Brinkley Ann, Hermitage, TN
Bristow Mary, Brentwood, TN
Brito Azneilto, Bessemer, AL
Brittenum Paemla, Bynali, MS
Broderick Michael, Johnson City, TN
Brooks Benny, Knoxville, TN
Brooks C., Cordova, TN
Brooks Sam, Memphis, TN
Brooksbank Thornton, Memphis, TN
Browmer John, Nashville, TN
Brown Allie, Atlanta, GA
Brown Angela, La Vergne, TN
Brown April, Nashville, TN
Brown Cathie, Jasper, TN
Brown Charles, Hendersonville, TN
Brown Chrystal, Linden, TN
Brown Dale, Somerville, AL
Brown Dan, TN
Brown Jazmine, Johnson City, TN
Brown Jerry, Lewisburg, TN
Brown Jim, Cookeville, TN
Brown Kathleen, Summertown, TN
Brown Megan, Hendersonville, TN
Brown Millie, Somerville, TN
Brown Shirley, Maryville, TN
Brown Steven, Allen & Heshall

Brown Whit, Hiawassee, GA
Brown Angela K., Hendersonville, TN
Brownard Tylor and Patricketta, Memphis, TN
Browning LK, Franklin, TN
Buchkovich Todd, Knoxville, TN
Buck Jason, Alcoa Inc., Farragut, TN
Buckingham Joby, TN
Bucklay H., Nashville, TN
Buckley Robert, Milford, CT
Buckner Hermica, Nashville, TN
Bull John, Nashville, TN
Bullard Patricia, TN
Bullard Tommy, TN
Bullington Lita, TN
Bullman Patsy, Henderson, TN
Bullock Dwain, Linden, TN
Bullock Peggy, Linden, TN
Bunch Brian, TN
Bunch Van, Signal Mountain, TN
Bunkowske Susan, Nashville, TN
Bunn Stephanie, Knoxville, TN
Bunting Craig, Kuttawa, KY
Burdine Ronald, Ackerman, MS
Burgess Dorothy, Sparta, TN
Burgess Leatrice, Memphis, TN
Burgess Nicky, Alamo, TN
Burnnett Greg, TN
Burns Tiffany, Nashville, TN
Burroughs Joan, Birmingham, AL
Burtler Isaac, Hohenwald, TN
Burton Ashli, Hendersonville, TN
Burton Patrick, Nashville, TN
Burzell Elizabeth, TN
Bush Lauren, SOCM, Madison, TN
Bush Robin, Hermitage, TN
Bush Victoria, Hohenwald, TN
Bushore Maki Kim, Johnson City, TN
Butcher David, Maryville, TN
Butler David and Carol, Hermitage, TN
Byler, Rebecca, Hendersonville, TN
Bynum Hillary, Brentwood, TN
Cabney Kathleen, TN
Cadieux Gabrielle, Nashville, TN
Cagle Donna A., Lexington, TN
Cagle Jeff, Lexington, TN
Calahan Sharyn, Huntsville, AL
Caldwell Wanda, TN
Campbell Amy, Goodlettsville, TN
Campbell Bill, Murfreesboro, TN
Campbell David, Andersonville, TN
Campbell Donna, Knoxville, TN
Campbell Ivy, Johnson City, TN
Campbell Morgan, Nashville, TN
Campbell Sheryl, Chattanooga, TN
Campbell Tonya, Nashville, TN
Canan C. T., Nashville, TN
Cannell Tracy Cheek, Huntsville, AL
Cannon Ann, Brownsville, TN
Cannon James, Somerville, TN
Cantorna Terrence, Houston, TX
Cantwell J. D., TN
Cappa Casey, Hendersonville, TN
Carfora Ammie, Scarsdale, NY
Carlisle Dolly, Nashville, TN
Carlough Linda, Butler, TN
Carlson Jered, Johnson City, TN
Carlson Kevin, Greeneville, TN
Carmichael William, TN
Carney Jeff, Smyrna, TN
Carothers Deondra
Carothers Marshall, Centerville, TN

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Carpenter, Dianne, Nashville, TN
Carpenter Jackie, TN
Carpenter Sarah, Nashville, TN
Carr Krissy, Nashville, TN
Carrick Kateryn, Nashville, TN
Carroll Kathy, Savannah, TN
Carson Lois J., TN
Carter Chester L., Louisville, MS
Carter John, Elster Inc., Knoxville, TN
Carter Michael, Antioch, TN
Carter Sharyl, Sweetwater, TN
Carter Tony, Nashville, TN
Cartwright Amanda, Nashville, TN
Cartwright Brooklyn, Nashville, TN
Carwile Max, Johnson City, TN
Casa Santa Chris, Goodlettsville, TN
Casas Kathryn, Kingsport, TN
Case Charles, Memphis, TN
Case Daniel, Memphis, TN
Case Linda J., Bartlett, TN
Case Sara, Nashville, TN
Casey Brian
Casey Paula, Clifton, TN
Cassels Jan, Bell Buckle, TN
Cassidy Vaughn, Jackson, TN
Casteel Phillip, Collinwood, TN
Castellaw Thomas, Brownsville, TN
Castillow Amber, Goodlettsville, TN
Caudle Jeremy, Greenfield, TN
Caulfield Dinah A., Antioch, TN
Caulfield Lindsey, Antioch, TN
Cavender Ashley, Sevierville, TN
Cawthorn Mary, Maryville, TN
Cebula Laura, Chicago, IL
Chaffin Kimberly, Smyrna, TN
Chalaena Natalia, Germantown, TN
Chambers Harriet, Murray, KY
Champion Ruby, Somerville, TN
Chapdelaine Perry, Brentwood, TN
Chard Sue, Portland, TN
Charlton Robert, Germantown, TN
Chavez Chelsea, Nashville, TN
Cheek Chris, Preston, MS
Cheely Jean, Crossville, TN
Chen Sophia, Nashville, TN
Chesser Robert, Seymour, TN
Chewning Joe, Cerulean, KY
Childer Ashley, Nashville, TN
Childress Cristin, Madison, TN
Chollman Jr. George, TN
Chowdhuri Pritindra, Cookeville, TN
Chrisman Katie, Nashville, TN
Chrisp Anneva, Jackson, TN
Christi Sara, Nashville, TN
Christmas Teresa, Bowling Green, KY
Clandening Rachel, Murfreesboro, TN
Clanton DJ, Knoxville, TN
Clark Donald, Pleasant Hill, TN
Clark Hannah, Hendersonville, TN
Clark Kenneth, Unionville, TN
Clark Ladrekus, Jackson, TN
Clark Lawrence, Smyrna, TN
Clarke Rachel, Nashville, TN
Clatcher Christina, Searcy, AR
Clay Bal, Noxapater, MS
Clenney Grace, Jackson, TN
Clevenger Faye, TN
Cliatt Miles, Decatur, GA
Clifft Freddie, Somerville, TN
Cluck Charles, TN
Coats Laura, Knoxville, TN
Cobb Rhonda Michie, TN
Cobb Robert, Knoxville, TN
Coburn Kenneth, Huntsville, AL
Cockerham Steve, Hampton, TN
Cockrum Colton, Memphis River Warriors, Memphis, TN
Cody Nell, TN
Coin Alice, Greenville, KY
Cole Rob, Kingsport, TN
Coleman Billy, Madisonville, TN
Coleman Katheryn, Oxford, MS
Coleman Marion, Tullahoma, TN
Coleman Paul, Murfreesboro, TN
Collier James, TN
Collier Joyce, TN
Collinge Mary, Memphis, TN
Collins Erica, Seymour, TN
Collins Harold, TN
Compton Bruce, Bristol, TN
Compton Steve, Athens, AL
Conner Chloe, Johnson City, TN
Conner James, Brydstown, TN
Conner Sarah, Hohenwald, TN
Connolly Christopher
Connor Robert, Paris, TN
Connor Will, Nashville, TN
Conrad Cathy, Jacksboro, TN
Conrad Jack, Memphis, TN
Conry Stella, Chattanooga, TN
Consolantis Carol, Memphis, TN
Conwill Robert, New Albany, MS
Cook Eric, Avon Lake, OH
Cook Kathy, Somerville, TN
Cook Marijo, Nashville, TN
Cook Terri, Nashville, TN
Cooke Spencer, Nashville, TN
Cool Melissa, Hampshire, TN
Cooley Jean, Morristown, TN
Cooney Narras, Nashville, TN
Cooper Daniel, Nashville, TN
Cooper JD, Memphis, TN
Cooper Lorrie W., Somerville, TN
Cope Dwight, Watauga, TN
Cope William, Memphis, TN
Copeland Thaddeus, Cullman, AL
Copp Martha, Johnson City, TN
Coppinger June, Chattanooga, TN
Corbett Barbara, TN
Corbin Sandra, Hermitage, TN
Corbitt Dwight, Dickson Solar Systems, Dickson, TN
Corneia Rebecca, Rochester, MA
Cornish Kevin, Collinsville, MS
Corpus Osnuel, Jonesborough, TN
Cotham Coy, Nashville, TN
Cotham James, Knoxville, TN
Cotton Greg, Shuqualak, MS
Couch Mike, Knoxville, TN
Coulter Elizabeth, Maryville, TN
Courtney Truman, TN
Covington Jenna, Alcoa, TN
Cowan Jack, Millington, TN
Cowart Bethany, Ringgold, GA
Cowart Randall, Eads, TN
Cox Hollie, McMinnville, TN
Cox Lindsey & Joe, Nashville, TN
Cox Rebecca, Linden, TN
Cox Robin, Operation Green, Cuty of Huntsville, Huntsville, AL
Cox Ronnie, TN
Craddock Melissa, Nashville, TN
Craft Joe, Huntsville, AL
Crafton, PE Nicholas T., Drafton Engineering, Memphis, TN
Cravens Donna, Antioch, TN
Craw Harold, Chattanooga, TN
Crawford Amanda, Kingsport, TN
Creekmore Chuck, Gallatin, TN
Cremerius J., Eads, TN
Crinsworth, Martha, Nashville, TN
Crisler Jason, Murfreesboro, TN
Crisler Tracy, Murfreesboro, TN
Crone Saj, Memphis, TN
Cronk Chelsea, Nashville, TN
Crosby Dean, Gatlinburg, TN
Cross Patricia, Knoxville, TN
Crouch Barbara, Ridgely, TN
Crow Barbara, Moulton, AL
Crow Charles & Dinah, Cumberland City, TN
Cuevas Erika, Nashville, TN
Cullom E., Cherry Log, GA
Culver Nikki, Somerville, TN
Cummins Kara, Lebanon, TN
Cummins Pat, Antioch, TN
Cunningham Joshua, Knoxville, TN
Cupples Reba Jean, Henderson, TN
Curtin Bridget, Mount Juliet, OH
Curtin Danielle, Lorain, OH
Cutts Matt, Greeneville, TN
Cyrus Jana, Crossville, TN
Czerwonka John, Chattanooga, TN
Dabbs Amelia, Memphis, TN
Dacosta Jon, Mt. Juliet, TN
Dake Morgan R., Nashville, TN
Dale Albert, Spring Hill, TN
Dallas Catherine, Winston Salem, NC
Daniel Karen, Knoxville, TN
Daniel William, Linden, TN
Danks Harold, Alicity Development, Chattanooga, TN
Dansby Ralph, Oakland, TN
Dansereau Richard, Knoxville, TN
Darby Kenneth, Jackson, TN
Dare Cheryl, Memphis, TN
Darling Ashton, Murfreesboro, TN
Daught Deborah, Johnson City, TN
Davenport Patricia, Knoxville, TN
Davidheiser James & Marilyn, Sewanee, TN
Davidson Bruce, Oakland, TN
Davidson Leah, Nashville, TN
Davies Jeremy, Clarksville, TN
Davis Betty, Moscow, TN
Davis Brent, Kingsport, TN
Davis Chelsea, Kingsport, TN
Davis Glenn, McMinnville, TN
Davis Joe, TN
Davis Joy, Etowah, TN
Davis Lawrence E., Nashville, TN
Davis Lewis, Hiawassee, GA
Davis Nicole, Murfreesboro, TN
Davis Robert, TN

Chapter 10 – EIS Recipients

Davis Roland, Gadsden, TN
Davis Shadow, Knoxville, TN
Davis Stuart, Murfreesboro, TN
Davis William, Shelbyville, TN
Day Freddie, TN
Dearing Ernest, TN
Deason Joyce, Nashville, TN
Deatherage Deborah, McKenzie, TN
Debaufer Harry, Shelbyville, TN
Debernardi James, Tellico Plains, TN
Decker John, Alexandria, KY
Degruchy Joseph, Antioch, TN
DeGutis Harris, Germantown, TN
Dekeyser Jean-Marc, Hendersonville, TN
Dekeyser Stephanie, Hendersonville, TN
Delaney Elisha, Franklin, TN
Della Sena Michelle, Scotch Plains, NJ
Dellus Pete, Franklin, TN
Delsedo Brandon, Spring Hill, TN
Demetreon Alice, Whitwell, TN
Demetriou Eugene, Memphis, TN
Demoski Cecilia, Old Hickory, TN
Denman Clay, Knoxville, TN
Denman Mary, Knoxville, TN
Denman Ronald, TN
Denton Clark, TN
Dervage Sara, Huntsville, AL
Deshdande Neel, Nashville, TN
Detmer Drs. Richard & Carol, Murfreesboro, TN
Devine Andy, Hermitage, TN
Devine Dan, Franklin, TN
Devoe Remy, Knoxville, TN
Devotie Timothy, TN
Diaz Suzanne, Nashville, TN
Dickinson Hannah, Memphis, TN
Dickovitch Kathy, Chapel Hill, TN
Dicks Rodger, Cordova, TN
Dickson Sierra, TN
Diehl Bradford, Burns, TN
Dieringer Steven, Nashville, TN
Dill Brian, Antioch, TN
Dillard Katelynn, Oxford, MS
Dillon Chad, Livingston, TN
DiMarco James, Jackson, TN
Dimaria Pamela Jo, Hendersonville, TN
Dimick Robert, Brentwood, TN
Dinep-Schneider Nicholas, Starkville, MS
Dioguardi Michael, Nashville, TN
Dishman Patricia, Nashville, TN
Dishman Sylvia, TN
Dittme Angela, Hendersonville, TN
Dixon Betty, Brownsville, TN
Dixon Doris, Hermitage, TN
Dixon Vernon & Mary, Hiawassee, GA
Dodd Kevin, Nashville, TN
Doineau Emma, Nashville, TN
Doka Polly, Knoxville, TN
Doms Mane, Joelton, TN
Dooley Gerald, Kingston Springs, TN
Dooley Joe, Gilbertsville, KY
Doonsape Uyiosa, Antioch, TN
Dotson James, Bristol, TN
Doty Caitlin, Nashville, TN
Dougher Kevin, Memphis, TN
Doughty Steve, Gallatin, TN
Downs Chris, Bessemer, AL
Draude-Wilson Jennifer, Nashville, TN
Dreher Chanitra, Hendersonville, TN
Drew Craig, Chattanooga, TN
Driscoll Maureen, Salem, OH
Driver Katherine, Lavergn, TN
Drumright Chris, Murfreesboro, TN
Drye Allyson, Clarksville, TN
Ducheney Ashley, Nashville, TN
Ducheney Michael, Nashville, TN
Duffie Sonia, Knoxville, TN
Dugger Ryan, Adams, TN
Dugger William, Elizabethton, TN
Dulaney Llaool, Mt. Juliet, TN
Duley Caroline, Nashville, TN
Dumas Jeffrey, Nashville, TN
Dunavant Charlotte, Lexington, TN
Dunaway Melissa, Knoxville, TN
Duncan Ann, Franklin, TN
Duncan Austin, Pikeville, TN
Duncan Dakota, Bowling Green, KY
Duncan Donna, Gallatin, TN
Duncan Tony, Johnson City, TN
Dunn Kyle, Nashville, TN
Dunn Suzan, Pigeon Forge, TN
Dunn Taylor, Nashville, TN
DuPont Peggy, Loudon, TN
Dura Victor, Rogersville, AL
Durand Stephen C., Signal Mountain, TN
Durcell Thomas, Murfreesboro, TN
Durham Merrill, Nashville, TN
Durham Michael, Nashville, TN
Dutton Amber, Nashville, TN
Dwyer Jeffrey, Memphis, TN
Dwyer Lori, Memphis, TN
Dyer Christopher, Hohenwald, TN
Dyer Frank & Marjorie, Knoxville, TN
Dyson Alfred, Dyson Engineering & Tech. Services, Memphis, TN
Eardley Christine, Henderson, TN
Earl Susan, Nashville, TN
Earnest Hollis Rachael, Oakland, TN
Easterling Kermit, Pleasantville, TN
Eatherly Spencer, Hermitage, TN
Eatherly Stephanie, Murfreesboro, TN
Echevarria Mari T., Knoxville, TN
Eckstrom Shirley, Rockwood, TN
Edebo Ekct Udeme, Nashville, TN
Edens Michelle, Elizabethton, TN
Edgar Ben, White Harvest Energy, McDonald, TN
Edmonds Johnny, TN
Edwards Barry, Nashville, TN
Edwards Elizabeth, Nashville, TN
Edwards Howard, Lisman, AL
Edwards James, Hermitage, TN
Edwards Sheri, Knoxville, TN
Edwards Sherry, Memphis, TN
Edwards Tyler, Jonesborough, TN
Eichenberger Troy, Chattanooga, TN
Elam Robert, Nashville, TN
Elder Andrew, Memphis, TN
Elder Binji, Nashville, TN
Eleogram, Dennis E., Millington, TN
Elhart Daniel, Murfreesboro, TN
Elliott Denny, Hixson, TN
Elliott James, Maryville, TN
Ellis Bobby, Atoka, TN
Ellis Hailey, Fairview, TN
Ellis Jason, Chapel Hill, TN
Ellison Ernest, Bradford, TN
Elrod Sean, Memphis, TN
Elston Debby, Mercer, TN
Emmanuele Kurt, Chattanooga, TN
Engle Jennifer, Chattanooga, TN
Ensch Megan, Nashville, TN
Ercelawn Ann, Nashville, TN
Erickson Forest, Maryville, TN
Ericson Rebecca, Bean Station, TN
Ernst Herb, Blairsville, GA
Erwin Shannon, Savannah, TN
Espy David, Nashville, TN
Espy Katherine A., Nashville, TN
Esterle Ann, Bowling Green, KY
Estes Chip, UtiliCom, Flora, MS
Estes John, Birmingham, AL
Ethendge Chrisy, Murfreesboro, TN
Etheridge Olivia, Friendship, TN
Evans Margaret, Cookeville, TN
Evans Peter, Florence, AL
Everett Lisa, Mt. Juliet, TN
Everhart Aubrey, Bristol, TN
Everitt Ivan, Nashville, TN
Everts Debbie, Rosemark, TN
Fabish Zachary, Sierra Club, Washington, DC
Fagala Whitney, Brentwood, TN
Fain Stella, TN
Fair Julie, Madison, TN
Fairbanks Stefany, Knoxville, TN
Faircloth Cynthia, Johnson City, TN
Faler Alfred, Goodlettsville, TN
Falin Ed, Gray, TN
Farmer Danny, TN
Farr Jessica, Nashville, TN
Farris Lynne, Old Hickory, TN
Faulk Chris, Murfreesboro, TN
Faulkner Susan, Nashville, TN
Fay Tony, Brentwood, TN
Fedorsin Martha, Maryville, TN
Fehr Angelique, Sturgis, MS
Felder Donna, Madison, AL
Felker Grace, Knoxville, TN
Ferge Jennifer, Somerville, TN
Ferguson Clayton, Antioch, TN
Ferguson Timmy Anne, Signal Mountain, TN
Ferrell Marilyn, Jackson, TN
Ferrell Retha, Rogersville, TN
Ficili Danielle, Nashville, TN
Fidler Gabriel, Maryville, TN
Fielder Mary, Nashville, TN
Finely Robert, TN
Fingerman Robert, Monteagle, TN
Firebaugh Melissa, Nashville, TN
Fisher Bradford, Johnson City, TN
Fisher Judy, Nashville, TN
Fisher Patrick, Arlington, TN
Fisher Tracie, Arlington, TN
Fisk Susan, Smyrna, TN
Fitchko Nikki, Crossville, TN
Fite Vaden, Atoka, TN
Fitzhugh Bob, Ashland City, TN
Fiveash Shelley, Memphis, TN

Chapter 10 – EIS Recipients

Flack Christian, Murfreesboro, TN
Flaming Emma
Fleenor Fitz, Antioch, TN
Fleming Chantel, Whites Creek, TN
Fleming Chuck, Johnson City, TN
Fletcher Dixie, Memphis, TN
Fletcher Karen, Waynesboro, TN
Flinn Maggie, Powder Springs, GA
Flint Shelley, Mt. Juliet, TN
Flippo Nicole, Hohenwald, TN
Floersch Elizabeth, Goodlettsville, TN
Flowers Jacob, Memphis, TN
Foley Pastor Jim, Birmingham, AL
Fones Glenn, Stanton, TN
Foraker Zane, USGBC – East Tennessee, New Market, TN
Ford Angela, Heiskell, TN
Ford Angela, Nashville, TN
Ford Charles, TN
Forester Laura, Nashville, TN
Forsythe Preston & Shari, Browder, KY
Fortenberry Ron, Kingston Springs, TN
Fortner Joyce, Powell, TN
Foster Jen, Nashville, TN
Foster Matt, Franklin, TN
Fowler Charles, Powell, TN
Fowler Gregg, Murfreesboro, TN
Fox Chris, Franklin, TN
Fox Dana, Knoxville, TN
Fox Jason, Camden, TN
Fox Sherman, RRC, Chattanooga, TN
Foxall Maggie, Nashville, TN
Frank Marie-Therese, Knoxville, TN
Franklin Barbara, Seymour, TN
Franklin Margaret, Collierville, TN
Franklin Terry, Philadelphia, MS
Franks William, Nashville, TN
Fray Mitchell, Nashville, TN
Frazier Mike, Drummonds, TN
Fredrick Emma, Johnson City, TN
Freeland Trish, Benton, KY
Freeman Donna, Nashville, TN
Freese Angela, Johnson City, TN
Freewoman Patricia, Beaumont, KY
French Tylur, Memphis, TN
Freshour Thomas, Greeneville, TN
Freudenberg Jimmy, Nashville, TN
Frey Adrienne, Franklin, TN
Friederichsen Jacqueline, Knoxville, TN
Friedlander Joseph, North American Coal Corp., Plano, TX
Frizzell Kirby, Atoka, TN
Frontczak Mary L., Peabody Energy, St. Louis, MO
Frost David, Johnson City, TN
Fry Daniel, TN
Fugshom Stefan, Nashville, TN
Fuhrhop Corey, Nashville, TN
Fulton Cheryl, Chapmansboro, TN
Fulton Wade, Preston, MS
Fumhop Liz, Nashville, TN
Fuson David, TN
Gabriel Jason, Trussville, AL
Galbreath Dodd, Nashville, TN
Gambrell Brent, Nashville, TN
Gammon Autumn, Lafayette, TN
Gandy Nekita, Starkville, MS
Ganster Aura, Nashville, TN
Gant Toni, Nashville, TN
Garber Elizabeth, Nashville, TN
Garceau-Hagen Dorothy, Memphis, TN
Garcia Tammy J., Nashville, TN
Gardiner David, Alliance for industrial Efficiency, Washington, DC
Garner Wayne, Cordova, TN
Garrabrant Chasty, Nashville, TN
Garrabrant Tom, Nashville, TN
Garrett Gary, Southern States Energy Board, Decatur, GA
Garrett Megan, Nashville, TN
Garrett Patricia, Nashville, TN
Garrison Jill, Linden, TN
Garrison Joyce, Linden, TN
Garrone Angela, Southern Alliance for Clean Energy
Garson Sandy, Harvest, AL
Gass Susan, TN
Gates Andrea, Antioch, TN
Gates Yolanda, Antioch, TN
Gatlin Mel and Joan, Christiana, TN
Gaw Jack, Cookeville, TN
Gazikas John, TN
Geames Sarah, Knoxville, TN
Gensemer Jeffrey, Nashville, TN
Gharanfoli Penny, Chattanooga, TN
Ghertner Patty, Nashville, TN
Ghier Casandra, Bartlett, TN
Giagnorio Corinne, Signal Mountain, TN
Gibbons Buff, Huntsville, AL
Gibbs Johana, La Vergne, TN
Gibby, Tiffany, Chattanooga, TN
Gibson Chris, Murfreesboro, TN
Gibson Corbin, Trenton, TN
Gibson Everett, Nashville, TN
Giddens Teresa, Henderson, TN
Gilbert Barb, Memphis, TN
Gilbert Carroll, TN
Gilbert Ellen S., Nashville, TN
Gilbert Linda, TN
Gilbert Richard, Franklin, TN
Gilbert Tim, Guntersville, TN
Gilbreath Chris, Covington, TN
Giles Mary, TN
Gilleland Carol, Nashville, TN
Gillenwater Ashley, Johnson City, TN
Gillespie Bryan T., Macon, MS
Gillespie Shelby, Chattanooga, TN
Gilliam Alice, TN
Gillian Arthur, Mason, TN
Gillis Kim, Nashville, TN
Gipson Corey, Quebeck, TN
Givens Roger, Morgantown, KY
Glasser Peter, Flag Pond, TN
Glosson Sheila, Nashville, TN
Glover Jerry, Somerville, TN
Godwin Hethalyn, New Market, AL
Goff Thomas, Lexington, TN
Goike Scott, Nashville, TN
Goldberg Hayley, Norcross, GA
Golden Joanne, Franklin, TN
Goldstein Mark, Brentwood, TN
Gonzalez Yarisbeth, Nashville, TN
Gooch Ryan, Nashville, TN
Goodin Noelle, Nashville, TN
Goodman Leigh, Burkesville, KY
Goodman Martha, Mt. Juliet, TN
Gordon JB, Memphis, TN
Gorenflo Louise, Sierra Club, Crossville, TN
Goss Pamela, Memphis, TN
Gossett Karman, Strawberry Plains, TN
Gosster Chris, Knoxville, TN
Goucher Candace, Henryville, PA
Gouge Marsha, Gray, TN
Graeter Phillip, Energy Ventures Analysis, Arlington, VA
Graham Jacob, Jackson, MI
Grainey Karen, Savannah, GA
Grandelski Katny, Tullahoma, TN
Grandquest Sheela, Nashville, TN
Grant Kelly, Lookout Mountain, TN
Gray Christopher, Culleoka, TN
Gray Jack, Murray, KY
Gray James, TN
Gray Jessica, Nashville, TN
Green Melva, Linden, TN
Green Patricia, Nashville, TN
Green Kathy, White Creeks, TN
Greene Arnold, TN
Greene Brad, Nashville, TN
Greene Edward, Memphis, TN
Greene Laurie, Hampshire, TN
Greening Lorna, Chattanooga, TN
Greenway Gloria, Nashville, TN
Greer Glen, Johnson City, TN
Gregg Jackie, TN
Gregory Dianne, Nashville, TN
Gregory Lindsay, Smyrna, TN
Gregory Patrina, Centerville, TN
Gregory Tegan, Pulaski, TN
Griffin Debbie, Madison, AL
Griffith Gloria, Mountain City, TN
Griggs Yvonne, Greeneville, TN
Grimaldi Angela, Strawberry Plains, TN
Grindle Anne, Sewanee, TN
Grindstaff James, Elizabethton, TN
Groninger Carol, Franklin, TN
Grose Thomas, CCL, Nashville, TN
Grossert Kathleen, Knoxville, TN
Groton Jimmy
Gueirero Edna, La Vergne, TN
Guenst John, Franklin, TN
Guess Lewis, Memphis, TN
Gulley Connie, TN
Gulley Jane, Memphis, TN
Gully Rodriquez, Dekalb, MS
Gunderson, John, Monteagle, TN
Gunter Tony, Boaz, AL
Guo Laura, Brentwood, TN
Guo Mingstreng, Brentwood, TN
Gupton Karen, Nashville, TN
Gurevich Vsevolod, Nashville, TN
H. Abby, Franklin, KY
Hack Laura, Antioch, TN
Hacker Al
Hacker Albert
Haddad Lisa, Nashville, TN
Hadlock John, Only, TN
Hafner John, Competitive Power Ventures, Inc., Braintree, MA
Hagan Scott, Murfreesboro, TN
Hagen Linda, Murfreesboro, TN
Haggard Charles, Pinson, TN
Haggard Cherie, Harrison, TN

Chapter 10 – EIS Recipients

Halbrooks Jennifer, Centerville, TN
Hale Tanika, Nashville, TN
Haley Andy, Nashville, TN
Haley Stephen, Goodlettsville, TN
Hall Dawn, Brownsville, TN
Hall Delores, TN
Hall Jennie, Castalian Springs, TN
Hallford D., Louisville, MS
Hallings Mary, Whites Creek, TN
Halpern Betty, Sarasota, FL
Hamby Claudia, Knoxville, TN
Hamill Jacob, Johnson City, TN
Hamilton Angela, Smyrna, TN
Hamilton John, Whites Creek, TN
Hamilton Judith, Athens, TN
Hamlett Terry, Medina, TN
Hammel John, Chattanooga, TN
Hammonds Deborah, Nashville, TN
Hampton Lexx, Nashville, TN
Haney Rip, Memphis, TN
Haney Tim, Decatur, TN
Hanna Christy, Knoxville, TN
Hanna Izzy, TN
Hansen Alison, Clarksville, TN
Hansen Annette, Crossville, TN
Hardee Archie, Pinson, TN
Hardee Michael, Henderson, TN
Hardesty Jill, Gallatin, TN
Hardesty June, Gallatin, TN
Hardin Jimmy, Linden, TN
Hardison Casey, Henderson, TN
Hargrove Jim, Bogota, NJ
Hargrove Teresa, Nashville, TN
Hargus St.John, TN
Harnishfeger Thomas, Cross Plains, TN
Harrell Dorris, TN
Harrell Nancy, Jackson, TN
Harrelson David, Centerville, TN
Harriman Vincent, Rutledge, TN
Harrington James, Stanton, TN
Harrington Wanda, Centerville, TN
Harris Billy, Meridian, MS
Harris Mariella, Memphis, TN
Harris Richard, Tellico Plains, TN
Harris Rita, Sierra Club, Memphis, TN
Harris Warren, Maryville, TN
Harrison Hunter, Johnson City, TN
Hart Greg, Somerville, TN
Hart Robin, TN
Hartigan John, Knoxville, TN
Hartley Alex, Nashville, TN
Hartweg Elijah, Murfreesboro, TN
Harvey Myron, Moscow, TN
Harvey Roger, Chattanooga, TN
Harwig Betty, Fayetteville, TN
Harwood Jane, Jackson, TN
Hatch Gari, Morton, MS
Hatfield Brenda, Roan Mountain, TN
Hatfield Glen, Roan Mountain, TN
Hatmaker Daniel, Powell, TN
Havens Susan Prince, Deer Lodge, TN
Hawkins Charles, TN
Hawkins Jeff, TN
Hayes Jamie, Bean Station, TN
Hayes Robert, Lawrenceburg, TN
Hayes Robin, Chattanooga, TN
Hayes Vanessa, Somerville, TN
Haynes Janice, Cosby, TN
Haynes Johnny, Brownsville, TN
Haynes Michelle, Gallatin, TN
Haynes Nicole, Hermitage, TN
Heald Mark, Pleasant Hill, TN
Heard Allison, Nashville, TN
Heath David, TN
Heath Hannah, Johnson City, TN
Hecht Michael, Prescott, AZ
Heckman Richard, Huntsville, AL
Heelan Helen, Henderson, TN
Heflinger Scott, Goodlettsville, TN
Hellstrom Amber, Murfreesboro, TN
Helms Sandra, Nolensville, TN
Helton Richard, Wartburg, TN
Helton, Jr. William, Louisville, TN
Hendrickson Callie, Nashville, TN
Hendrickson Faye, Nashville, TN
Hendrickson Greg, Maryville, TN
Henley Robert, Cleveland, TN
Henrie Raymond, Beech Bluff, TN
Henry Jack, TN
Henry James, LaVergne, TN
Hensley Kristin, Signal Mountain, TN
Hensley Paula, Linden, TN
Hensley Rylan, Nashville, TN
Henson John, Guntown, MS
Henson Stochia, Murfreesboro, TN
Hereford Earl, Signal Mountain, TN
Hernandez Cynthia, Hendersonville, TN
Hernandez Mari, SolarCity, Washington DC, DC
Hernanz Cynthia, Knoxville, TN
Herron Kyndal, Gallatin, TN
Hickman Donnie, Dekalb, MS
Higdon Matthew, Knoxville, TN
Higgs Jennifer, Kingston Springs, TN
Higgs Tim, Kingston Springs, TN
High Charles, Nashville, TN
High Charlie, Nashville, TN
Hightower Andrea, Clarksville, TN
Hildenbrandt Jerry, Hohenwald, TN
Hill Alicia, Kingsport, TN
Hill Anne, Nashville, TN
Hill Catherine, Nashville, TN
Hill Conley, TN
Hill Phoebe, Nashville, TN
Hill Sandra, College Grove, TN
Hillegas Jan, Jackson, MS
Hiller Zach, EnerNOC, Lenoir City, TN
Hilliard Hunter, Evansville, IN
Hilliard Mike, Hendersonville, TN
Hillis William, Cordova, TN
Hillman Lucy, Knoxville, TN
Hills William, Cordova, TN
Hilton Matt, Knoxville, TN
Hinson Wendy, Memphis, TN
Hinton David B., Nashville, TN
Hiser Jean, Oak Ridge, TN
Hodge Joyce, TN
Hodge Thomas, TN
Hodges Brenda, Sewanee, TN
Hodgin Beth, Cleveland, TN
Hogan Anna, Memphis, TN
Hogan Elizabeth, Ethridge, TN
Hoke Jim, Nashville, TN
Holden Michelle, Rockvale, TN
Holder Robert, Lewisburg, TN
Holdridge Karen, Camden, TN
Holiway Vila, TN
Holland Dallas, Memphis, TN
Holland Lawrence, Huntsville, AL
Holland Lindsay, Charleston, TN
Holliday Stacey, Chattanooga, TN
Holloway Amanda, Lebanon, TN
Holloway Richard, LaVergne, TN
Holman Darrell
Holman Derek, Nashville, TN
Holmes Miguel, Memphis, TN
Holt Gleason, Lenoir City, TN
Holt Goald, Nashville, TN
Holt Kevin, Covington, TN
Holt Mary, Birmingham, AL
Holton Elizabeth, Nashville, TN
Hood Shelby, Franklin, TN
Hooper Glenna, Nashville, TN
Hoot Cathy, Franklin, TN
Hoover Alvin, Maben, MS
Hoover Lisa, Maben, MS
Hopkins Paige, Nashville, TN
Hopland Jessica, Johnson City, TN
Hopley George, Purchase, NY
Hopper Morgan, CRISP Communications, Huntsville, AL
Horne Eli G., Sevierville, TN
Horner Frank, Lobelville, TN
Horner Susanna, Hendersonville, TN
Horton Joel, Maryville, TN
Houmes Elizabeth, Bowling Green, KY
Houser Mary, Trenton, TN
Howard Cornell, TN
Howard Eugene, Franklin, TN
Howard Margaret, TN
Howard Reggie, Fayette County Commission
Howcraft Joshua, Moscow, TN
Howell Thomas, Rugby, TN
Hsiu Chung Ling, Nashville, TN
Hubbard Joan, TN
Huddleston Mary, TN
Hudgins Connie, Centerville, TN
Hudson Garrett, Johnson City, TN
Huff Eddie, TN
Hughes Pamela, Pinson, TN
Hugon J. P., Burlington, NC
Hull Patricia, TN
Humbert Stephen, Memphis, TN
Humphries Merrillyn, Hodges, AL
Hunter Jody, Signal Mountain, TN
Hunter Margie, Nashville, TN
Hunter Wendy, Nashville, TN
Huser, Daniel, Chattanooga, TN
Huskey Wayne, TN
Huss Phil, Wearwell Corp., Smyrna, TN
Huss Phil and Michelle, Rockvale, TN
Hutchings William, Birmingham, AL
Hutson Virgil, Hixson, TN
Hyman Keith, Nashville, TN
Ignace Caleb, TN
Ingraman Adrian, Johnson City, TN
Inness Linda, Philadelphia, TN
Irizarry Alice, Nashville, TN
Irminger Pam, Oak Ridge, TN
Irvin Keel, Joelton, TN
Irvin Tammy, Joelton, TN
Irwin Michael, Knoxville, TN
Isbill Angela, TN

Chapter 10 – EIS Recipients

Iskander Shafik, Oak Ridge, TN
Isle Tim, White House, TN
Isoreve Iulia, Lebanon, TN
Itcha Michael, TN
Jack Michael, Millington, TN
Jack Sabrina, Millington, TN
Jacks Ruth Louise Bruning, Mineral Bluff, GA
Jackson Anthony Lee, Lebanon, TN
Jackson Ashley, Brownsville, TN
Jackson Dan, Greeneville, TN
Jackson Donald, Jackson, TN
Jackson Kay, Jackson, TN
Jackson Kisha, LaVergne, TN
Jackson Morgan Leigh, Burns, TN
Jackson P., Memphis, TN
Jackson Sherry, Lebanon, TN
Jackson Todd, Nashville, TN
Jacobson Christina, Brentwood, TN
Jacques David, Nashville, TN
James Brenda, TN
James Christopher, Brentwood, TN
James Ellen, Knoxville, TN
James Katie, Nashville, TN
James William, Oakland, TN
Jameson Lucia, Old Hickory, TN
Jamison Sam, Pottstown, PA
Jarjoura Zachary, Oxford, MS
Jarrell Lara, Ashland City, TN
Jasud Lawrence, Memphis, TN
Jeanes Dana, MLGW
Jeffers Jack, Oneida, TN
Jenkins Carole, Lawrenceburg, TN
Jenkins JJ, Louisville, MS
Jenkins Tiffany, Nashville, TN
Jennings Roger, Greeneville, TN
Jennings Sam, Clinton, TN
Jervis Craig, Nashville, TN
Jett Charles, Murfreesboro, TN
John Janice, Unionville, TN
John Phillip, Mount Juliet, TN
Johns Jennifer, Nashville, TN
Johnson Ashley, Nashville, TN
Johnson Barry, Cottontown, TN
Johnson David, Knoxville, TN
Johnson Dianne, Nashville, TN
Johnson Francie, Knoxville, TN
Johnson Gil, Treadway, TN
Johnson Helen, TN
Johnson Hunter, Maben, MS
Johnson James, Memphis, TN
Johnson Jasalyn, Murfreesboro, TN
Johnson John C., Atoka, TN
Johnson Larry, Lafayette, TN
Johnson Lynn S., Murrieta, GA
Johnson Maxwell, Nashville, TN
Johnson Mercedes, Johnson City, TN
Johnson Paula, Corinth, MS
Johnson Robert and Deborah, South Fulton, TN
Johnson Shirley, TN
Johnson Steve, LightWave Solar, Antioch, TN
Johnson Tony, Smyrna, TN
Johnson Tracie, Akron, OH
Johnson William, Luka, MS
Johnson, Ph.D Dr. Roger C., McKenzie, TN
Johnson, Sr. Sewell, TN
Johnston, Gretel, BEST/MATRR, Scottsboro, AL
Johnston Susan, Nashville, TN
Joker Rhiannon, Johnson City, TN
Jokerst Andrew, Murfreesboro, TN
Jonakin Jon, Cookeville, TN
Jones Betty, Drakesboro, KY
Jones Charlie, TN
Jones Chris, Carthage, TN
Jones Debbie, Denmark, TN
Jones Ed, Sierra Club Chickawaw Group, Memphis, TN
Jones Mark, Murfreesboro, TN
Jones Ola Cleon, Jamestown, TN
Jones Pam, Old Hickory, TN
Jones Ronnie, Talbott, TN
Jordan-Doulgas Brian, Nashville, TN
Joseph Chloe, Johnson City, TN
Joyce Robert T., Knoxville, TN
Judge Defrey, Lebanon, TN
Jurkonis Paula, LaVergne, TN
Kaaz Spencer, Memphis, TN
Kachinsky Joel and Roberta, Summertown, TN
Kaczmarek Ruth, Springville, TN
Kaline Kelsey, Nashville, TN
Kaller Don and Gerry, Chattanooga, TN
Kamar S., Cleveland, TN
Kane Deanna, Kingsport, TN
Kashner Albert, Cookeville, TN
Kauten James, Monterey, TN
Kay Nancy, Rogersville, TN
Kear Carly, Nashville, TN
Keeling Jack, Cleburne, TX
Keenan James, North American Coal, Starkville, MS
Keeton Billy, Jackson, TN
Keeton Erwin, Somerville, TN
Keiper Cheryl, Mt. Juliet, TN
Keiser Dave, Madison, TN
Keller Robert, Greeneville, TN
Kelley Dennie, Knoxville, TN
Kelley Eugenia, Somerville, TN
Kelley Jody, Koscuisko, MS
Kelley Laurelyn, Nashville, TN
Kelley Megan, Nashville, TN
Kelley Robert, Knoxville, TN
Kelley-Mackey Nirva, Murfreesboro, TN
Kelly Barbara, Chattanooga, TN
Kelly Michael, Memphis, TN
Kelly Seamus, Nashville, TN
Kelly Wendy, Mex, TN
Kelly-Navaro Kaenika, Antioch, TN
Kelly-Navaro Shelagh, Franklin, TN
Kemp Kim, Louisville, MS
Kemp Trish, Nashville, TN
Kemplin Judith, TN
Kendall Heather, Union City, TN
Kendrick Cindy, Knoxville, TN
Kennedy Patrick, TN
Kenny Anne, College Grove, TN
Kerley Mike, Kansas City, MO
Kerr James, TN
Kerr Jennifer, Johnson City, TN
Kerske Mark, Nashville, TN
Kevlin Terry, Nashville, TN
Keyser Donald, Johnson City, TN
Kibodeaux Alex, TN
Kile Charles, Murfreesboro, TN
Kilpatrick Robyn, Murfreesboro, TN
Kimbrough Charles E., Nashville, TN
Kindel Michael, Annapolis, MD
Kinder Amy, Annapolis, MD
King Dawn, Brentwood, TN
King Frankie, Somerville, TN
King Jeff, Starkville, MS
King Mark, Memphis, TN
King Terry, Russellville, AL
Kinser Tonya, TN
Kintz Nathalie, Cookeville, TN
Kirby Guy, Jackson, TN
Kivari Stephanie, Columbia, TN
Kixmiller Kiki, Smyrna, TN
Klaus Robert, Chattanooga, TN
Klepper Larry, Greeneville, TN
Kline Kelly, Lebanon, TN
Kline Sommers, Nashville, TN
Kloville Carol, Memphis, TN
Kluck Vickie, Hohenwald, TN
Koehn Stephanie, Nashville, TN
Kohl Martin, Knoxville, TN
Kool Dr. Josette, Boaz, AL
Kornrich Bill, Sneedville, TN
Kortness Leslie, White House, TN
Korwek Kim, Nashville, TN
Koss Laura, Shelbyville, TN
Kotaski Wayne, Crossville, TN
Kraft Meryl, Nashville, TN
Kramer Lisa, Nashville, TN
Kramer Paul, Nashville, TN
Kramer Ron, Nashville, TN
Krause Lisa, Bartlett, TN
Kreski Bob, Madison, TN
Kresowik Mark, Sierra Club, Washington, DC
Kurer Harly, Nashville, TN
Kurtz Sandra, Chattanooga, TN
Kyser David, Knoxville, TN
Ladlee Gloria, Cresco, PA
Lakota Tala, White House, TN
Lamb Nathan, TN
Lambert Beverly, Selmer, TN
Lammers Lisha, Sweetwater, TN
Lammers Martha, Pleasant Hill, TN
Lancaster Wanda, Pigeon Forge, TN
Lance Will, Blairsville, GA
Landau Lawrence, Oak Ridge, TN
Landers Connor, TN
Landon Alexandra, Clean Line Energy, Houston, TX
Landrum Mary, Nashville, TN
Lane Davis, TN
Lane Michael, TN
Langford Derone, Shuqualak, MS
Lanning Joyce, Birmingham, AL
Laper Jeffrey, Memphis, TN
LaQuita Harris Sierra, Memphis, TN
Large Wanda, TN
Larrance Nada, TN
Larson Matthew, Denver, CO
Laster Kelia, Dyer, TN
Lastovka Barbara, Dickson, TN
Latham Oscar, Madisonville, TN
Latham Robert, Bleech Bluff, TN
Lauderback Katelyn, Cleveland, TN

Chapter 10 – EIS Recipients

Laundis Carol, Johnson City, TN
Laura Nancy and Edwin, Columbia, TN
Lauritzen Heidi Poulsen, Memphis, TN
Lavender Jo Anne, Knoxville, TN
Law Grant, Chattanooga, TN
Lawless Collie, TN
Laws Abraham, Erwin, TN
Layla Rhonda, Louisville, MS
Leach Roy, Humboldt, TN
Leathers Alison, Nashville, TN
Ledbetter Paul, Memphis, TN
Ledford Brittany, Elizabethton, TN
Lee Charles, Nashville, TN
Lee Marilyn, Florence, AL
Lee Steven, Huntsville, AL
Lee Sylvia, Memphis, TN
Leifel Jeff, Lenoir City, TN
Leifel Michelle, Lenoir City, TN
Leighton Jennifer, Huntsville, AL
Leinaar Ted, Johnson City, TN
Leinoff Manivuana, Nashville, TN
LeMense Diana, Madison, TN
Lenchis Rob, Nashville, TN
Leonard Bobbi, Kingsport, TN
Leonard Janie, TN
Leonard Kenny, TN
Lequire Alan and Andree, Nashville, TN
Lese Angie, Nashville, TN
Lesser Jenna, Chicago, IL
Lessing Robert, TN
Lessner Roberta, Kodak, TN
LeSure Michele, Gainesville, FL
Levenshus Jonathan, Sierra Club, Knoxville, TN
Levy Stephen, TN Solar Energy Assoc., Knoxville, TN
Lewis Brandon, Nashville, TN
Lewis Daniel, Bailey, MS
Lewis David, Lexington, TN
Lewis J. C., Lindenhurst, IL
Lewis John, Antioch, TN
Lewis Kevin, Nashville, TN
Lewis Rena, Lexington, TN
Lewis Taylor, Johnson City, TN
Lewis-Wild Robin, Mineral Bluff, GA
Licht Udo, Chattanooga, TN
Liddel Amy, Centerville, TN
Liebe Glenn Anne, Brentwood, TN
Lien Tara and Becky, Farmington, MN
Liford Debbie, Lenoir City, TN
Liles Charles, Rossville, TN
Limeberry Veronica, Johnson City, TN
Lin Julia, Nashville, TN
Linder Kristi, Cohutta, GA
Lindsay John, TN
Lindsey Christi, Clarksville, TN
Lindsey Tim, MacK, TN
Lindy DF, Chattanooga, TN
Lingo Glenda, Nashville, TN
Lingo John, Centerville, TN
Linker Jennifer, Chicago, IL
Lipford Frances, Mason, TN
Litwile Ray, Lewisburg, TN
Lively Mark, Polytech Services, Alpharetta, GA
Livesay Dale, TN
Locke Caroline, Johnson City, TN
Locke Tangela, Nashville, TN
Lockett David W., Antioch, TN
Loflin Miles, Sierra Club
Loflin Peggy, Knoxville, TN
Logan Ann, Franklin, TN
Loller Travis, Associated Press, Nashville, TN
Lomax Tracie, Hohenwald, TN
Lombardo Donna, Powell, TN
Long Mike, TN
Loope John, Louisville, TN
Lopez Christopher, Knoxville, TN
Lopz Joseph P., Nashville, TN
Louanqlath Monk, Smyrna, TN
Loubere Phil, Murfreesboro, TN
Love Candace, Lebanon, TN
Love Jennifer, Maryville, TN
Loveday Kelsey, Powell, TN
Loving Denton, Speedwell, TN
Lovino Teresa, Memphis, TN
Lovitt Frosty, Memphis, TN
Lovorn Allan, Louisville, MS
Lowe Aaron, Murfreesboro, TN
Lowe Michelle, Citizen's Climate Lobby, Nashville, TN
Lowe Reginald, Clarksville, TN
Lowery Mike, Mentone, AL
Lowman Michael, TN
Loyet Jason, Solar Site Design, Nashville, TN
Lucas David, Chattanooga, TN
Luck Mickey, Fort Payne, AL
Luecke Gail, Collierville, TN
Lughino Chris Ann, Nashville, TN
Lukasavitz Lee Ann, Nashville, TN
Luna Charlie, Columbia, TN
Lund LaVern, Liberty Fuels Co., Meridian, MS
Lundberg Tom, Sevierville, TN
Lundy Tara, Knoxville, TN
Lunghino Chris Ann, Community Sustainability USA Inc., Nashville, TN
Luntsford Lorraine, Chattanooga, TN
Lusk Candy, Hixson, TN
Luther Marty, TN
Luxmoore Robert, Harriman, TN
Lyall Jordan, Jonesborough, TN
Lyle Jo Ann, Chuckey, TN
Lynch Dennis
Lynn Amanda, Nashville, TN
Lynn Jeremiah, Antioch, TN
Lynn Jerry, TN
Mabray Jacob, Memphis, TN
MacDonald Jamie, Nashville, TN
Machanoff Mary, Oliver Springs, TN
Maclennan Gail, Dandridge, TN
MacNichols Peter, Murfreesboro, TN
Maddux Samuel, Hendersonville, TN
Madorn Lucas, Antioch, TN
Magallanes Matthew, Franklin, TN
Mahan Simon, Lafayette, LA
Mai Myr, Nashville, TN
Mairs Judith, Chattanooga, TN
Mall Jonathan, Nashville, TN
Mallard Bobbie, Loudon, TN
Mallette Pamalia, Dover, TN
Malo Eric, Nashville, TN
Malone Taylor, Johnson City, TN
Mana Chee, Johnson City, TN
Mandrell Irlene, Hendersonville, TN
Mangan-Lamb Lois, Chattanooga, TN
Mangrum Velma, Antioch, TN
Manneschmidt Charles, Knoxville, TN
Manthe Ellen, Bartlett, TN
Mara Emma, Johnson City, TN
Marcec Jerry, Old Hickory, TN
Marcec Wen, Old Hickory, TN
Marcum Ed, Knoxville News Sentinel
Markham Holmes Anne, Nashville, TN
Marlow Jim, TN
Marnitz Kim, Nicholas, KY
Marotti Tonya, Dyer, TN
Marshall Carla, Linden, TN
Marshall Charlie, TN
Martin Adam, TN
Martin D. Jeanette, Chattanooga, TN
Martin Jeff, Knoxville, TN
Martin Stela, Knoxville, TN
Martin Tina, Morristown, TN
Mascolino Susan, Memphis, TN
Mashburn Ginna, Knoxville, TN
Mast Gregory, Mountain City, TN
Masterson Amy, Columbia, TN
Mastin Mary, Sierra Club, TN Environmental Council, Cookeville, TN
Matee Hope, Nashville, TN
Matthews Cathy, Nashville, TN
Matthews Sandra, Memphis, TN
Mattingly Michael, Paris, TN
Mattison Bryan, North American Coal, Ackerman, MS
May Maureen, Nashville, TN
Maycock Lila, Nashville, TN
Mayfield Joy, Goodlettsville, TN
Mayfield Virginia, Jackson, TN
Maze Ashley, Nashville, TN
McAdams Randy
McAne Cartti, Nashville, TN
McCampbell Bette, TN
McCarthy Sandra, Birmingham, AL
McCartney Katie, Goodlettsville, TN
McCarver Ruth, Mt. Juliet, TN
McCathie Cathy, Germantown, TN
McClaflin James, TN
McClanahan Linda, Ooltewah, TN
McCoig Charles, TN
McConnell Heath A., Gray, TN
McConnell James, Avon, CT
McCoy Ann, Nashville, TN
McCune Christopher, Pattern Energy, San Francisco, CA
McDaniel Dorothy, TN
McDonald Douglas, Drummonds, TN
McDonald Lori, Greenville, KY
McDonald Mary, Spring Hill, TN
McDonald Scott and Amanda, Nashville, TN
McDonell Leslie, Nashville, TN
McEleney Edward, Norris, TN
McElhaney Phyllis, TN
McElroy Melissa, Johnson City, TN
McFadden, PhD John F., TN Environmental Council, Nashville, TN
McFerrin Katlin, Knoxville, TN
McGarry Theresa, Johnson City, TN
McGinnis-Craft Kathy, Knoxville, TN
McGrew Rebecca, Ackerman, MS

Chapter 10 – EIS Recipients

McGrew, Rebecca, MS Lignite Mining Co., Ackerman, MS
McGuigan Marie, Knoxville, TN
McGuinn David, Johnson City, TN
McGuire Rebekah, Portland, IN
McIlmoil Rory, Appalachian Voices, Trade, TN
McIntyre Kathleen, Philadelphia, TN
McKee Jackie, Spring Hill, TN
McKenna Cara, Nashville, TN
McKenna Josh, Nashville, TN
McKinney Emmett, Palos Verdes Estates, CA
McKinnon Al, Henderson, TN
McKinnor Joy, Henderson, TN
McKnight Linda, Joelton, TN
McKnight Luther T & Anne, Nashville, TN
McLaughlin Corinne, Memphis, TN
McLean Ross, Memphis, TN
McLeary Barbara, Dyer, TN
McMillan Donna, Chattanooga, TN
McNabb Jr. Dennis, Unicoi, TN
McNary Cristina, Nashville, TN
McNeal Dawn, Knoxville, TN
McNeece Laurie, Madisonville, TN
McNiel Jim, Woodbury, TN
McNutt Jim, Knoxville, TN
McPeak Judy, Lebanon, TN
McPherson Connie, Bristol, TN
McQuerry Brooke, Nashville, TN
McRey Julie, Nashville, TN
McSpadden Barbara, TN
Meade Bruce, Dyersburg, TN
Meadows Tara, Murfreesboro, TN
Mealer Cynthia, Germantown, TN
Meals Delton, Medon, TN
Meals Wonnell, Medon, TN
Means Marilyn, Stanton, TN
Medlin Barry, Oak Ridge, TN
Medlock Cheyenne, Memphis, TN
Meggs Claire, Knoxville, TN
Mehdy Pamela, Nolensville, TN
Meinbresse Molly, Nashville, TN
Melson Toni, Christiana, TN
Mercado Milton, Pleasant View, TN
Mercer Wanda, Jackson, TN
Merchant Jeanne, Birmingham, AL
Meredith Debbie, Nashville, TN
Merrand Steven, Nashville, TN
Merriam Joanne, Nashville, TN
Merritt Dale, EnerNOC, Franklin, TN
Messamore Samantha, Knoxville, TN
Messerole Steve, Bristol, TN
Metoyer John, Bartlett, TN
Metoyer Samantha, Bartlett, TN
Metz John, Overland Park, KS
Meyer Bobbie, Knoxville, TN
Meyer Ferdinand, Antioch, TN
Meyer Meredith, Nashville, TN
Meyers Michelle, Nashville, TN
Meza Carolina, Hendersonville, TN
Michaud Susan, Germantown, TN
Michello Tracy, Smyrna, TN
Miesel Marie, Nashville, TN
Migarity Aaron, Nashville, TN
Milan Serena, Johnson City, TN
Miles John, Liberty Fuels, Noxapater, MS
Miller Amy, Dickson, TN
Miller Andrea, Johnson City, TN
Miller Betty, TN
Miller Cathy, Antioch, TN
Miller Chris, Greeneville, TN
Miller Cynthia, Hohenwald, TN
Miller Kaye, Olive Branch, MS
Miller Linda, Bradyville, TN
Miller Mike, Scottsville, TN
Miller Rachel, Chattanooga, TN
Miller W. Allen
Miller, Jr. Dr. Arthur J., Knoxville, TN
Millican Cynthia, Birmingham, AL
Mims Natalie, Knoxville, TN
Minaker Peggy, Nashville, TN
Minaker Sean, Nashville, TN
Minier Steven, Jackson, TN
Mink Frank
Minor Letita, Memphis, TN
Minton Maddy, Hendersonville, TN
Miralia Lynn, Nashville, TN
Mitchell Catie, Nashville, TN
Mitchell Jayni, Cordova, TN
Mitchell Philip, Eads, TN
Mitten Denise, Nashville, TN
Mizell Noel
Moffett Cristy, Bailey, MS
Moffett Joseph, Liverty Fuels, Bailey, MS
Mohary Lisa, Hendersonville, TN
Mohr Becky, Manchester, TN
Molff Bert A., Memphis, TN
Mollerup Jeff, Memphis, TN
Moloney Linda, Glasgow, KY
Monday Dorothy, Knoxville, TN
Mondelli Sr. John, Pegram, TN
Mongeon Paul, North American Coal, Ackerman, MS
Monk Grace, Chattanooga, TN
Monroe Jessica, Knoxville, TN
Montgomery Joye, Knoxville, TN
Montgomery Micah, Chuckey, TN
Moon Joe, Dunnellom, FL
Moore Harold, TN
Moore Lisa, Nashville, TN
Moore Michael, Greeneville, TN
Moore Mildred, TN
Moore Nathan, Southern Environmental Law Center, Nashville, TN
Moore Paula, TN
Moore Robert, TN
Moore Timothy, Cookeville, TN
Morales Pat, Townsend, TN
Morgan Barbara, TN
Morgan Clayton, Lenoir City, TN
Morgan Janice, Murray, KY
Morgan Thacker, TN
Morgan Windle, Nashville, TN
Moritz Farrar, Hermitage, TN
Morris Beverly, Chattanooga, TN
Morris David W., Brentwood, TN
Morris Kevin, Jacks Creek, TN
Morrison Bob, Mountain City, TN
Morrison Mike, Oak Ridge, TN
Morriss Phyllis, Springfield, TN
Morrow Myra, Linden, TN
Morse Gary, Smyrna, TN
Mortimer Samuel, Hixson, TN
Morton Melinda, Elizabethton, TN
Morton Thomas, Meridian, MS
Moses Susan, Chattanooga, TN
Mosley James, Scooba, MS
Moss James, Sparta, TN
Mosser Rockann, Nashville, TN
Mott Marcie, Chattanooga, TN
Moudry Joseph, Birmingham, AL
Moyers Lloyd, TN
Muldoon Kelly, Old Hickory, TN
Muldoon Mareen, Old Hickory, TN
Muldoon Sean, Old Hickory, TN
Mulhearn Patrick, Bartlett, TN
Mullins Gail, Knoxville, TN
Munjal Alex, Johnson City, TN
Munoz Ray, Memphis, TN
Munro Nancy, Oak Ridge, TN
Murchison Joel, Chattanooga, TN
Murdoch Kathryn, Huntsville, AL
Murdock Leanna, Chucey, TN
Murphy Carol, Lebanon, TN
Murphy Kelly, Steffes Corp., Dickinson, ND
Murphy Michael, Goodlettsville, TN
Murphy Rachel, Nashville, TN
Murray Ashley, Oakland, TN
Murray Catherine, Johnson City, TN
Murray Mary, Johnson City, TN
Mustafa Shaahid, LaVergne, TN
Mwakowiki Jane, Nashville, TN
Myers August, Germantown, TN
Myers Janet, Brentwood, TN
Myers Ralph, Somerville, TN
Myers Steve, Brentwood, TN
Mynatt Jessica, Dandridge, TN
Nadler Elizabeth, Nashville, TN
Nantz Luke, Nashville, TN
Nash Alicia, Hohenwald, TN
Nava Jennie, Billings, MT
Nave Bettie, Woodbury, TN
Neal Bradford, Franklin, TN
Neal Joyce, Pinson, TN
Neilsen Nancy, Louisville, TN
Nell Coole Jaeleso Margia, Madison, TN
Nellis Brad, Knoxville, TN
Nelms Jerry, Memphis, TN
Nelson David J., Bowling Green, KY
Nelson Joshua, Jacksboro, TN
Nelson Katherine, Nashville, TN
Nelson Linda, Birmingham, AL
Nelson Michael, Nashville, TN
Nelson Raelyn, Goodlettsville, TN
Nelson Shirley A., Bowling Green, TN
Neubauer Karen, Huntsville, AL
Newell Gabriela, Nashville, TN
Newell Heath, Phila, MS
Newhart Kimberly R., Bowling Green, KY
Newhert Kenneth, Bowling Green, KY
Newman Jacqueline, Greenville, KY
Newman Melinda, Greenville, KY
Newman Tom, Huntsville, AL
Newton Perry, Amory, MS
Neyhart Sam, Memphis, TN
Nezli Beatrice, Nashville, TN
Nicholl Mike, Nashville, TN

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Nichols Jason, Maryville, TN
Nichols Richard, Humboldt, TN
Nichols Terry, Spring City, TN
Nicks Mara, Union City, TN
Nies Carol, Nashville, TN
Nieves Robert, Nashville, TN
Nikolaeva Elena, Hixson, TN
Niles Susan, Nashville, TN
Nine Harmon, Nashville, TN
Nister Elwood, TN
Noe Mark, TN
Noe Tom, Johnson City, TN
Noel Elizabeth, Nashville, TN
Nolter Robert, Knoxville, TN
Norris Kris and Terry, Hermitage, TN
Northcross Betty, LaGrange, TN
Norton Dennis, Spring Hill, TN
Novak Bill, Brentwood, TN
Novak David, Henderson, TN
Novick Laura, Nashville, TN
Nuk Ayesha, Nashville, TN
Oakley John, Mt. Juliet, TN
Oaks Sara, Cordova, TN
O'Brian Colin, Madison, TN
O'Brien J., Westinghouse Electric Co., Cranberry Township, PA
Oconnor Teryl, Franklin, TN
Odebralski Jessica, Lewisburg, TN
O'Dell Allison, Cookeville, TN
O'Dell Justin, Cookeville, TN
Oden Martin, DeKalb, MS
Odle Maggie, Nashville, TN
Odom Amanda, Hohenwald, TN
O'Donnell Kevin, Johnson City, TN
Oehler Shawn, Shelbyville, TN
Ogden Sara, Hohenwald, TN
Ogdin Dustin, Nashville, TN
Oglander Evamarie, Nashville, TN
Ogle Barbara, TN
O'Kroley Colen, Bon Aqua, TN
Olson Bruce, Hendersonville, TN
O'Neill Teresa, Brandon, MS
Ora Shirley, Nashville, TN
Orr Chad, TN
Osborne Kennith, Johnson City, TN
Osburn Ruth, Nolensville, TN
Osmand Pam, Knoxville, TN
Ostby Brien, Alcoa, TN
Ott Michael, Nashville, TN
Owenby Randi, Johnson City, TN
Owens James, Franklin, TN
Owens Linda, Moscow, TN
Owens Mario, Whites Creek, TN
Owens Sherry, Memphis, TN
Owensby Andrew, Nashville, TN
Owensby Ashley, Nashville, TN
Owensby Craig, Nashville, TN
Owensby Patricia, Nashville, TN
P Julia, Memphis, TN
Paddock Brian, Cookeville, TN
Padgett Cheyenne, Johnson City, TN
Page Diana, Nashville, TN
Painter Scott, TN
Palmgren Charlie, Franklin, TN
Paneu Anton, Johnson City, TN
Pannell Mathew, Athens, TN
Panzini James, Hermitage, TN
Panzini Micah, Hermitage, TN
Parbery Lu, Florence, AL
Parish Jon, Nashville, TN
Parker Brian, Murfreesboro, TN
Parker Greg, Nashville, TN
Parker Stacie, Dandridge, TN
Parks Wesley, Somerville, TN
Parrish LuAnne, Corinth, MS
Partin Stefan, SOCM, Knoxville, TN
Pascarelli K., Summertime, TN
Pate Brittany, Nashville, TN
Patrick John, Foggy Hollow Farm, Joelton, TN
Patrick Kathy, Rossville, TN
Patterson Sally, Hiwassee, GA
Patterson Willie L., TN
Patterson Jr. Joey, Hermitage, TN
Patton Beka, Knoxville, TN
Patton Brandon, Nashville, TN
Patton Emily, Mt. Juliet, TN
Patton Melody, Mt. Juliet, TN
Paul Rachael, Bluff City, TN
Paxton Barbara, TN
Payne Deborah, KY Environmental Foundation, Berea, KY
Payne Kelsie, White House, TN
Peace Joan, Shelbyville, TN
Peach Barbara, Nashville, TN
Pearce Bob, Memphis, TN
Pearce Linda, Brentwood, TN
Pearcy Carol, Smyrna, TN
Pearson Bill, TN
Pearson David, Jackson, TN
Pearson Lois, Jackson, TN
Peatman Jim, Nashville, TN
Peatman V., Nashville, TN
Peavler Cheyenne, Jonesborough, TN
Peek Albert Ray, Piperton, TN
Peery Cheryl, Hohenwald, TN
Pelikan Ann, Crossville, TN
Pelton Maggie, Nashville, TN
Pence Ken, Nashville, TN
Pencheva Vera, Nashville, TN
Pendrex Barry, Nashville, TN
Peppard Christopher, Pleasant View, TN
Percell Gordon, Jackson, TN
Percu Rebecca, Nashville, TN
Perion Gail, Ooltwah, TN
Perkins Mishelle, Murfreesboro, TN
Perkins Wallace, Stevenson, AL
Perry Charles
Perry Versie, Oakland, TN
Perry Vivian, Somerville, TN
Perry Willie L., Mumford, TN
Persinger Trish, Piqua, OH
Pessar Joshua, Nashville, TN
Peteres Mary, Nashville, TN
Peters Kathy, Nashville, TN
Peters Pamela, Jackson, TN
Peterson Harold, Huntsville, AL
Peterson Lynn, Starkville, MS
Petree Judith, Knoxville, TN
Petrilla E., Nashville, TN
Petrilla J., Nashville, TN
Pettit Elsie, Nashville, TN
Petty Stephanie, Joelton, TN
Pevahouse Joyce, Linden, TN
Pewitt David, Moscow, TN
Phelps Richard, Johnson City, TN
Philipson John, Memphis, TN
Phillips James, KY
Phillips Ray, Knoxville, TN
Phillips Raymond Lee, Somerville, TN
Phillips T. L., Memphis, TN
Phipps Kraig, TN
Pickett Bonnie, Centerville, TN
Pierce James, Knoxville, TN
Pierce Joseph, Sewanee, TN
Piezonki Joanne, Rio Rancho, NM
Pin Francois, Knoxville, TN
Pirtte Barbara, Somerville, TN
Pittman Anthony, Johnson City, TN
Pitts Diane, Knoxville, TN
Plank William, Knoxville, TN
Plemmons Sean, Bartlett, TN
Plumlee Jon, Antioch, TN
Plumlee R. Mark, Memphis, TN
Politte Melina, Maryville, TN
Polizzi Pamela, Morgantown, GA
Polli Lillian, TN
Polovich Christina, Knoxville, TN
Polson Karen, Cleveland, TN
Pope Elsie, Memphis, TN
Popham Karen, Knoxville, TN
Popp Michael, Hendersonville, TN
Porter James A., Henderson, TN
Post Wilfred M., Powell, TN
Posten Russ, Nashville, TN
Posten Sophi, Nashville, TN
Posten Wendy, Nashville, TN
Potter Jo, Memphis, TN
Potter Makayla, Bowling Green, KY
Powell William, Glasgow, MS
Prasad Dhaarini, Franklin, TN
Prather Hali, Florence, AL
Prather Linda, Nashville, TN
Pratt Anna, Gatlinburg, TN
Prauezeo Bill, Johnson City, TN
Prendergast Katie, TN
Prewitt Allison, Nashville, TN
Prewitt Brandi, Nashville, TN
Price Alisa, Lafayette, TN
Price Brian K., Nashville, TN
Price Gero, Jonesborough, TN
Prince Cheri, Mt. Juliet, TN
Pritchard Christine, Harriman, TN
Procter Elizabeth, Mineral Bluff, GA
Puckett Elizabeth, Denmark, TN
Pugh Cathy, Brownsville, TN
Pugh James, Maryville, TN
Pugh Terry, TN
Pullen Lisa, Centerville, TN
Pullen Robbie, Centerville, TN
Pullen Robert, Centerville, TN
Putz Wilma, Mountain City, TN
Qualls Kyle, Maryville, TN
Qualls Melissa, Centerville, TN
Quarles Dene
Queen John F., Nashville, TN
Queen Robin, Nashville, TN
Quigley Edwin, Muscle Shoals, AL
Quintana Lori, Nashville, TN
R Cara, Nashville, TN
Raabe Karen, Scottsville, KY
Rabito Sam, Knoxville, TN
Radyko Michael, Nashville, TN

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Raff Carl, Hydrocore, Cordova, TN
Ragbourn Zach, Knoxville, TN
Rainey David, Bartlett, TN
Rainey John, Franklin, TN
Rakes Brittney, Pearisburg, VA
Raley R. V., TN
Ramprasad Mittur, Tullahoma, TN
Ramsaur Anne, Rockford, TN
Randall Meredith, Nashville, TN
Randolph Judith, Pioneer, TN
Ranney Patrick, Nashville, TN
Raper Alicia, Johnson City, TN
Rasch Joseph, Johnson City, TN
Rasson Rommy, Duck River, TN
Raths Erica, Johnson City, TN
Rauch Samuel, TN
Rauto Gretchen, Nashville, TN
Ray Evans, Tullahoma, TN
Ray Gilbert, Hohenwald, TN
Ray Osha, Cane Ridge, TN
Raymond Heidi, Memphis, TN
Reber Bill, Livingston, TN
Reddig Joyce, Madison, TN
Redmond Haley, Johnson City, TN
Reece Jacob Laurel, Bloomery, TN
Reed Glen, Union City, TN
Reed Kelly, Nashville, TN
Reed Sean, Nashville, TN
Reese Marte', Nashville, TN
Reeves Royce, Somerville, TN
Reeves William, Somerville, TN
Regen David, Nashville, TN
Rehman Syed, Malvern, PA
Reid John, Mountain City, TN
Reiter Fred, Nashville, TN
Resha Makieshi, Antioch, TN
Reynolds Tamara, Nashville, TN
Reynolds Thomas, Scooba, MS
Rhea Joanne, Memphis, TN
Rhodes Donald, Enville, TN
Rhodes Valerie, Antioch, TN
Riall David, East Ridge, TN
Riccardi Patrizia, Nashville, TN
Rice Ryan, TN
Rice Sheila, Talbott, TN
Richardson Patricia, Somerville, TN
Richie Lauren, Pleasant Grove, AL
Rickman Lydia, Nashville, TN
Riddle Joel, Kennesaw, GA
Ridenour Monica, TN
Ridings Dan, Nashville, TN
Ridings Terri, Knoxville, TN
Riley Jim, Oakland, TN
Rios Michael, Murfreesboro, TN
Risner Terry, Mount Carmel, TN
Rivers Russell, Jonesborough, TN
Roach Kelly, Nashville, TN
Roadasmel Kathy, Mt. Juliet, TN
Robbins Allen, Jackson, TN
Roberts Beth M., Memphis, TN
Roberts Carly, Murfreesboro, TN
Roberts Constance, Knoxville, TN
Roberts James, Hopkinsville, KY
Roberts Laurie, Nashville, TN
Roberts Mary Carolyn, Nashville, TN
Robertson Alan, Dekalb, MS
Robertson Cade, Nashville, TN
Robertson Ernest, Cookeville, TN
Robertson Grace,Lightwave Solar, Nashville, TN
Robinette Jessica, Greeneville, TN
Robinson Eric, Memphis, TN
Robinson Laura, Piperton, TN
Robison Linda Midgett, Millington, TN
Rocchietti Megan, Gatlinburg, TN
Roddy Elaine, Cookeville, TN
Roddy Ellen, Knoxville, TN
Roden Mike, Nashville, TN
Rodrigez Leslie, Nashville, TN
Rodrigez Maria, Antioch, TN
Rodriguez Andre, Nashville, TN
Rodriguez Ramcey, Nashville, TN
Rogers Colleen, Brownsville, TN
Rogers Goodrich, Scottsboro, AL
Rogers Jeff, TN
Rogers John, TN
Rogers Milton, Columbia, TN
Rogers Nancy, Chattanooga, TN
Rogers Randolph, JCEDA, TN
Rogers William L., Knoxville, TN
Rogger R., Ft. Laudersale, FL
Rollins LaKetta, Antioch, TN
Rompa Lindsey, Johnson City, TN
Rose Brian, Smyrna, TN
Rose Donald, Nashville, TN
Rose Wendy, Cookeville, TN
Rosenthal Millie, Jackson, TN
Roshdo Monica, Clarksville, TN
Ross Landra Sue, Nashville, TN
Ross Linda, Memphis, TN
Rosson Malissa, Duck River, TN
Rouse Brad, Hiawassee, GA
Rousseau Jane, Memphis, TN
Routon Keven, Sierra Club, Atoka, TN
Routon Susan, Sierra Club
Roy Velma Jean, TN
Rubin Amelia, Black Mountain, NC
Rucker Robert, TN
Rumbarger Alicia, Memphis, TN
Rupe Kevin, Antioch, TN
Rupert Ralph, TN
Rush Amy, Corryton, TN
Rush Amy, Knoxville, TN
Rushton Callie, Mclean, VA
Russ Abel, Environmental Integrity Project, Washington, DC
Russ Emily, Chucky, TN
Russell Ciara, Greeneville, TN
Russell Paula, TN
Rutledge David, Crossville, TN
Rutter Jennifer, Hendersonville, TN
Rutter Sara, Nashville, TN
Ruupe Tehya, Knoxville, TN
Safer Don, TN Environmental Council, Nashville, TN
Saffles Landen, Nashville, TN
Salley Matthew, Mathiston, MS
Salter Ian, Nashville, TN
Sanazaro Larry, Eddyville, KY
Sanders Helen, Moulton, AL
Sanders Lindsay, CSG, Nashville, TN
Sanders Sandi, Franklin, TN
Sanderson Paul, Brentwood, TN
Sands Eileen, Chattanooga, TN
Sargent Roger, Whitwell, TN
Sassomer Rebecca, Madison, WI
Satterfield May, Kingsport, TN
Saums Mary, Nashville, TN
Saunders Yvonne, Goodlettsville, TN
Scarbrough Rachel, Nashville, TN
Schaad Joseph, TN
Schart Bradley, Harvest, AL
Schart Jessica, Gallatin, TN
Schechter Eric, Nashville, TN
Scheer Steven, Germantown, TN
Scheffler Peter
Scheidt Will, Nashville, TN
Schenker Sally, Nashville, TN
Schery Teris, Nashville, TN
Schettino Cheyenne, Nashville, TN
Schiller Dan, Nashville, TN
Schiller Joe, TN Solar Energy Assoc., Clarksville, TN
Schilling Anna, Mt. Juliet, TN
Schlafer-Parton Rachel, Luttrell, TN
Schmidt Gary, Springfield, TN
Schmidt Stephen, Chattanooga, TN
Schmitt Sonya
Schnapp Paul, Patriot Coal Corp., St. Louis, MO
Schoenberger Jay, Palo Alto, CA
Schoenrock Douglas, Fayetteville, TN
Schofield Bobbie, Hermitage, TN
Schramm William, Oak Ridge, TN
Schuchard Susan, Nolensville, TN
Schwaldi Frank, Syracuse, NY
Schwimmer Abby, SE Energy Efficiency Alliance, Germantown, TN
Sciple Bobby, Scooba, MS
Scoggins Bob, Dayton, TN
Scott Clarence, TN
Scott Leyla, Murfreesboro, TN
Scott Michael, Nashville, TN
Scott Trina, Woodlawn, TN
Scurlock Mary, Pleasantville, TN
Seals Chad, TN
Seals George, Chattanooga, TN
Seay Nikki, Newport, TN
Sechler Don, Hendersonville, TN
Sell Barbara, TN
Selser John, Clinton, TN
Seltzer Hank
Senter Charlie, TN
Sexton Richard, Jonesborough, TN
Seybert Claudia, Nashville, TN
Shackelford Doug, Shelby Town, MI
Shackelford Steve, Shelby Town, MI
Shah Pooja, Knoxville, TN
Shalun Annya, Germantown, TN
Shamim Cecily, Nashville, TN
Shannon John, Darden, TN
Shapiro Zach, Germantown, MO
Sharp Connie, Hohenwald, TN
Sharp Kim, Franklin, TN
Sharp Todd, Franklin, TN
Shaver Stefanie, Blue Ridge, GA
Shaw John, Nashville, TN
Shaw Phyllis, Gordonsville, TN
Shelton Charleen, Crossville, TN
Shelton David, Little Rock, AR
Shelton Dorothy, Nashville, TN
Shelton Terry, Burns, TN
Shelton Todd, Knoxville, TN
Shepherd, Joshua, Johnson City, TN

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Shepherd, Wayne, Jonesborough, TN
Sherrard Kathy, Sevierville, TN
Sherrer Christy, Tullahoma, TN
Sherrill Mickel, Crossville, TN
Sherry Rhonda, Eagleville, TN
Shewmake Christy, Huron, TN
Shilstone Max, Clean Line Energy
Shirey William, Decatur, AL
Shirk David, Memphis, TN
Shockley Charlene, Eads, TN
Short Delores, TN
Short Linda, TN
Shoup Ann, Chattanooga, TN
Shreve Brenda, Decatur, AL
Shular Gary, TN
Shulkin Zachary, Germantown, TN
Shumate Kimberly, Burlison, TN
Sias Matthew, Nolensville, TN
Sibley Cathleen, Memphis, TN
Sibley John,Southface, Atlanta, GA
Sifford William, TN
Sigmon David, Blue Ridge, GA
Sikova Jacqui, Johnson City, TN
Silberberger Christine, Nashville, TN
Silberberger Maria, Nashville, TN
Siler Stephen, Fayetteville, TN
Silkes Lance, Memphis, TN
Silva Suzanne, Franklin, TN
Silvarahawk Loreen, Madisonville, TN
Silvers Wilfred, Knoxville, TN
Simmons Nancy, St. Louis, MO
Simmons Rich, St. Louis, MO
Simmons Sarah, Brownsville, TN
Simon Jack, Memphis, TN
Simpson Gregory, Powell, TN
Sims D'montae, Murfreesboro, TN
Singhal Ruchi, Nexus Energy Center, Huntsville, AL
Sisko Kasey, Cookeville, TN
Sislak David, Springfield, TN
Skinner Kathleen, Rockford, TN
Slawson George, Jamestown, TN
Slone Ercel, TN
Smaluk-Nix Kathleen, Louisville, KY
Smith Barry, Henderson, TN
Smith Brenda, McMinnville, TN
Smith Bruce, Knoxville, TN
Smith Christina, Memphis, TN
Smith Dorathy, Enville, TN
Smith Earletta, Nashville, TN
Smith Emily, Del Rio, TN
Smith G., Long Beach, NY
Smith Helen, Roan Mountain, TN
Smith Janet, Nashville, TN
Smith Jennifer, Nashville, TN
Smith John, Oliver Springs, TN
Smith Josh, Nashville, TN
Smith Justin, Piqua, OH
Smith Justin A., Hermitage, TN
Smith Larry, Madison, TN
Smith Marsha, Murfreesboro, TN
Smith Rodney, Newland, NC
Smith Sally, Seymour, TN
Smith Sara E., Johnson City, TN
Smith Shay, Dekalb, MS
Smith Sophie, Gallatin, TN
Smith Stacia, Gallatin, TN
Smith Polk Shelva, Nashville, TN
Smoke Stu, Jackson, TN
Smyth Deborah, Johnson City, TN
Snell Barbara, Gallatin, TN
Snider Jay, Chattanooga, TN
Snook Lynda, Kingsport, TN
Snyder Sarah, Shady Valley, TN
Solomon Louise, Nashville, TN
Sommers Jeremy, Elizabethton, TN
Sondheim Steven, Sierra Club, Memphis, TN
Soudoplatoff, Catherine, Nashville, TN
Souza Tracy, Franklin, TN
Spagler Sydney, Nashville, TN
Spang Bill, Knoxville, TN
Spangler Amanda, Nashville, TN
Spangler Chloe, Nashville, TN
Sparks John, Athens, AL
Sparks Suzanne, Smyrna, TN
Spence Betty, Maryville , TN
Spence John, Trenton, TN
Spiegel Shana M., Franklin, TN
Splittgerber M., Knoxville, TN
Spoon Dewey, TN
Spradlin Michael and Virginia, Kingsport, TN
Springer Claire, Madison, AL
Springer Katie, McKenzie, TN
Sproul Sylvia, Lenoir City, TN
Spry Richard, Nolensville, TN
Spurlock Kimberly, Hohenwald, TN
St. James Syduct, Nashville, TN
Stafford Ronnie, Somerville, TN
Stallings Georgia, TN
Stallings Pat, Joelton, TN
Stallings Randy, Armuchee, GA
Stallons Carroll, TN
Standing Barbara, Memphis, TN
Stanfield Kevin
Stanislowsky Mary Ann, Jonesborough, TN
Stanley Brant, Savannah, TN
Stanley Robert, Chattanooga, TN
Stansberry Karen, TN
Stansberry Travis, TN
Stansell Bettye, TN
Stansell Dennis, Suches, GA
Stanton Ryan, Schneider Electric, Nashville, TN
Stapleton Danny, TN
Starbuck Lisa, Knoxville, TN
Starrett Katie, Johnson City, TN
Stebbins Tracy, Starkville, MS
Steele Donald, Elizabethton, TN
Steele Tyrone, Dekalb, MS
Stegmeyer Joe, Nashville, TN
Stegmeyer Karen, Nashville, TN
Steigerwaldt Henry, Hermitage, TN
Steinberg, Helmut, Memphis, TN
Steiner Brandy, Old Hickory, TN
Stephens Albert, Chattanooga, TN
Stephens Heather, Sevierville, TN
Stephenson Jason, Ackerman, MS
Stepp Mark, TN
Sterling Dominique, Murfreesboro, TN
Stevens Catherine, Memphis, TN
Stevens Stephanie, Gatlinburg, TN
Stevenson John, Nashville, TN
Stewart Ann, Memphis, TN
Stewart Janet, Antioch, TN
Stewart Walter, Roan Mountain, TN
Stiers Mary, TN
Stiltner Bridgett, Bluff City, TN
Stiltner Rachel, Johnson City, TN
Stinson J. K., Nashville, TN
Stokely John, TN
Stolling Jeff, Union, MS
Stoltz James, Pleasantville, TN
Stone Penny, Huntsville, AL
Stout Brian, TN
Stout Terry, TN
Stovall William, Beech Bluff, TN
Stowe Tyler, Murfreesboro, TN
Strand Russell, TN
Strause Garett, Bartlett, TN
Strawberri Chardonay, Murfreesboro, TN
Streete John, Memphis, TN
Strickland Lynn, Strickland Consulting, Memphis, TN
Stringer Larry, Nashville, TN
Strong Blondell M., Nashville, TN
Stryker Sally, Nashville, TN
Stuart Karen, Memphis, TN
Stubblefield Anne, Memphis, TN
Sturgill Gary, Old Hickory, TN
Sudbrock Andy, Fairview, TN
Sudha A., Franklin, TN
Suiter Megan, Madison, AL
Sulski Jodie, Nashville, TN
Summers Judy, Summertown, TN
Sumner Kathleen, Tracy City, TN
Surbrook Scott, Bartlett, TN
Sutton Jeremy, TN
Sutton Robert, Memphis, TN
Sutton John, Columbia, TN
Swanson Kevin, Johnson City, TN
Swanson, Rebecca, Franklin, TN
Swartz Kristi, EnergyWire, Atlanta, GA
Sweet Raven, Jackson, TN
Swenson Marjory, Oak Ridge, TN
Swindler Pam
Swiney Mack, Bristol, TN
Swingle George, Knoxville, TN
Swink Isis, Nashville, TN
Swisher Katie, Knoxville, TN
Taber Caleb, Greeneville, TN
Taggart Robert, Oxford, MS
Tait Daniel, Nexus Energy Center, Huntsville, AL
Tait Daniel, Decatur, AL
Tallent Howard, TN
Talley Nicole, Murfreesboro, TN
Talley Zachery, Murfreesboro, TN
Tallman Elizabeth, Ooltewah, TN
Tamble Keshia, Nashville, TN
Tamri Maretta, Madison, TN
Tank Tyrome, Phila, MS
Tarkington Phyllis, Cordova, TN
Tavares Edgar, Houston, TX
Tawheed Kashee F., Sevierville, TN
Taylor Bill, Nashville, TN
Taylor Bob
Taylor Charles, Somerville, TN
Taylor Connie, Decatur, TN
Taylor Edward, Somerville, TN
Taylor James, Waynesboro, TN

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Taylor Madeleine, Memphis, TN
Taylor Mickly, Nashville, TN
Taylor Rin, Murfreesboro, TN
Teaghe Matthew, Madisonville, TN
Teague Deborah, Johnson City, TN
Teague Lora Tiffany, Knoxville, TN
Teague Steve, Tellico Plains, TN
Tedwell Patsy, Pinson, TN
Teffeteller Tony, Maryville, TN
Tejaela Ana, Murfreesboro, TN
Tellinghuisen Joel, Nashville, TN
Tennysa Eric, Nashville, TN
Terry Clifford, Knoxville, TN
Terry Vickie, Clairfield, TN
Teselle Eugene, Nashville, TN
Tharp Karen, Signal Mountain, TN
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Thomas Kenneth, Nashville, TN
Thomas Lisa, Lexington, TN
Thomas Michael, Four County EPA, MS Manufacturers Assoc., Ackerman, MS
Thomas Rob, Lexington, TN
Thomasson Tamara, Knoxville, TN
Thompson Cheryl, Cordova, TN
Thompson Donald, Nashville, TN
Thompson Donald, Henderson, TN
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Thompson Jill, Old Hickory, TN
Thompson Joseph, Fancy Farm, KY
Thompson Lauren, Nashville, TN
Thompson Sue Anne, Memphis, TN
Throupgood Bob, Johnson City, TN
Tickle, Md Sam, Millington, TN
Tidwell Madget, Pegram, TN
Timmerman Karen, Cullman, AL
Tine Priscilla, Knoxville, TN
Tine Tina, Knoxville, TN
Tinsley Brenna, Glasgow, KY
Tippett Kimberly, Huntsville, AL
Tippner Rebecca, Johnson City, TN
Tipton Amy, Brownsville, TN
Tipton Bennie, TN
Tipton Hannah, Johnson City, TN
Tipton Jerry, TN
Tirelli Cristina Reggio Emilia, KY
Tisdale Samuel, Dekalb, MS
Tlumak Jeffrey, Nashville, TN
Tobey Kathy, Nashville, TN
Toles Pam, Oakland, TN
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Toohey Connie, Kingsport, TN
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Tracy Randall, Burlison, TN
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Trentlage Tom
Trevillion-Hill Maryann, Oxford, MS
Tritschler Thomas, Readyville, TN
Trott Justinn, Birmingham, AL
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Trouart John, North American Coal, Ackerman, MS
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Tsao Stephanie, Washington DC, DC
Tucker Bambi, Bradyville, TN
Tuggey Victoria, Madison, AL
Tuggh Zach, Johnson City, TN
Tuggre Stamie, Bristol, TN
Turbeville Pam, Mountain Brk, AL
Turbyfill Elizabeth, Johnson City, TN
Turbyfill Jack, Johnson City, TN
Turner Bobbie, Medon, TN
Turner Leonard, TN
Turner Ralph, Johnson City, TN
Turner Wayne, Nashville, TN
Tweed Camellia, Greeneville, TN
Tycer Ann Douglas, Brentwood, TN
Tyler Carol, Lexington, TN
Tyler Harold, Lexington, TN
Uddin Ifte, Johnson City, TN
Uddin Moin, Johnson City, TN
Ukeiley Robert, Berea, KY
Ulm Scott, Fayetteville, TN
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Umbarger Sue, Summertown, TN
Umphrey Laura, Savannah, TN
Upchurch Liz, Knoxville, TN
Upton Michelle, Mt. Juliet, TN
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Urban Amy, Nashville, TN
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Uselton Marsha, Knoxville, TN
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Van der Walt Shannon, Laguna Hills, CA
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Vanacore Vince and Sandi, Monterey, TN
Vance Emily, Vestavia, AL
Vance Samuel L., Huntsville, AL
Vasquez Evelyn
Vasquez Yvette
Vaughan Ronnie, Jackson, TN
Vaughn Dian, Nashville, TN
Venegas Lisa, Nashville, TN
Venkatraman Santosh, Brentwood, TN
Verran Stephen, Maryville, TN
Ververis Chris, Nashville, TN
Viale-Gertler Donna, Kingston Springs, TN
Vicento Robert, Memphis, TN
Villeneuve Michele, Kingsport, TN
Von Arb Kathleen, Nolensville, TN
Vookles Genia, Memphis, TN
Vowell Lorrie, NACCO, McCool, MS
Wade GF, Harrison, TN
Wade Irene, Memphis Symphony
Waganer Taylor, Hermitage, TN
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Wagnon Sharon, Cleveland, TN
Wagoner Jacqueline, Oakdale, TN
Walk Sedric, Meridian, MS
Walker Brad, TN
Walker Laverne, Clarksville, TN
Walker Lori, Nashville, TN
Walker Louise, Nashville, TN
Walker Lynn, Nashville, TN
Walker Melba, Nashville, TN
Walker Sarah Beth, Mt. Juliet, TN
Wallace Angela, Smyrna, TN
Wallace Beth, Treadway, TN
Walleman Mark, Pulaski, TN
Walls Sharon, University, MS
Ward Casey, Nashville, TN
Ward Sarah, Nashville, TN
Ward Terry, Brandon, MS
Warner Rita, Greenback, TN
Warters Courtney, Nashville, TN
Wasekiewicz Lisa, Nashville, TN
Washburn Donald, Lobelville, TN
Washington Wanda, TN
Wasilew James, Louisville, TN
Wasson Lawrence, Franklin, TN
Waters Tim
Watson David, Covington, TN
Watson Ella, TN
Watson Frances, TN
Watson Monica, Nashville, TN
Watters Mechelle, Clarksville, TN
Watts Denise, Memphis, TN
Watts Hal, Knoxville, TN
Watts Vera, Knoxville, TN
Waxach Christine, Johnson City, TN
Weaver Jessica, Pulaski, TN
Webb Eada, Oak Ridge, TN
Webb Robin M., Nashville, TN
Weber Roman, Nashville, TN
Webster Phillip, Erin, TN
Webster Tracy, Linden, TN
Wedgewood Gary, Mt. Pleasant, TN
Weeks Brenda, Nashville, TN
Weisfield Brad, Somerville, TN
Welch Debbie, Monteagle, TN
Welch Lesley, Nashville, TN
Welkowitz Stacy, New York, NY
Wellen Robert, Knoxville, TN
Weller Mark, Nashville, TN
Wellman Kennedi, Nashville, TN
Wells David, Stony Creek Farm, Whites Creek, TN
Wells Diana, Hazel Green, AL
Wells Elizabeth, Springfield, TN
Wells Harriet, Eads, TN
Wells Makenzie, Pigeon Forge, TN
Wells Nancy, Gardendale, AL
Wells Tia, Pigeon Forge, TN
Werner Dawn, Midway, TN
West Becky, West Rogers
West Kevin, Nashville, TN
West Kristin, Whites Creek, TN
Westbrook Lisa, Smyrna, TN
Westbrooks Rickey, Hohenwald, TN
Westfall Christopher, Lascassas, TN
Wheaton Joyce, Murfreesboro, TN
Whitaker Jenny, Nashville, TN
White Alison, Birmingham, AL
White Charles, Lexington, KY
White David, Knoxville, TN
White Emma, Richmond, VA
White Haley, Kingsport, TN
White James, Waverly, TN
White Kim R., Meridian, MS
White Pattie, Lexington, TN
White Ronald, Dunlap, TN
White W., Muscle Shoals, AL
White, Jr. Charles, Lexington, TN
Whitehead John, Memphis, TN
Whitehouse Sylvia, Knoxville, TN
Whites Andrea, Nashville, TN
Whiteway Chris, Hollytree, AL

Chapter 10 – EIS Recipients

Whitfield Toni, Memphis, TN
Whitt Cindy, Franklin, TN
Whittington Autumn, Pegram, TN
Whittle Mary, Earthjustice, Philadelphia, PA
Whitton Marlea, Hendersonville, TN
Whitworth George, Memphis, TN
Widby Chris, Knoxville, TN
Wiesmeyer Roger, Nashville, TN
Wiggins Lisa, Fackler, AL
Wilbert Drew, Middleton, WI
Wild Marge, Nashville, TN
Wilder Deloris, TN
Wilder Larry, TN
Wiles Jason, Nashville, TN
Wiles Meg, Readyville, TN
Wilkey Janis, Chattanooga, TN
Wilkins Sara, Athens, TN
Wilkinson Deborah, Milligan College, TN
Willcox Steve, Antioch, TN
Willett Cynthia, Smyrna, TN
Williams Ashley, Watertown, TN
Williams Barbara, Dickson, TN
Williams Beatrice, Somerville, TN
Williams Beverly, Rogersville, TN
Williams Cheryl, Signal Mtn, TN
Williams Jeremy, Nashville, TN
Williams Joshua, Birmingham, AL
Williams Kristi, Newbern, TN
Williams Melissa, Florence, AL
Williams Michelle, Brentwood, TN
Williams Stephanie and Tina, Nashville, TN
Williams Susan, SRW & Assoc., Knoxville, TN
Williamson Barry, MLGW
Willis Alisa, Newbern, TN
Willis Brad, Monford, TN
Willis James, Sevierville, TN
Willis Martha, Millington, TN
Willis Phillip, Bartlett, TN
Willner Ally, Johnson City, VA
Wills Kenneth, Hoover, AL
Wilmot Leigh, Memphis, TN
Wilson Arlene, Nashville, TN
Wilson Carin, College Grove, TN
Wilson Cheryl, Franklin, TN
Wilson Deron, LaVergne, TN
Wilson Diamondie, Shelbyville, TN
Wilson Douglas, Louisville, TN
Wilson James, Nashville, TN
Wilson Jason, Nashville, TN
Wilson John, Memphis, TN
Wilson John D., Southern Alliance for Clean Energy, Knoxville, TN
Wilson Laura, Nashville, TN
Wilson Le'Dontqe, LaVergne, TN
Wilson Lester, TN
Wilson Martha, Brentwood, TN
Wilson Martin, Armstrong Coal Co., St. Louis, MO
Wilson May, Chattanooga, TN
Wilson Rob, College Grove, TN
Wilson Salah
Winbigler Houston, Memphis, TN
Winder Abby, Saint Joseph, MO
Wine Ronald, TN
Winkowski Robin M., Hermitage, TN
Winslow Kenneth, TN
Winstead Edna, TN
Winstead Ricky, TN
Winston Nat, Hermitage, TN
Winters Tom, Mt. Pleasant, TN
Wiscowski Sharon, Knoxville, TN
Wiser C., College Grove, TN
Witherspoon Mary, Huntsville, AL
Wolf Bradley, Memphis, TN
Wolfe Dany Kermit, TN
Wolfe Laura, Knoxville, TN
Wolfe Stuart, Hendersonville, TN
Wolfenberger Roslyn, TN
Wolff Arthur, Memphis, TN
Wolff Bert A., Memphis, TN
Wolford Estel, TN
Wolski Don, Middleton, DE
Wolski Deb, Middletown, DE
Wong Brian, Nashville, TN
Wong Isabelle, Nashville, TN
Wood Breanna, Nashville, TN
Wood Renee, Portland, TN
Woodard Richard, Maryville, TN
Woodruff Carla, Centerville, TN
Woods Laci, Johnson City, TN
Woods Louise, Nashville, TN
Woodson Mick, Bellbuckle, TN
Wotton Bernard, Collegedale, TN
Wright Author, TN
Wright Lexie, Erwin, TN
Wright Morgan, Butler, TN
Wright Terry, Green Energy Development, Inc., Suwanee, GA
Wright Terry, Johns Creek, GA
Wright Vickie, Collinwood, TN
Wu Jennifer, Livingston, NJ
Wyatt John, Coker Creek, TN
Wyatt Shirley, Dover, TN
Wyatt Steven, Knoxville, TN
Wynn Ralph, Townsend, TN
Xu Cindy, Johnson City, TN
Yambor Marjorie, Bowling Green, KY
Yann Jimmy, Polytech Services, Inc., Alpharetta, GA
Yazbak Katherine, Nashville, TN
Yazu Alicyn, Johnson City, TN
Yokley Marilyn, Nashville, TN
York Ashlyn, Mt. Carmel, TN
Young Cathy, Nashville, TN
Young Jessica, Nashville, TN
Young Kim, Nashville, TN
Young Michael, Cinnaminson, NY
Young Syd, Nashville, TN
Youngblood, Jody, Owens Cross Roads, AL
Yuknavage Ann, Nashville, TN
Yunkun Eric, Collierville, TN
Zacovic Sam, Hendersonville, TN
Zaman Omar, Germantown, TN
Zat Ella, Oakland, TN
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Zi Jinghuan, Brentwood, TN
Zielinski David, Crossville, TN
Zimmerman Alen, Bowling Green, KY
Zimmerman Nancy, Thorn Hill, TN
Zipperer Stephen, Murfreesboro, TN

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