Energy Vision

2020

2

Volume 2, Technical Document

Environmental Consequences

Summary

One of TVA's broad strategic goals is environmental responsibility. Energy Vision 2020 approaches this goal in a way that is fundamentally different than most environmental reviews—environmental concerns have been fully integrated into the planning process.

This document addresses the environmental aspects of the evaluation process and provides additional scientific and analytical, or technical, basis for comparing the impact of alternative energy strategies on the environment. Cumulative potential environmental impacts are addressed. In addition, potential socioeconomic impacts are addressed.

The assessment is made at a macro, or regional, scale rather than at a micro, site-specific scale.

Volume 2, Technical Document 2

Environmental Consequences

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Environmental Consequences

Introduction

Numerous surveys and opinion polls indicate that most Americans hold protection of the environment as very important. TVA Board Chairman Craven Crowell has emphasized that no major business activity will succeed without a high regard for the environment and that TVA must be environmentally responsible.

In keeping with these sentiments, one of TVA's broad strategic goals is environmental responsibility. Energy Vision 2020 approaches this goal in a way that is fundamentally different than most environmental reviews—environmental concerns have been fully integrated into the planning process. This has allowed TVA to reformulate energy resource strategies to mitigate potential environmental impact, lessening the need to trade off environmental protection for economic cost savings.

This document addresses the environmental aspects of the evaluation process and provides additional scientific and analytical, or technical, basis for comparing the impact of alternative energy strategies on the environment. The document also examines and compares both direct and indirect potential environmental impacts associated with each strategy. Cumulative environmental impacts are addressed. In addition, potential socioeconomic impacts are addressed.

ENVIRONMENTAL IMPACT CONTEXT

Integrated resource planning is broad and strategic; therefore, the environmental review has been programmatic rather than site-specific. When energy resource options are implemented, there can be important environmental effects, depending on how options are deployed and where they are located. These potential option and site-specific impacts will be considered in the environmental reviews that tier from the Energy Vision 2020 review. Such reviews will give TVA decision makers and the public an opportunity to consider any potentially significant impacts before decisions are made.

These site-specific reviews can avoid potentially significant impacts to wetlands, sensitive habitats, prime farmland, threatened or endangered species, cultural and historic resources, alteration of sensitive aquatic habitats, aesthetics and noise, and socioeconomic impacts. Proper site selection and detailed modeling can also avoid local air impacts such as plume impact on elevated terrain. Site selection may also influence some indirect impacts such as those from fuel sources and transportation.

Evaluation Method

The analytical approach used for Energy Vision 2020 is the multi-attribute tradeoff method. This approach allows TVA to quantitatively integrate the identified environmental impacts of proposed strategies and formulate alternative strategies to mitigate them while retaining other beneficial characteristics. The approach also allowed the public to help set the values (criteria) by which strategies were judged and to see how those values can result in tradeoffs.

TVA developed 2,000 different strategies for Energy Vision 2020. These strategies consist of different combinations of energy resource options that were first screened for acceptable performance using multiple criteria, including environmental criteria. The strategies themselves were analyzed through the use of computer models to identify those particular combinations of resource options that best meet the criteria and effectively deal with various uncertainties. In this process, the environmental performance of the strategies was fully integrated into the evaluation in the same manner as financial, rate, economics, and other criteria.

The multi-attribute tradeoff method allowed potential environmental impacts of each strategy to be compared to all other evaluation criteria and to all other strategies on an objective basis. This process identified where there were real tradeoffs among criteria. One of the most important tradeoffs occurred between better environmental performance and lower electric rates. Achieving better environmental performance (less impacts) typically produces higher rates or costs. In the past, utilities usually chose between lower costs or better environmental performance.

The integrated, multi-attribute tradeoff method allowed TVA to mitigate potential environmental tradeoffs by reformulating strategies to lessen the degree of tradeoff. Energy resource options that were primarily responsible for producing undesirable results in more favorable strategies were replaced by options that produced more desirable results. These modified strategies were then reintegrated and their performance with respect to

the evaluation criteria and tradeoffs they produce was reexamined. This was done several times until seven modified strategies were created that respond reasonably well to all Energy Vision 2020 criteria, including environmental criteria. Potential tradeoffs were sharply reduced.

As a result of this process, the final strategies have similar, although not identical, energy resource options. This tends to produce similar environmental impacts. With the final seven strategies, it is possible to meet the future needs of TVA's customers with much better environmental performance compared to other unmitigated strategies.

Environmental Protections

As stated, one of TVA's strategic goals is environmental responsibility. This leads TVA toward those energy resource options that are more environmentally friendly. Apart from this goal, environmental regulations reduce the risk of significant environmental impacts from the implementation of energy resource options. The Clean Air Act, the Clean Water Act, the Endangered Species Act, the Surface Mining Reclamation and Control Act, and the Resource Conservation and Recovery Act are just a few of the major laws in this country that are formulated to prevent or lessen various environmental impacts. In addition, as a federal agency, TVA must consider the potential environmental impacts of proposed decisions under the National Environmental Policy Act.

No major energy resource can be constructed without complying with a substantial number of federal, state, and local environmental requirements. These regulatory processes typically provide multiple opportunities for public comment and participation. Most federal environmental laws allow citizens to bring suit to enforce compliance with requirements, and various federal, state, and local environmental regulatory agencies exist to police compliance.

Although these environmental laws and their implementing regulations do not eliminate all risk of environmental impacts, they substantially reduce impacts. Consequently, the risk of significant impacts associated with the implementation of any of the final strategies identified in Energy Vision 2020 is lessened substantially. Moreover, such impacts should be identified in the subsequent environmental reviews that TVA will conduct before it decides to put specific resource options in place.

SECTION 1: DESCRIPTION OF ALTERNATIVE STRATEGIES

Purpose

This section describes TVA's final seven alternative strategies developed through the integration process and the reference, or "No Action," strategy. In addition, the general features of the strategies that distinguish them from one another are described. As a result of the integration process discussed in the preceding section, most of the strategies are very similar and differences in their environmental performance are relatively small.

Note that, for purposes of the National Environmental Policy Act, the terms "strategy", "alternative", and "alternative strategy" should be considered synonymous.

Elements of a Strategy

As described in Volume 1, Chapter 9, Resource Integration/Alternative Strategy Comparisons, each strategy includes some component of each of the elements described below. Understanding these elements will help understanding of why there are environmental differences among the strategies.

SUPPLY PROFILE

The supply profile refers to actions TVA may take to provide for generation of electricity for its customers. These "supply side" options vary by fuel type, technology, and commercial terms. Coal, natural gas, and nuclear have been the dominant fuels for electricity supply for the utility industry historically and are dominant in TVA's final strategies. However, certain renewable resources, such as biomass, wind, and landfill methane, that may either be continuously replenished or are not consumed, are also considered as viable options in the final strategies. (Hydroelectric power is also a renewable resource, but for purposes of this evaluation, is considered separately and not included in the general renewables category.) Different technologies may use the same fuel. Natural gas can be used to generate electricity from simple cycle combustion turbines, combined cycle facilities, fuel cells, etc. Also, TVA may choose to build, own, and operate a new electricity generating facility, purchase the energy from another electric utility, or purchase the energy from a non-utility independent power producer (IPP) or cogenerator.

ENVIRONMENT

While all elements of a strategy affect its environmental performance, certain decisions specifically targeting alternative ways of meeting environmental constraints have been included in this element. These decisions include the approach to complying with Phase II of the 1990 Clean Air Act Amendments and control options associated with carbon dioxide reduction and TVA's commitment to the U.S. Department of Energy's Climate Challenge.

CUSTOMER SERVICE, PRICING/RATES

The options included in this element include activities that directly influence the amount of electrical energy consumed by TVA's customers. Demand side management (DSM) includes both actions that may decrease total consumption (conservation) and those that change the time of day when consumption occurs (load shaping). Off-system sales (sales to other utilities) increase the need for electricity and can be controlled by marketing and pricing activities. Similarly, marketing and pricing programs (electric rate programs) can be put in place to either increase or decrease system consumption. For example, time-of-day pricing may be used to shape or curb consumption, while a "declining block" rate structure that lowers price as consumption increases may be an inducement to increase consumption. Beneficial electrification options (for example, variable speed electric motors, electric arc steel furnaces) are intended to increase the consumption of electricity while reducing the consumption of other primary fuels with a net benefit to the environment.

TRANSMISSION

Options that represent improvements to the TVA electricity transmission system by reducing transmission losses were included. None of the final strategies being evaluated include these transmission improvement options.

Strategy Definition

Figure T2-1 defines the reference strategy, or "No Action" strategy (Strategy D) and the seven alternative strategies evaluated in Energy Vision 2020 in general terms by strategic element.

For purposes of comparison, Strategy D is the reference or "No Action" strategy for Energy Vision 2020. The "No Action" strategy was to identify those resource options which TVA would most likely have employed to meet demand in the absence of the information and analysis produced as a result of the Energy Vision 2020 process. Taking into account the difficulties TVA has encountered in completing the nuclear units that it has had under construction, it was determined that TVA would likely have looked to some mix of combined cycle combustion turbines, new coal-fired units and limited amounts of purchased power. These became the core elements of the

FIGURE T2-1. **Characteristics of Final Energy Vision 2020 Strategies, Resource Options Embedded in Each Strategy**

Strategy	Supply-Side Characteristics	Customer Service Characteristics	Environmental Controls
Strategy D Combined Cycle, Purchased Power, Coal (Reference)	Supply-side options emphasize a blend of TVA-built, Independent Power Producers, and cogenerators to reduce production cost and debt • Combustion turbines • Combined cycle • Independent Power Producers and cogeneration natural gas combined cycle • Independent Power Producer coal • Clean coal [1]	Low-price block of Demand-Side Management (block one) reduces demand with minimum rate increase	Sulfur Dioxide • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing fossil units
Strategy J Bellefonte Coproduct, Renewables, Independent Power Producers	Supply-side expansion features an integrated coal gasification plant that produces a high-value chemical coproduct, projected for siting at Bellefonte Nuclear Plant • Combustion turbines • Bellefonte conversion to integrated gasification combined cycle with chemical coproduct • Independent Power Producer combined cycle • Landfill and coalbed methane • Clean coal • Hydro modernization	Low-price block of Demand-Side Management (block one) reduces demand with minimum rate increase	Sulfur Dioxide • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing units Carbon Dioxide and other fossil emissions • A customer service level of biomass (waste wood) cofiring of 0.3%
Strategy M Combined Demand-Side Management and Off-System Sales	Supply-side options mix emphasizes coal expansion and low-cost renewables for low production cost • Combustion turbines • Pulverized coal at an existing plant • Clean coal • Landfill and coalbed methane • Pulverized coal with scrubbers • Hydro modernization	Low-price and low-cost Demand-Side Management (two blocks) reduces need for generation Off-system sales	Sulfur Dioxide • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing units Carbon Dioxide and other fossil emissions • A customer service level of biomass (waste wood) cofiring of 0.3%

[1] Clean coal technologies include integrated gasification - combined cycle and integrated gasification - cascaded humidified advanced turbine.

FIGURE T2-1. **Characteristics of Final Energy Vision 2020 Strategies, Resource Options Embedded in Each Strategy** *CONTINUED*

Strategy	Supply-Side Characteristics	Customer Service Characteristics	Environmental Controls
Strategy O Bellefonte Coproduct, More Demand-Side Management, More Off-System Sales	Supply-side expansion features an integrated coal gasification plant that produces a high-value chemical coproduct, projected for siting at Bellefonte Nuclear Plant • Combustion turbines • Bellefonte conversion to integrated gasification combined cycle with chemical coproduct • Independent Power Producer combined cycle • Landfill and coalbed methane • Clean coal • Hydro modernization	Low-price and low-cost block of Demand-Side Management (two blocks) reduces need for generation Off-system sales	Sulfur Dioxide • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing units Carbon Dioxide and other fossil emissions • A customer service level of biomass (waste wood) cofiring of 0.3%
Strategy Q Flexible Strategy with External Options	Supply-side expansion features purchase options with rights, but not obligations, to purchase power • Combustion turbines • Bellefonte conversion to integrated gasification combined cycle with chemical coproduct • Independent Power Producers combined cycle • Purchase of peaking capacity • Flexible base capacity purchase • Flexible peaking capacity purchase • Landfill and coalbed methane • Clean coal • Hydro modernization	Low-price block of Demand-Side Management (block one) reduces demand with minimum rate increase Low-level beneficial electrification provides improved rate impact Off-system sales	Sulfur Dioxide • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing units Carbon Dioxide and other fossil emissions • A customer service level of biomass (waste wood) cofiring of 0.3%
Strategy R Flexible Strategy with Internal Options	Supply-side expansion features preplanning, design, and siting work to support flexible start dates of TVA-built options • Combustion turbines • Bellefonte conversion to integrated gasification combined cycle with chemical coproduct • Independent Power Producer combined cycle • Combined cycle • Purchase of peaking capacity • Flexible base capacity purchase • Landfill and coalbed methane • Clean coal • Hydro modernization	Low-price block of Demand-Side Management (block one) reduces demand with minimum rate increase Low-level beneficial electrification provides improved rate impact Off-system sales	Sulfur Dioxide • Scrubbers are added at several existing fossil units • Switching to lower sulfur coals at several existing units Carbon Dioxide and other fossil emissions • A customer service level of biomass (waste wood) cofiring of 0.3%

FIGURE T2-1. **Characteristics of Final Energy Vision 2020 Strategies, Resource Options Embedded in Each Strategy** *CONTINUED*

Strategy	Supply-Side Characteristics	Customer Service Characteristics	Environmental Controls
Strategy S Low Cost, Low Rates, Improved Environment	Supply-side expansion features an integrated coal gasification plant that produces a high-value chemical coproduct, projected for siting at Bellefonte Nuclear Plant • Combustion turbines • Bellefonte conversion to integrated gasification combined cycle with chemical coproduct • Independent Power Producers combined cycle • Landfill and coalbed methane • Clean coal • Hydro modernization	Low-price block of Demand-Side Management (block one) reduces demand with minimum rate increase Low-level beneficial electrification provides improved rate impact Off-system sales spread fixed cost over more sales	Sulfur Dioxide • Scrubbers are added at several existing units • Switching to lower sulfur coals at several existing units Carbon Dioxide and other fossil emissions • A customer service level of biomass (waste wood) cofiring of 0.3%
Strategy T Low-Cost Renewables, Low-Price Demand-Side Management, Repowering, Bellefonte Coproduct Partnership	Supply-side expansion relies on low emission options, renewables, and an integrated coal gasification plant that produces a high-value chemical coproduct, projected for siting at Bellefonte Nuclear Plant • Natural gas combined cycle repowering of several existing coal units • Bellefonte conversion to integrated gasification combined cycle with chemical coproduct • Combustion turbines • Independent Power Producers combined cycle • Clean coal • Compressed air energy storage • Landfill and coalbed methane • Wind • Pulverized coal • Hydro modernization	Low-price block of Demand-Side Management (block one) reduces demand with minimum rate increase	Sulfur Dioxide • Gas repowering of some existing units • Switching to lower sulfur coals at several existing units Carbon Dioxide and other fossil emissions • Carbon dioxide penalty added to assumed cost of generation options to shift generation to lower emission sources • A customer service level of biomass (waste wood) cofiring of 0.3%

Energy Vision 2020 "No Action" strategy and formed the reference strategy for purposes of analysis and benchmarking integration results across alternative strategies.

TVA considered but rejected a second approach to defining the "No Action" strategy. This approach was to cease acquiring new resources to meet future demand for electricity from the TVA system. Except for additional demand that could be met through more efficient use of the energy generated by TVA's existing resources, future demand (new loads) would not be met. This is the approach used to define a "No Action" alternative by the Bonneville Power Administration in its February 1993 resource plan environmental impact statement. Because of TVA's statutory responsibilities and duty to serve demand in its region as a public utility, such a "no-serve" approach was considered fictitious and rejected in favor of the first approach.

Figure T2-2 provides an example of how each strategy might be implemented, based on the results of the computer modeling evaluations described in Volume 1, Chapter 9, Resource Integration/Alternative Strategy Comparisons and Volume 2, Technical Document 8, Resource Integration. While it is highly unlikely that the actual implementation of the strategies would follow the exact sequence given in this figure, these implementation strategies represent credible sequences for resource selection and form the basis for the analysis and comparisons that follow.

FIGURE T2-2. **Implementation of Final Energy Vision 2020 Strategies, Cumulative Capacity Additions (Megawatts)**

		YEAR				
Strategy	**Resource Option**	**2000**	**2005**	**2010**	**2015**	**2020**
D-Reference	Combustion Turbines	1,050	2,550	3,750	4,800	5,700
	Combined Cycle—Independent Power Producer	0	450	750	750	750
	Integrated Gasification—Combined Cycle	0	0	735	2,205	3,675
	Combined Cycle	470	1,880	2,820	2,820	2,820
	Integrated Gasification—Cascaded Humidified Advanced Turbine	0	0	420	1,260	2,100
	Combined Cycle—Cogeneration	0	175	175	175	175
	Coal-Independent Power Producer	0	300	300	300	300
	Total Capacity	**1,520**	**5,355**	**8,950**	**12,310**	**15,520**
J	Bellefonte IGCC Conversion with Coproduct	0	484	484	484	484
	Coalbed Methane Recovery	0	250	1,000	1,000	1,000
	Combustion Turbines	1,500	2,550	3,900	4,950	5,850
	Hydroelectric Improvements	0	0	162	162	162
	Integrated Gasification—Combined Cycle	0	0	735	2,940	4,410
	Integrated Gasification—Cascaded Humidified Advanced Turbine	0	0	420	1,260	2,100
	Independent Power Producer	150	1,650	1,950	1,950	1,950
	Landfill Methane Recovery	0	500	500	500	500
	Total Capacity	**1,650**	**5,434**	**9,151**	**13,246**	**16,456**
M	Coal	0	1,610	1,610	1,610	1,610
	Coalbed Methane Recovery	0	0	250	1,000	1,000
	Combustion Turbines	1,050	2,400	3,600	4,800	5,550
	Hydroelectric Improvements	0	0	162	162	162
	Integrated Gasification—Combined Cycle	0	0	735	2,205	3,675
	Integrated Gasification—Cascaded Humidified Advanced Turbine	0	0	420	1,260	2,100
	Landfill Methane Recovery	0	0	500	500	500
	Shawnee Fossil Plant Unit 11	0	168	168	168	168
	Total Capacity	**1,050**	**4,178**	**7,445**	**11,705**	**14,765**
O	Bellefonte IGCC Conversion with Coproduct	0	484	484	484	484
	Coalbed Methane Recovery	0	0	750	1,000	1,000
	Combustion Turbines	1,050	2,550	3,750	4,950	5,700
	Hydroelectric Improvements	0	0	162	162	162
	Integrated Gasification—Combined Cycle	0	0	735	2,940	4,410
	Integrated Gasification—Cascaded Humidified Advanced Turbine	0	0	420	1,260	2,100
	Independent Power Producer	0	900	1,050	1,050	1,050
	Landfill Methane Recovery	0	500	500	500	500
	Total Capacity	**1,050**	**4,434**	**7,851**	**12,346**	**15,406**

Combustion Fuel Use

A comparison of the combustion fuel used in implementing each strategy provides useful information that directly relates to the comparison of environmental consequences. *Figure T2-3* identifies the capacity and electricity generation by fuel for each strategy in the years 2005 and 2020. Note that every energy strategy uses coal and natural gas. Also, most strategies employ renewable fuels (co-fired wood used along with fossil fuel in a boiler, landfill methane recovery and coal seam methane recovery) in differing amounts. The table in *Figure T2-4* gives the coal and co-fired biomass average annual tonnage and gas volume for each strategy. Biomass refers to wood and perennial grasses used for fuel. Coal use increases from the current level of 35 to 40 million tons annually to 46 to 52 million tons for all strategies including the reference, or "No Action," strategy. Strategy T uses the

FIGURE T2-2. **Implementation of Final Energy Vision 2020 Strategies, Cumulative Capacity Additions (Megawatts)** *CONTINUED*

		YEAR				
Strategy	**Resource Option**	**2000**	**2005**	**2010**	**2015**	**2020**
Q	Bellefonte IGCC Conversion with Coproduct	0	484	484	484	484
	Coalbed Methane Recovery	0	500	1,000	1,000	1,000
	Combustion Turbines	0	900	3,000	4,050	4,800
	Flexible Baseload	0	1,189	289	289	289
	Flexible Peakload	900	900	0	0	0
	Hydroelectric Improvements	0	0	162	162	162
	Integrated Gasification—Combined Cycle	0	0	2,205	3,675	5,145
	Integrated Gasification—Cascaded Humidified Advanced Turbine	0	0	840	1,680	2,520
	Independent Power Producer	300	300	300	300	300
	Landfill Methane Recovery	0	500	500	500	500
	Peak Power Purchases	300	900	900	900	900
	Total Capacity	**1,500**	**5,673**	**9,680**	**13,040**	**16,100**
R	Bellefonte IGCC Conversion with Coproduct	0	484	484	484	484
	Combined Cycle	0	470	470	470	470
	Coalbed Methane Recovery	0	500	1,000	1,000	1,000
	Combustion Turbines	750	2,100	3,150	4,200	4,950
	Flexible Baseload	0	289	289	289	289
	Hydroelectric Improvements	0	0	162	162	162
	Integrated Gasification—Combined Cycle	0	0	1,470	3,675	5,145
	Integrated Gasification—Cascaded Humidified Advanced Turbine	0	0	840	1,680	2,520
	Independent Power Producer	150	300	300	300	300
	Landfill Methane Recovery	0	500	500	500	500
	Peak Power Purchases	900	900	900	900	900
	Total Capacity	**1,800**	**5,543**	**9,565**	**13,660**	**16,720**
S	Bellefonte IGCC Conversion with Coproduct	0	484	484	484	484
	Coalbed Methane Recovery	0	750	1,000	1,000	1,000
	Combustion Turbines	1,500	2,850	4,050	4,950	5,850
	Hydroelectric Improvements	0	0	162	162	162
	Integrated Gasification-Combined Cycle	0	0	1,470	3,675	4,410
	Integrated Gasification- Cascaded Humidified Advanced Turbine	0	0	840	1,680	2,520
	Independent Power Producer	300	1,050	1,050	1,050	1,050
	Landfill Methane Recovery	0	500	500	500	500
	Total Capacity	**1,800**	**5,634**	**9,556**	**13,501**	**15,976**
T	Bellefonte IGCC Conversion with Coproduct	0	484	484	484	484
	Compressed Air Energy Storage	0	0	1,011	1,011	1,011
	Coal	0	0	0	710	710
	Coalbed Methane Recovery	0	0	0	500	1,000
	Combustion Turbines	1,050	2,550	3,750	3,900	4,800
	Hydroelectric Improvements	0	0	162	162	162
	Integrated Gasification—Cascaded Humidified Advanced Turbine	0	0	0	420	1,260
	Independent Power Producer	0	450	450	450	450
	Landfill Methane Recovery	0	0	500	500	500
	Repowering Existing Coal-Fired Plants	1,410	3,045	3,045	4,320	5,170
	Shawnee Fossil Plant Unit 11	0	0	0	168	168
	Wind Turbines	0	800	2,000	2,000	2,000
	Total Capacity	**2,460**	**7,329**	**11,402**	**14,625**	**17,715**

FIGURE T2-3. **Strategy Matrix – Capacity and Energy by Fuel Type**

Strategy	Year	Nuclear (MW)	Nuclear (GWH)	Coal (MW)	Coal (GWH)	Natural Gas (MW)	Natural Gas (GWH)	Hydro and Storage (MW)	Hydro and Storage (GWH)	Renewables (MW)	Renewables (GWH)	Purchases (MW)	Purchases (GWH)	Demand-Side Management (MW)	Demand-Side Management (GWH)
Existing System	2005	5,577	30,171	14,968	96,212	2,292	1,009	5,498	19,268	0	0	1,800			
Existing System	2020	5,577	32,414	14,968	100,654	2,292	1,403	5,498	20,780	740	5,898.5	1,000			
D-Reference	2005	5,577	32,778.4	14,968	108,471.8	6,722	7,652.3	5,498	20,426.8	0	0.0	2,725	6,163.5	-997	2,934.6
	2020	5,577	32,778.4	20,743	149,405.5	10,812	10,549.1	5,498	20,854.4	0	0.0	2,225	6,845.9	-517	1,481
J	2005	5,577	32,778.4	15,452	109,999.5	4,842	2,502.5	5,498	20,426.8	750	6,180.7	3,450	5,258.6	-998	2,934.6
	2020	5,577	32,778.4	21,962	151,251.9	8,142	3,780.2	5,660	20,857.9	1,500	12,361.4	2,950	3,979.7	-517	1,481
M	2005	5,577	32,778.4	16,746	116,322.6	4,692	2,885.5	5,498	20,426.8	0	0.0	1,800	725.3	-2,047	8,194.8
	2020	5,577	32,778.4	22,521	150,338.7	7,842	4,602.6	5,660	20,857.9	1,500	12,361.4	1,000	78.8	-957	1,481
O	2005	5,577	32,778.4	15,452	109,112.1	4,842	2,884.3	5,498	20,426.8	500	4,120.5	2,700	3,169.4	-2,049	8,194.8
	2020	5,577	32,778.4	21,962	150,196.2	7,992	4,572.4	5,660	20,857.9	1,500	12,361.4	2,050	2,279.9	-958	1,481
Q	2005	5,577	32,778.4	15,452	110,182.6	3,192	1,454.0	5,498	20,426.8	1,000	9,240.9	5,089	7,444.8	-999	1,404.9
	2020	5,577	32,778.4	23,117	154,951.1	7,092	4,169.2	5,660	20,857.9	1,500	12,361.4	2,489	1,519.4	-517	1,481
R	2005	5,577	32,778.4	15,452	110,364.9	4,862	3,466.7	5,498	20,426.8	1,000	8,240.9	3,289	4,984.4	-999	1,404.9
	2020	5,577	32,778.4	23,117	155,148.6	7,712	4,339.7	5,660	20,857.9	1,500	12,361.4	2,489	1,988.0	-517	1,481
S	2005	5,577	32,778.4	15,452	109,099.8	5,142	3,011.9	5,498	20,426.8	1,250	10,304.0	2,850	3,819.8	-999	1,404.9
	2020	5,577	32,778.4	22,382	151,793.4	8,142	4,778.0	5,660	20,857.9	1,500	12,361.4	2,050	2,334.5	-517	1,481
T	2005	5,577	32,778.4	13,521	100,215.7	8,517	18,585.2	5,498	20,426.8	0	0.0	2,250	3,882.9	-998	2,934.6
	2020	5,577	32,778.4	15,659	116,157.0	13,042	29,929.6	6,672	25,307.4	2,500	15,111.0	1,450	3,366.0	-517	1,481

MW= Megawatts
GWH= Thousands of Megawatt-Hours

least amount of coal and the largest amount of natural gas. All remaining strategies use 51.7 to 52.2 million tons of coal annually.

Strategy T uses 162 billion standard cubic feet of natural gas annually (one standard cubic foot of natural gas contains approximately 1,000 Btu). The range of natural gas use of other strategies extends to a minimum of 41 billion standard cubic feet, which is 75 percent less than Strategy T. Landfill methane recovery and coalbed methane recovery use vary from a low of 23.4 to a high of 48.9 billion standard cubic feet. Methane recovery varies from 15 to 80 percent of the natural gas used for the same strategy.

FIGURE T2-4. **Combustion Fuel Required for Each Strategy (Annual Average Mass or Volume)**

Strategy	Coal (Millions of Tons)	Biomass Cofiring (Tons)	Landfill/ Coalbed Methane (Billions of Standard Cubic Feet)	Natural Gas (Billions of Standard Cubic Feet)
D-Reference	52.1	0	0	93.5
J	51.3	184,643	45.8	64.9
M	52.2	187,909	34.8	41.0
O	51.2	184,493	44.2	53.9
Q	51.7	186,227	48.9	68.4
R	51.9	186,956	48.9	63.4
S	51.8	186,903	49.4	59.2
T	45.9	186,903	23.4	162.0

No generating facilities specifically designed for short rotation woody crops or refuse-derived fuels are found in the seven strategies. However, significant co-firing of wood with coal in existing boilers is used in all strategies.

Both wood and landfill methane are renewable energy sources. Additionally, the use of coalbed methane recovery, landfill methane recovery, and wood waste fuel reduces the greenhouse warming potential of these emissions. This is a result of using captured or recovered methane as a fuel source. When methane, with a radiative forcing function of 21, is combusted, the resultant emissions are carbon dioxide with a radiative forcing function of one. The radiative forcing potential for any greenhouse gas is an indication of the relative effect of the gas on potential global warming compared to carbon dioxide, which has a radiative forcing potential of one. For example, methane

has a radiate forcing potential of 21, which means its effect on potential global warming is 21 times greater than that of an equivalent weight of carbon dioxide. Similarly, wood waste left to decay converts about 25 percent of the carbon mass to methane; thus, when burned, a methane release is avoided. The table in *Figure T2-5* presents the fuels on an energy content basis. The chart in *Figure T2-6* shows how the annual average combustion fuel energy use varies with each strategy for the entire period of the study.

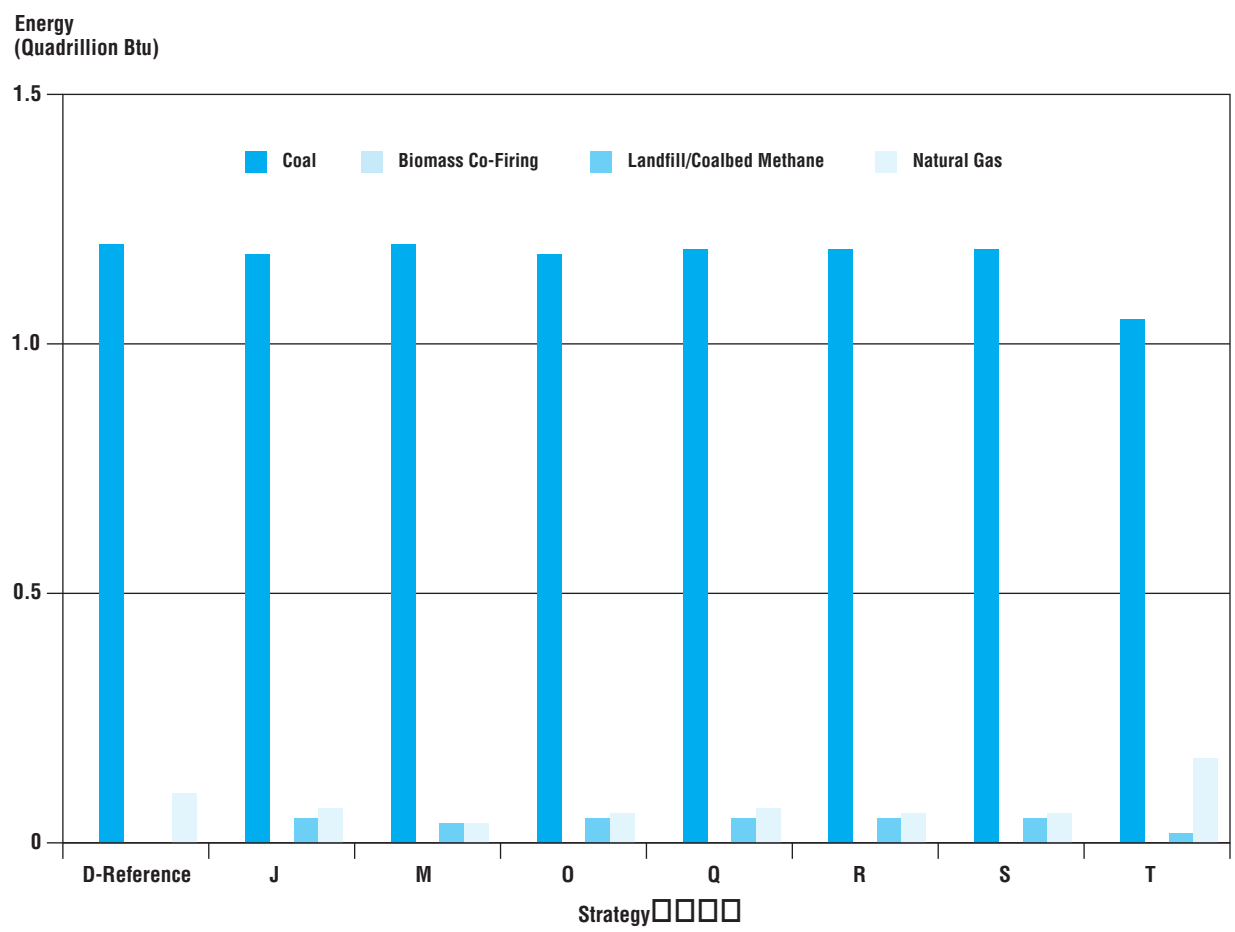
On an energy basis, 1.05 to 1.2 quadrillion Btu's of fuel energy is supplied by coal in each strategy. The energy content of the other combustion fuels combined is 0.1 to 0.2 quadrillion Btu's per strategy. Total combustion fuel energy use is between 1.25 and 1.31 quadrillion Btu's.

All strategies expand TVA's use of combustion fuels over present levels, while diversifying the types or sources of these fuels.

FIGURE T2-5. **Combustion Fuel Energy Use for Each Strategy (Annual Average)**

Strategy	Coal (Quadrillion Btu)	Biomass Cofiring (Quadrillion Btu)	Landfill/ Coalbed Methane (Quadrillion Btu)	Natural Gas (Quadrillion Btu)
D-Reference	1.20	0.00000	0.0000	0.0955
J	1.18	0.00166	0.0468	0.0664
M	1.20	0.00169	0.0356	0.0419
O	1.18	0.00166	0.0452	0.0551
Q	1.19	0.00168	0.0500	0.0699
R	1.19	0.00168	0.0500	0.0648
S	1.19	0.00168	0.0505	0.0605
T	1.05	0.00168	0.0239	0.1660

FIGURE T2-6. **Combustion Fuel Energy Use for Each Strategy (Annual Average)**



Sources of Energy Supply by Strategy

Every energy strategy includes TVA's existing resources plus proposed new resources. Each strategy depends on coal-fired, natural gas-fired, nuclear, and hydroelectric, including pumped storage, energy supply options. Certain strategies depend to differing degrees on landfill methane and coalbed methane combustion, wood waste co-firing, wind turbine operation, and demand-side management programs.

The table in *Figure T2-7* quantifies the different types of energy sources included in the strategies to meet the need for power in 2020. There are six groupings: coal, nuclear, natural gas, hydroelectric (including pumped storage), renewables, and demand-side management. The chart in *Figure T2-8* shows how the use of each energy supply group varies for the strategies. Coal-fired generation is the dominant supply source, varying from 55 percent for Strategy T to 64 percent of all energy supplied for the

FIGURE T2-7. **Energy Sources Used to Meet the Need for Power in 2020 (Megawatt-Hours)**

Strategy	Coal	Nuclear	Natural Gas	Hydroelectric/ Storage	Renewables	Demand-Side Management	Total
D-Reference	120,139	32,557	11,743	20,406	0	2,387	187,232
J	119,545	32,557	7,273	20,406	7,252	2,387	189,420
M	121,382	32,557	3,817	20,406	5,521	6,318	190,002
O	119,607	32,557	5,614	20,406	7,005	6,318	191,507
Q	122,142	32,557	6,450	20,406	7,746	1,346	190,647
R	122,080	32,557	6,549	20,406	7,746	1,346	190,685
S	121,924	32,557	6,248	20,406	7,829	1,346	190,310
T	104,677	32,557	20,518	22,338	6,961	2,387	189,439

FIGURE T2-8. **Energy Sources to Meet the Need for Power in 2020**

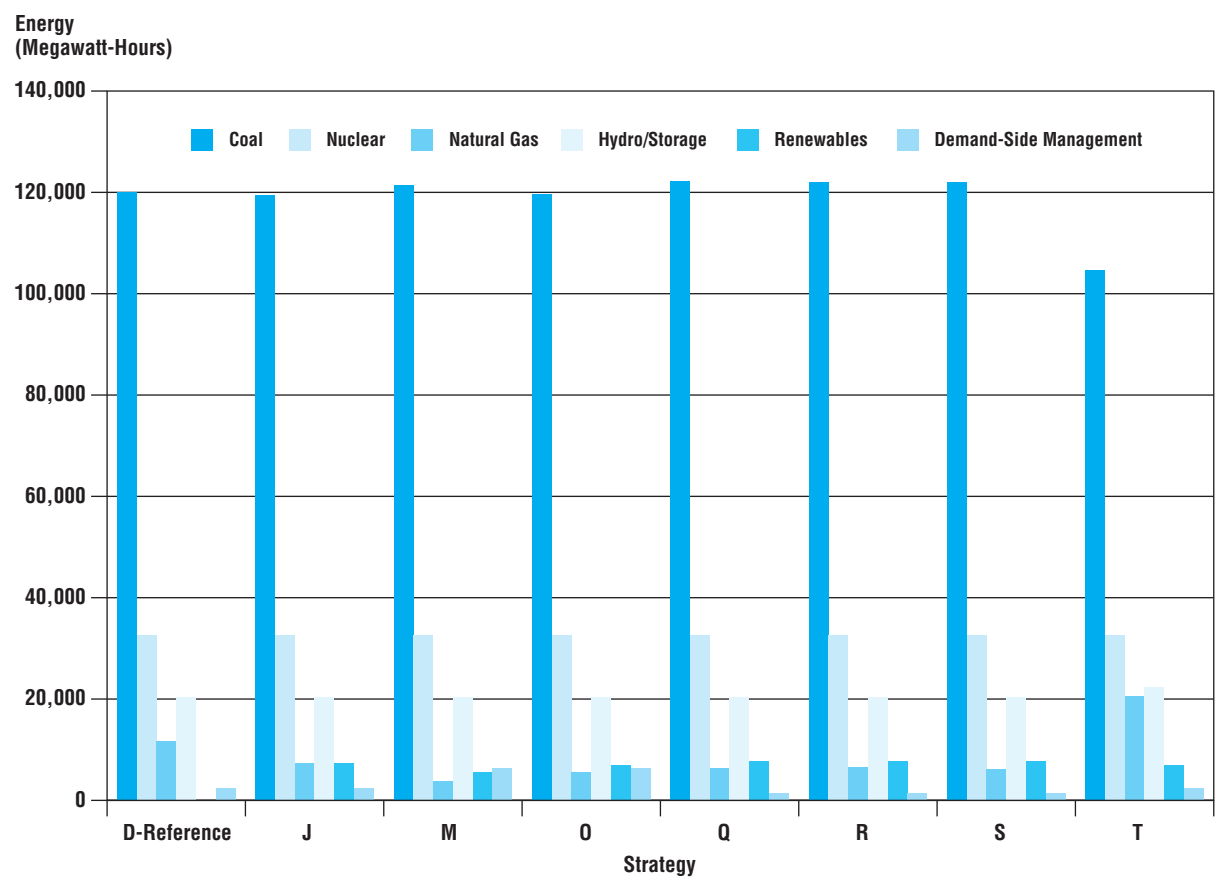


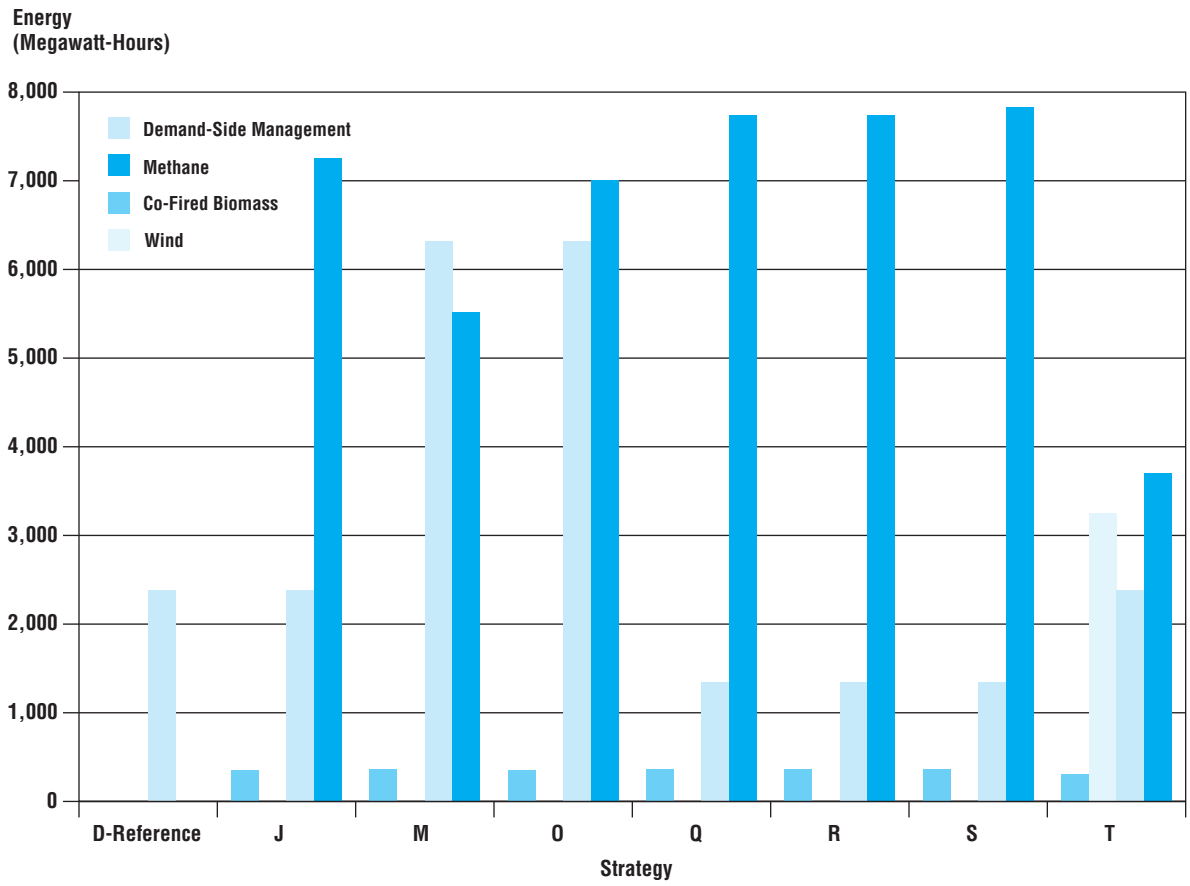
FIGURE T2-9. **Energy Supplied in 2020 by Renewable and Demand-Side Management Options (Megawatt-Hours)**

Strategy	Wind	Methane	Demand-Side Management	Total
D-Reference	0	0	2,387	2,387
J	0	7,252	2,387	9,639
M	0	5,521	6,318	11,839
O	0	7,005	6,318	13,323
Q	0	7,746	1,346	9,092
R	0	7,746	1,346	9,092
S	0	7,829	1,346	9,175
T	3,252	3,708	2,387	9,347

reference, or "No Action," strategy. Nuclear is about 17 to 19 percent of energy supplied, followed by hydroelectric, and pumped storage, with 11 percent. Natural gas-fired generation varies from 2 percent for Strategy M to 11 percent for Strategy T. Renewables are 3 to 4 percent of energy supplied. Demand-side management provides 0.7 to 3.3 percent of energy supplied.

The table in *Figure T2-9* gives the breakout of the energy supplied by demand-side management and various renewable energy options that vary with each strategy. The chart in *Figure T2-10* graphically illustrates the variation of different types of renewables and demand-side management across strategies.

FIGURE T2-10. **Energy Supplied in 2020 by Renewable and Demand-Side Management Sources**



Energy Savings by Strategy

The amount of energy saved in the various strategies is due to improved power system efficiency, as well as demand-side management programs. The reference strategy uses 1.29 quadrillion Btu's of non-renewable combustion fuels and Strategy T uses 1.22 quadrillion. Compared to the reference strategy, Strategy T represents an annual savings of 0.07 quadrillion Btu's, which is the maximum savings for any strategy. The fuel energy savings for each strategy is given in *Figure T2-11*. The electric energy reductions of demand-side management vary from 1,346 to 6,318 thousand kilowatt-hours as given in *Figure T2-9*.

FIGURE T2-11. **Energy Savings of Non-Renewable Combustion Fuel**

Strategy	Coal and Natural Gas Fuel Energy Used (Quadrillion Btu)	Energy Reduction From the Reference Strategy (Quadrillion Btu)
D-Reference	1.29	0.00
J	1.25	0.05
M	1.24	0.05
O	1.23	0.06
Q	1.26	0.03
R	1.26	0.04
S	1.25	0.04
T	1.22	0.07

SECTION 2: SOCIOECONOMIC IMPACTS OF ALTERNATIVE STRATEGIES

Economic Development

Energy Vision 2020 defines economic development as growth in regional economic activity. Measurement criteria include total personal income in "constant" 1994 dollars (i.e., with inflation accounted for) and total non-farm employment. These provide measures for the effects of various Energy Vision 2020 strategies on the overall, long-term health or welfare of the economy for the next 25 years. This analysis concentrates on changes to the welfare of the overall economy due to Energy Vision 2020 strategies. It does not address changes to the distribution of income or employment.

Three types of factors associated with Energy Vision 2020 options affect regional economic development:

- Direct expenditures for labor and materials incurred in the Tennessee Valley during the construction and operation phases of an energy resource option
- Changes to TVA electric rates resulting from implementation of a particular option
- Changes to customers' disposable income as a result of increased or decreased costs from the implementation of a particular option in a distinct Energy Vision 2020 strategy (changes could be caused either by customer expenditures or electric bills)

In general, the greater the direct regional expenditures associated with a particular option, the more positive are the effects on regional economic development. This can be offset, however, by the fact that higher rates caused by higher costs have a negative effect on regional economic development. Thus, an option that has high expenditures in the Tennessee Valley compared to other options may also have high costs and high rates. The overall effect on economic development of a particular option may be positive or negative compared to other options, depending on the net sum of the expenditure effects and the rate and cost effects.

This section describes the methodology used to calculate how alternative strategies affect economic development. The final strategies analyzed in Energy Vision 2020 are described in *Figures T2-1* through *T2-3*. The tables in *Figures T2-12* and *T2-13* present the results of analysis for each Energy Vision 2020 strategy in terms of changes in income and employment compared with a base case reference, or "No Action," strategy (Strategy D).

FIGURE T2-12. **Economic Development Impacts (Annual Average, 1996-2020), IRP Strategies Relative to Strategy D - Reference or "No Action" Case**

			TOTAL IMPACT		IMPACTS DUE TO OPTION EXPENDITURES (DIRECT AND INDIRECT)		IMPACTS DUE TO RATES		IMPACTS DUE TO TOTAL RESOURCE COSTS	
Strategy	Category/Rank [2]		Employment	Income [1]	Employment	Income [1]	Employment	Income	Employment	Income
D- Reference	poor	14	0	0	0	0	0	0	0	0
J	good	5	16,569	739,482	4,176	184,171	9,787	420,773	2,606	134,537
M	moderate	8	11,884	529,624	6,232	273,954	4,146	176,989	1,506	78,681
O	good	4	19,976	893,436	5,484	240,868	11,256	482,723	3,236	169,844
Q	good	2	23,970	1,046,616	6,806	297,746	15,104	641,810	2,060	107,060
R	good	1	24,240	1,060,647	6,934	302,862	15,187	647,444	2,119	110,341
S	good	3	21,288	927,450	6,222	269,018	13,383	570,775	1,683	87,657
T	good	6	15,743	692,771	2,509	105,974	11,090	476,690	2,144	110,107

[1] Income in thousands of 1994 $

[2] Out of 21 strategies

METHODOLOGY

The indirect effects of direct expenditures and rate and total resource cost changes were calculated using TVA's Regional Economic Simulation Model. This model maps the Valley's economic structure, its inter-industry linkages, and responses to TVA rate and cost changes In addition to being used for Energy Vision 2020, the model is also used to provide the economic outlook for TVA's load forecasting. Volume 2, Technical Document 5, Load Forecast, contains more information about this model. The analysis includes data on direct expenditures in terms of applicable payrolls, material and supply purchases, and fuel costs for all energy resource options which comprise a particular strategy. It also includes data on TVA rates and total resource cost resulting from each strategy. A three-step process calculated the total economic development effects for each strategy:

- Direct expenditures for options were evaluated for both the construction and operation periods, and combined into the overall strategies.
- The economic model was used to calculate the indirect effects associated with the direct expenditures resulting from each strategy.
- The results of these analyses were combined with the projections from the model of direct economic development effects due to rates and costs for each strategy.

CONSTRUCTION PERIOD EVALUATION

Only supply-side options, including independent power producers, had project construction associated with them. Data on payroll income for the construction period associated with each option was used as the input into the economic model for the construction phase analysis. The model measures two types of indirect effects:

- The increase in goods manufactured in the Valley as a result of the material and supply purchases in the region associated with a project
- The additional income generated in the regional economy resulting from spending by workers hired as a result of the construction activity

Model results were evaluated in terms of changes in the Valley's income and employment between strategies involving construction compared to a strategy that had no construction activity, the "No Action" strategy.

TVA verified model projections by comparing them with available figures regarding material and supply purchases. It was estimated that 20 to 40 percent of purchases could be regional. The economic model captured regional increases due to purchases relative to payrolls for an average construction project. If a project had a ratio of purchases to payrolls significantly different than the average, the model results would not produce a correct accounting of the regional purchase effect without being adjusted. The increase in regional manufacturing evidenced in model results for the options was not significantly different than the average. Thus, the model results did not have to be adjusted for the analysis.

OPERATIONS PERIOD EVALUATION

Both supply-side and demand-side options had operational activities associated with them. The analysis of operations was similar to that for construction. Data on payrolls for the option was

FIGURE T2-13. **Direct and Indirect Economic Development Impacts Due to Option Expenditures (Annual Average, 1996-2020), IRP Strategies Relative to Strategy D - Reference or "No Action" Case**

	IMPACTS DUE TO OPTION EXPENDITURES (DIRECT AND INDIRECT)		DIRECT IMPACTS DUE TO OPTION EXPENDITURES		INDIRECT IMPACTS DUE TO OPTION EXPENDITURES	
Strategy	Employment	Income [1]	Employment	Income	Employment	Income
D- Reference	0	0	0	0	0	0
J	4,176	184,171	675	29,553	3,501	154,618
M	6,232	273,954	1,469	62,242	4,762	211,711
O	5,484	240,868	1,082	45,831	4,402	195,037
Q	6,806	297,746	1,314	56,189	5,492	241,557
R	6,934	302,862	1,340	56,936	5,593	245,926
S	6,222	269,018	1,189	50,663	5,033	218,355
T	2,509	105,974	-43	-1,981	2,552	107,955

[1] Income in thousands of 1994 dollars

entered into the economic model, and changes in income and employment between strategies including the project and those without the project were calculated. Estimates provided for material and supply purchases in the region served as a check against model results. In this case, several options had purchase estimates that were higher than those calculated by the model. To compensate, supplemental regional expenditures were added to the model results for these options.

Since fuel adds another cost factor to operations, TVA also analyzed fuel purchase patterns to determine what purchases would occur within the region. Natural gas comes from outside the region, and coal purchases generally come from the part of Kentucky outside the region. Of the final strategies, only the reference strategy had regional fuel effects which were generated by lignite assumed to be purchased within the region. For the reference strategy, the fuel purchases were entered into the economic model as part of operations to calculate the overall economic development effects.

TOTAL ECONOMIC DEVELOPMENT EFFECTS FOR ENERGY VISION 2020 STRATEGIES DUE TO OPTION EXPENDITURES

Once each option had been evaluated over both the construction and operation period, the direct payroll effects for each option were compiled by strategy and year. This data was input into the economic model and included any necessary accounting for above average purchases and regional fuel purchases during operations. The model was then run for each strategy in order to measure the overall economic development effects for each strategy, including indirect effects. Model results were evaluated in terms of changes in the Valley's income and employment for each strategy compared with the reference, or "No Action," strategy.

TOTAL ECONOMIC DEVELOPMENT EFFECTS FOR ENERGY VISION 2020 STRATEGIES DUE TO RATES AND COSTS

Effects upon economic development due to differences in rates among strategies were evaluated by entering data on rates by year for each strategy before running the model. The economic model captures the effects on the economy due to TVA rate changes to manufacturing customers and the impact of these changes upon the overall economy.

The analysis also estimated the effects of total resource cost differences among strategies. Differences in electric bills and other costs, such as participant costs of demand-side management programs, affect the amount of available disposable income. Net cost changes add to or subtract from the spending capacity of customers and thus affect the amount of disposable income available for spending. This is known as the "re-spending effect," since disposable income when returned to the economy generates additional economic growth.

Estimates of annual total resource costs for each strategy were used to estimate net cost differences among strategies. These were used with the TVA regional economic simulation model to compute the re-spending effects of each strategy.

TOTAL ECONOMIC DEVELOPMENT EFFECTS FOR ENERGY VISION 2020 STRATEGIES

Total economic development effects were calculated by adding the income and employment effects due to direct expenditures, rates, and total resource costs for each strategy by year and then calculating annual averages. Overall economic development effects were rated relative to the reference, or "No Action," strategy. Three possible rankings estimated the degree of economic development impact of each strategy (good, moderate, and poor). *Figure T2-12* shows the total economic development effects for each strategy. *Figure T2-13* shows the effects due to expenditures broken out with direct and indirect effects.

Environmental Justice

Executive Order No. 12898 directs certain federal agencies to consider environmental justice in the environmental reviews of their programs and activities. Although TVA is not one of the agencies designated in the executive order, it has considered the issue of environmental justice in the context of Energy Vision 2020.

Environmental justice refers primarily to ensuring that no segment of the population bears a disproportionate burden of health and environmental impacts of society's activities. Some studies suggest that poor, predominantly minority populations are exposed disproportionately to adverse health and environmental impacts because hazardous waste management facilities and other industrial facilities with potentially impactive air and water releases are sited in their communities. Other studies dispute these findings.

In the context of the generation and transmission of electric energy, various populations can be affected in a number of ways. The environmental analysis done for Energy Vision 2020 indicate that air pollution from the combustion of coal probably poses the greatest risk of adverse health and environmental impacts. Many air pollutant impacts, however, occur on a regional scale and do not affect any population segment disproportionately. Depending upon the situation, however, measurements have revealed that there can be more localized effects associated with short-term exposures to higher pollutant concentrations due to plume downwash. TVA's coal-fired plants

are located in largely rural settings, and except for TVA's Allen Fossil Plant, the surrounding populations are largely white. Incomes in rural areas, however, tend to be at the low-median level for the region. Allen Fossil Plant is located in Memphis, Tennessee, one of the areas in the TVA region that has a higher non-white population.

The siting of industrial facilities has raised the most concern with respect to environmental justice. Because Energy Vision 2020 is a programmatic-level review, the siting of energy resource options is not addressed in detail. When putting discrete options in place is proposed in the future, additional environmental reviews will be conducted and environmental justice concerns and effects will be addressed in those reviews as appropriate. Depending on the nature of the particular resource option and the kinds of impacts it may have, TVA will make a special effort to involve potentially affected low-income and minority populations in the review of options.

Concerns have been expressed nationally about rate impacts due to the implementation of some demand-side management programs. Depending on how demand-side management programs are structured, nonparticipants could subsidize the costs of programs delivered to participants who enjoy the benefits of such programs. Low-income electricity users can be affected in this way. However, measures can be taken to lessen the risk of this happening. TVA has designed a number of its demand-side management programs to avoid this, as explained in Volume 1, Chapter 8, Customer Service Options.

SECTION 3: AIR QUALITY IMPACTS OF ALTERNATIVE STRATEGIES

Understanding Air Quality Impacts

This section discusses the differences among TVA's final energy strategies with respect to potential impacts on air resources.A description of these strategies can be found in *Figures T2-1* through *T2-3*.

Air impacts to be considered in the evaluation of TVA's future energy alternatives are (1) human health, (2) visibility, (3) crop and forest productivity, (4) materials damage, and (5) greenhouse gases. Volume 2, Technical Document 1, Comprehensive Affected Environment provides an overview of air quality issues, emissions contributions, air pollution trends, and current impacts. The term "ambient air" is used to describe the surrounding air. These analyses conclude that the health and environmental impacts of greatest concern at current ambient exposures in the Tennessee Valley are:

- Potential impacts to health of sensitive individuals due to fine particles in the air, ozone, or potentially from short-term sulfur dioxide exposures
- Ozone impacts to crop and forest health and productivity
- Acid deposition impacts to sensitive forest and aquatic ecosystems
- Visibility impairment due to fine particles in the air
- Some degradation of material surface due to acid deposition or ozone

Ambient air loadings of hazardous air pollutants to which TVA is a contributor are of low risk to human health and the environment in the Tennessee Valley. Impacts of greenhouse gases are scientifically uncertain. Levels of emissions of greenhouse gases are tracked as an indirect measure of potential impacts.

As discussed in Volume 2, Technical Document 1, Comprehensive Affected Environment, many variables affect the relationships between emissions, exposures, and impacts. Typically, assessments of source contributions are done through meteorological and atmospheric chemistry modeling. However, these models require accurate meteorological, land cover, topographic (physical geography), emissions, and background air quality data. Modeling TVA contributions to impacts at specific receptors would require:

- Detailed emissions inventories for all contributing sources
- Atmospheric modeling of secondary pollutant formation and transport as a function of specific meteorological conditions
- Quantitative assessment of the relationships between exposures and the impacts of concern

Much of these data are not available at a regional scale, and exposure and impact relationships are also not always well understood. Consequently, simplifying assumptions were made to estimate TVA's contribution to air pollutant levels in the Tennessee Valley. These are discussed in Volume 2, Technical Document 1, Comprehensive Affected Environment.

Source-specific atmospheric modeling was also not undertaken in the Energy Vision 2020. TVA's purpose in Energy Vision 2020 is to select a preferred future energy supply strategy and does not include site-specific details of how that strategy might be implemented. The current analysis focuses on probable differences in impacts among candidate strategies and is based on projected future emissions and estimated TVA contributions to total pollutant loadings. When TVA considers site-specific actions to implement selected options, it will, as appropriate, conduct more detailed source-specific atmospheric modeling.

ASSUMPTIONS FOR FUTURE REGULATIONS

The Environmental Protection Agency is currently considering revising the national ambient air quality standards for ozone, particulate matter, and sulfur dioxide, and establishing a new acid deposition standard. Any of those regulatory decisions could require further reductions in TVA's sulfur dioxide and nitrogen oxides emissions. However, these reductions would most likely impact TVA's existing coal-fired power plants more than future new power supply sources, since standards for new plants or sources are more stringent than those for existing plants.

The Environmental Protection Agency is also currently considering whether utility emissions of hazardous air pollutants should be regulated. Mercury is receiving specific regulatory consideration. If mercury emissions from utility sources are regulated, controls would likely be national in scope and include TVA sources.

TVA has already voluntarily committed to limit potential increases in its carbon dioxide emissions. Legislation has been proposed to stabilize or reduce carbon dioxide emission levels.

In projecting future emissions trends, uncertainty in future regulations was addressed by assigning probability to alternative regulatory outcomes. All energy strategies incorporate the same probabilities of future regulation. Among the strategies, the reference, or "No Action," strategy relies most heavily on fossil fuels and represents maximum probable environmental impacts of the TVA system.

Analysis of Energy Vision 2020 Strategies

AIR QUALITY INDICES FOR ALTERNATIVE STRATEGIES

TVA's existing energy resources and many of the resource options considered for Energy Vision 2020 can affect air quality in different ways. Air indices were developed to help characterize how TVA power system operations and alternative energy strategies might affect air quality impact areas which include:

- Human health - inhalation
- Visibility impairment
- Forest and crops
- Materials (structural and cultural)

Potential effects of emissions of greenhouse gases, a fifth air quality impact area of interest, is considered in a separate index.

Indices were developed to help characterize how the emissions associated with alternative strategies might contribute to these five air impact categories. *Figure T2-14* shows these indices. Results for the air indices are derived by weighting the annual average air emissions from 1996 to 2020 in each strategy by the relative importance assigned to each air emission. The relative importance was assigned based on TVA's contribution to pollutant loadings that could affect human health and the environment. Additional information about these measurements and how they were weighted can be found in Volume 2, Technical Document 1, Comprehensive Affected Environment. The indices allow the emissions of greater concern for impacts to be given greater emphasis in multi-attribute analysis of alternative energy strategies.

TVA's final strategies were compared to the "No Action" strategy (Strategy D), which is the reference strategy in Energy Vision 2020. Strategy D was assigned a value of 1.0 for all indices. The values for the other final strategies then indicated whether they are better or worse than Strategy D with respect to the impact in question (a value greater than 1.0 indicates a worse effect, less than 1.0 a better effect).

The reference, or "No Action," Strategy D and Strategy M use the most coal, while Strategy T uses the least coal and the most natural gas and renewables. The air indices values (0.91) for Strategy T are the lowest compared to the reference strategy (value of 1.0) and represent a 9 percent difference in TVA contribution to total pollutant loadings compared to the reference strategy.

The differences in index values do not represent differences in ultimate impact contributions. For example, if TVA is estimated to contribute less than 25 percent of secondary pollutant load-

FIGURE T2-14. **Air Quality Impact Environmental Indices for Each Strategy and Impact Area**

	IMPACT AREAS				
Strategy	**Health-Inhalation**	**Visibility Impairment**	**Forest & Crops Productivity**	**Materials Damage**	**Greenhouse Gases**
D- Reference	1.00	1.00	1.00	1.00	1.00
J	0.98	0.97	0.98	0.97	0.93
M	0.94	0.93	0.95	0.93	0.91
O	0.95	0.94	0.96	0.94	0.90
Q	0.94	0.92	0.95	0.93	0.93
R	0.95	0.94	0.96	0.95	0.93
S	0.95	0.94	0.96	0.95	0.93
T	0.91	0.91	0.91	0.91	0.87

Air indices have been developed for health-inhalation impacts, visibility impairment, forest and crop productivity, materials damage, and greenhouse gases.

ings in the Tennessee Valley, a 9 percent difference in TVA's contribution might result in a 2.25 percent difference in total exposures. Such a difference would be difficult to measure given the large annual variability in secondary pollutant formation caused by climate conditions. For individual episodes of highest pollutant loadings, differences in loadings due to differences in TVA strategies may be detectable.

All strategies improve on the index for greenhouse gases compared to the reference strategy. Improvements range from 7 percent for strategies J, Q, R, and S to 13 percent for Strategy T.

SUMMARY OF EMISSIONS AS A FUNCTION OF ENERGY STRATEGIES

TVA's emissions of sulfur dioxide and nitrogen oxides are the primary measures that can be used to differentiate among impacts of TVA future energy strategies. However, TVA's sulfur dioxide, nitrogen oxides, particulate matter, hazardous air pollutants, and carbon dioxide emissions are all primarily functions of the annual amount of coal burned. Strategies that rely on existing coal-fired power plants are more likely to have higher sulfur dioxide and nitrogen oxides emissions than new coal-fired sources because new sources have more efficient emission controls. Regulatory actions that lower permitted emissions are likely to raise the costs of operating existing sources and may shift economics to favor new generation.

If other factors are equal, energy strategies that reduce projected coal use will have lower air quality impacts. Natural gas has negligible sulfur dioxide emissions and all strategies incorporate natural gas for new energy supply. Natural gas also has lower nitrogen oxides emissions than coal. Energy supply requirements that are met by renewables and demand-side management will have lower air emissions than equivalent supply from fossil fuels. If other factors are equal, these supply options will have positive benefits to the environment in proportion to their usage in various strategies.

The air indices do not address differences due to siting of future energy supply resources. New or expanded sources of emissions located in the eastern Tennessee Valley might contribute more to ozone in the southern Appalachians than sources sited in the western Valley. New or expanded sources located in western Tennessee could impact ozone levels and nonattainment conditions in the Nashville metropolitan area and potentially affect sulfate loading in southern Appalachia. The indices also do not address where impacts will occur. Impacts to visibility in Class I areas have greater legal implications than degraded visibility in urban areas of the Tennessee Valley. Power supplied by purchases outside the Tennessee Valley could have impacts on resources in areas other than the Tennessee Valley.

When specific energy supply strategies are implemented affects the timing of emission reductions and differs among the strategies considered. Earlier emission reductions are assumed to be environmentally preferable to equivalent reductions occurring later over the period 2000 to 2020. For example, earlier reduc-

FIGURE T2-15. **Emissions and Percent Changes Between 1996 and 2020 by Strategy**

	SULFUR DIOXIDE			NITROGEN OXIDES			MERCURY			CARBON DIOXIDE		
	Tons		%	Tons		%	Pounds		%	Thousands of Tons		%
Strategy	1996	2020	Change	1996	2020	Change	1996	2020	Change	1996	2020	Change
D-Reference	810,000	483,176	-40.35	468,530	452,866	-3.34	4,884	5,669	16.07	103,144	157,126	52.34
J	810,000	429,003	-47.04	468,530	436,944	-6.74	4,884	5,218	6.84	103,144	141,380	37.07
M	810,000	412,232	-49.11	468,530	429,493	-8.33	4,884	4,897	0.00	103,144	140,593	36.31
O	810,000	421,120	-48.01	468,530	433,653	-7.44	4,884	5,134	5.10	103,144	139,698	35.44
Q	810,000	396,791	-51.01	468,530	423,914	-9.52	4,884	4,915	0.63	103,144	141,486	37.17
R	810,000	398,084	-50.85	468,530	424,402	-9.42	4,884	4,929	0.42	103,144	141,682	37.36
S	810,000	421,123	-48.01	468,530	433,614	-7.45	4,884	5,152	5.49	103,144	142,382	38.04
T	810,000	448,843	-44.59	468,530	409,504	-12.60	4,884	5,032	3.03	103,144	128,853	24.93

FIGURE T2-16. **Average Annual Emissions and Change From the Reference Strategy**

	SULFUR DIOXIDE		NITROGEN OXIDES		MERCURY		CARBON DIOXIDE	
Strategy	Tons	% Change From Ref	Tons	% Change From Ref	Pounds	% Change From Ref	Thousands of Tons	% Change From Ref
D-Reference	563,048	0	455,804	0	5,490	0	130,352	0
J	541,563	-4	450,220	-1	5,335	-3	120,531	-8
M	511,777	-9	439,000	-4	5,159	-6	119,041	-9
O	518,733	-8	442,052	-3	5,299	-3	116,811	-10
Q	508,166	-10	439,015	-4	5,163	-6	121,351	-7
R	522,283	-7	443,399	-3	5,266	-4	121,639	-7
S	522,499	-7	443,366	-3	5,270	-4	121,261	-7
T	516,696	-8	411,742	-10	5,014	-9	115,042	-12

tions in nitrogen loading as a function of TVA energy supply strategies could result in earlier improvement in ozone impacts to human health, crop and forest productivity, and materials. Earlier reductions in nitrogen oxides could also result in improved soil nutrient content at sensitive receptors where nitrogen saturation has negative environmental impacts. However, for most crops and forests in the Tennessee Valley, current levels of nitrogen deposits have neutral to positive impacts. Earlier reductions in sulfate could produce earlier benefits to human health, visibility, aquatic impacts from acid deposition, and materials.

SUMMARY OF TRENDS IN TVA EMISSIONS

The trends in TVA's emissions during the Energy Vision 2020 period provide additional information about the potential effect of Energy Vision 2020 strategies that is not reflected in the indices. For each strategy, *Figure T2-15* gives the amount of the first and last year emissions and the percentage change from the first year of the study period (1996) to the last year (2020). (Because impacts from fine particulate matter are related more to secondary particles than primary particulate emissions, trends in primary particulate emissions are not considered here.) The graphs in *Figure T2-17* through *T2-20* illustrate the emissions trend for each strategy over the study period. Sulfur dioxide and nitrogen oxides emissions are projected to decrease between 1996 and 2020 for all strategies, despite increases in coal usage in all strategies. Mercury emissions remain the same or increase while carbon dioxide emissions increase in all strategies between 1996 and 2020. (*See Figure T2-15.*)

The table in *Figure T2-16* differs from *Figure T2-15* in that *Figure T2-16* indicates the total emissions for each of the final strategies averaged over the 25-year study period. This table also differs from *Figure T2-15* in presenting the percent change in average emissions for each final strategy compared to the reference strategy. Since the total emissions averaged over the study period best indicate total emissions, these quantities (*Figure T2-16*) are used in calculating the air quality impact indices shown in *Figure T2-14*.

Sulfur Dioxide

When comparing emissions at different points in time, sulfur dioxide emissions in the reference strategy are projected to be reduced from 1996 levels by about 40 percent in 2005 with smaller reductions after 2005. All other strategies have larger reductions in sulfur dioxide emissions than the reference strategy. (See *Figure T2-15.*) *Figure T2-17* projects trends in sulfur dioxide emissions for each strategy.

When comparing total emissions averaged over the study period against the reference strategy, sulfur dioxide emissions for all final strategies are 4 to 10 percent lower compared to the reference strategy (*Figure T2-16*).

- The reductions in sulfur dioxide would lead to reductions in sulfate contributing to acid deposition and fine particulate matter. However, reductions in sulfate concentrations would be less than projected TVA sulfur dioxide reductions. For example, sulfate formation can be limited by availability of oxidants (e.g., hydrogen peroxide or ozone) that react with the sulfur dioxide to form sulfate. Also, TVA is only one contributor to sulfur dioxide emissions that contribute to sulfate formation.
- Some improvement in TVA's contribution to potential impacts on human health, visibility, and rates of degradation of materials are expected for all strategies, due to reductions in TVA sulfur dioxide emissions. However, these benefits may not occur within the Tennessee Valley but at some distance beyond it, since the rate of sulfate production is slow and the air mass into which the sulfur dioxide is emitted may travel outside the Tennessee Valley before the sulfate is produced.
- Potential benefits to crops and forests from projected reductions in TVA emissions of sulfur dioxide are expected to be

small because sulfur is a less important pollutant than nitrogen for these systems.

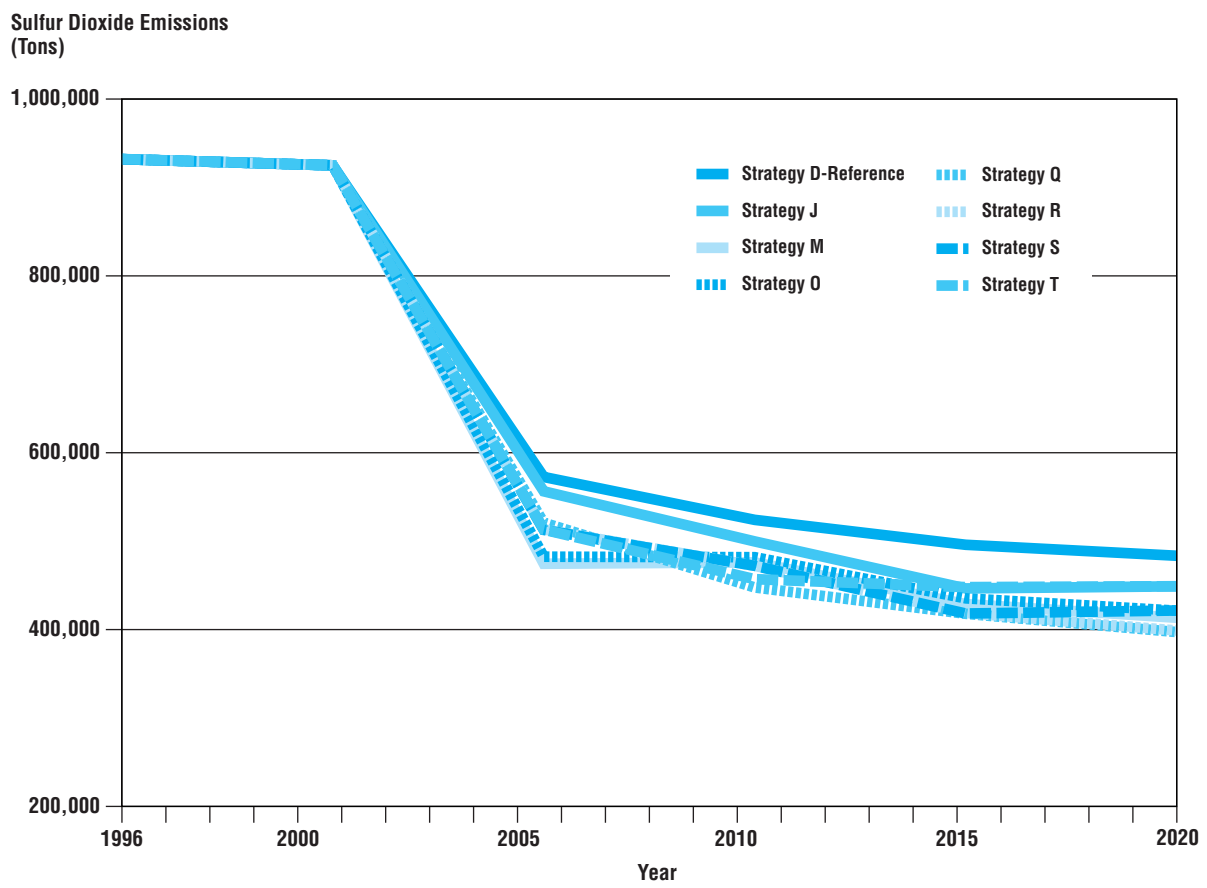
Nitrogen Oxides

Nitrogen oxides emissions are projected to drop from 10 to 20 percent, depending upon the strategy, between 1996 and 2000 due to implementation of Phase II controls under the 1990 Amendments to the Clean Air Act. After the year 2000, nitrogen oxides emissions are projected to increase for all strategies as a function of increasing generation. Emissions are projected, however, to remain 3 to 13 percent lower than 1996 levels (*Figure T2-15*). *Figure T2-18* shows the nitrogen oxides emissions trend for each strategy.

When comparing total emissions averaged over the study period against the reference strategy, the strategy with the lowest emissions, Strategy T, has 10 percent lower nitrogen oxides emissions than the reference strategy (*Figure T2-16*).

- Reductions in TVA emissions of nitrogen oxides could lead to an improvement in ozone (a chemical oxidant that can affect the respiratory system of exercising unmedicated asthmatics) exposures in the Tennessee Valley if TVA reductions are not offset by increases in nitrogen oxides emissions from other sources. For example, emissions from automobiles and other mobile sources are likely to increase substantially during this same period.
- For all strategies, benefits to human health could occur as a result of TVA reductions of nitrogen oxides emissions. Small benefits to visibility, crop and forest productivity, and materials could also result.
- In the immediate vicinity of TVA coal-fired power plants (within about 20 kilometers), where ozone is consumed in the plume, TVA nitrogen oxides emission reductions could actually increase ambient ozone levels.

FIGURE T2-17. **Yearly Sulfur Dioxide Emissions for Each Strategy**



Mercury

When comparing emissions at the beginning and end of the study period, mercury emissions are projected to increase 16 percent in the reference strategy (*Figure T2-15*). All other strategies either have no increase or smaller increases. *Figure T2-19* projects the trend for mercury emissions for each strategy.

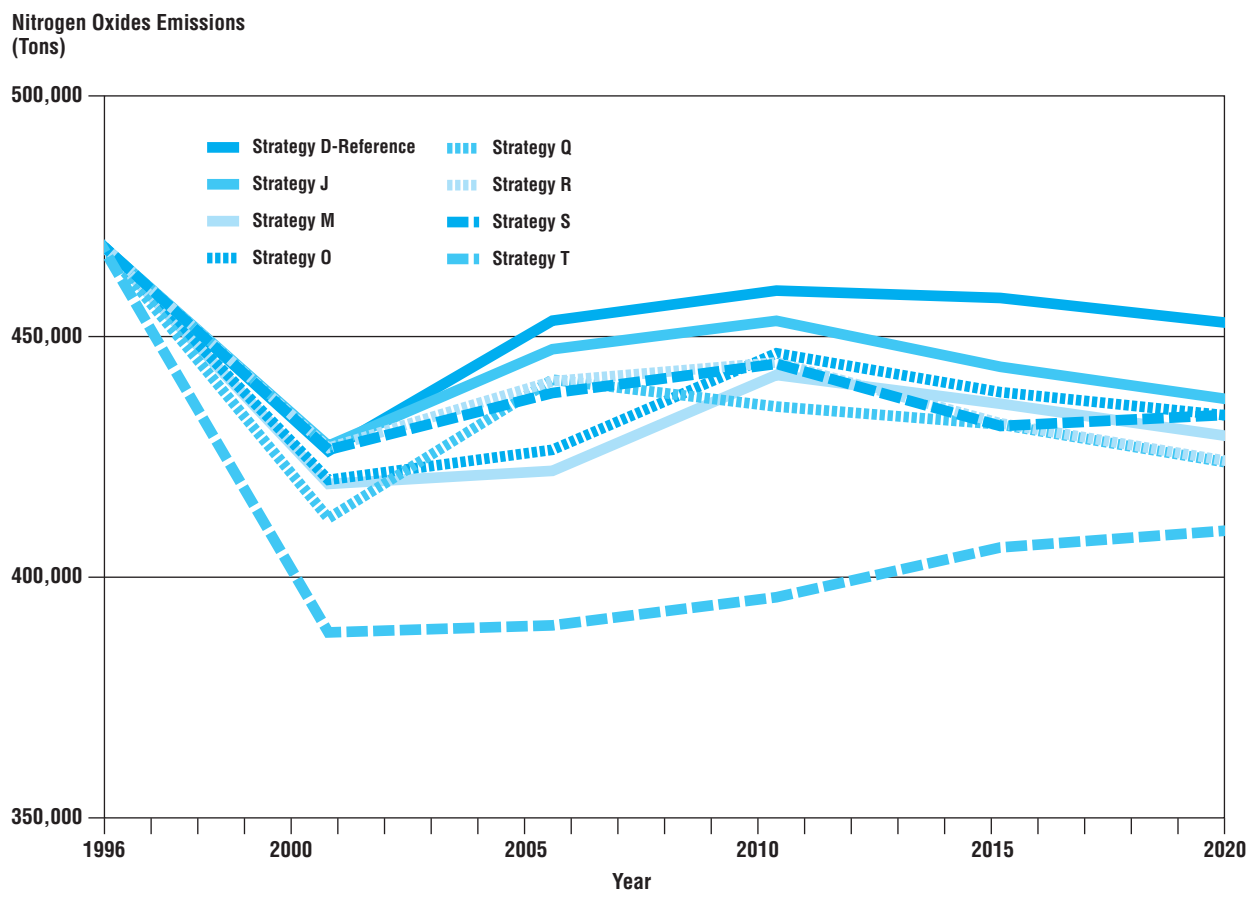
When comparing total emissions for all final strategies averaged over the study period against the reference strategy, mercury emissions are 3 to 9 percent lower compared to the reference strategy (*Figure T2-16*).

Differences in mercury loadings in the Tennessee Valley due to TVA future energy strategies may be detectable. However, because impacts of atmospheric deposition of mercury in the Tennessee Valley are small, changes in impacts as a function of TVA strategies would be very small. TVA emissions are a very small fraction of total mercury impacting sensitive ecosystems outside the Tennessee Valley; thus, these differences in mercury levels are not expected to be detectable at sensitive receptors.

Carbon Dioxide

There remains considerable uncertainty regarding the possible effect of carbon dioxide and other emissions on global climate. However, at the Earth Summit in Rio de Janeiro, Brazil in June 1992, the United States and over 150 other nations signed the United Nations Framework Convention on Climate Change, establishing the objective of stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous manmade interference with the climate system. In October 1993, the President announced the Climate Change Action Plan which has the goal of returning United States greenhouse gas emissions to 1990 levels by the year 2000. As part of this action plan the United States Department of Energy initiated the Climate Challenge

FIGURE T2-18. **Yearly Nitrogen Oxides Emissions for Each Strategy**



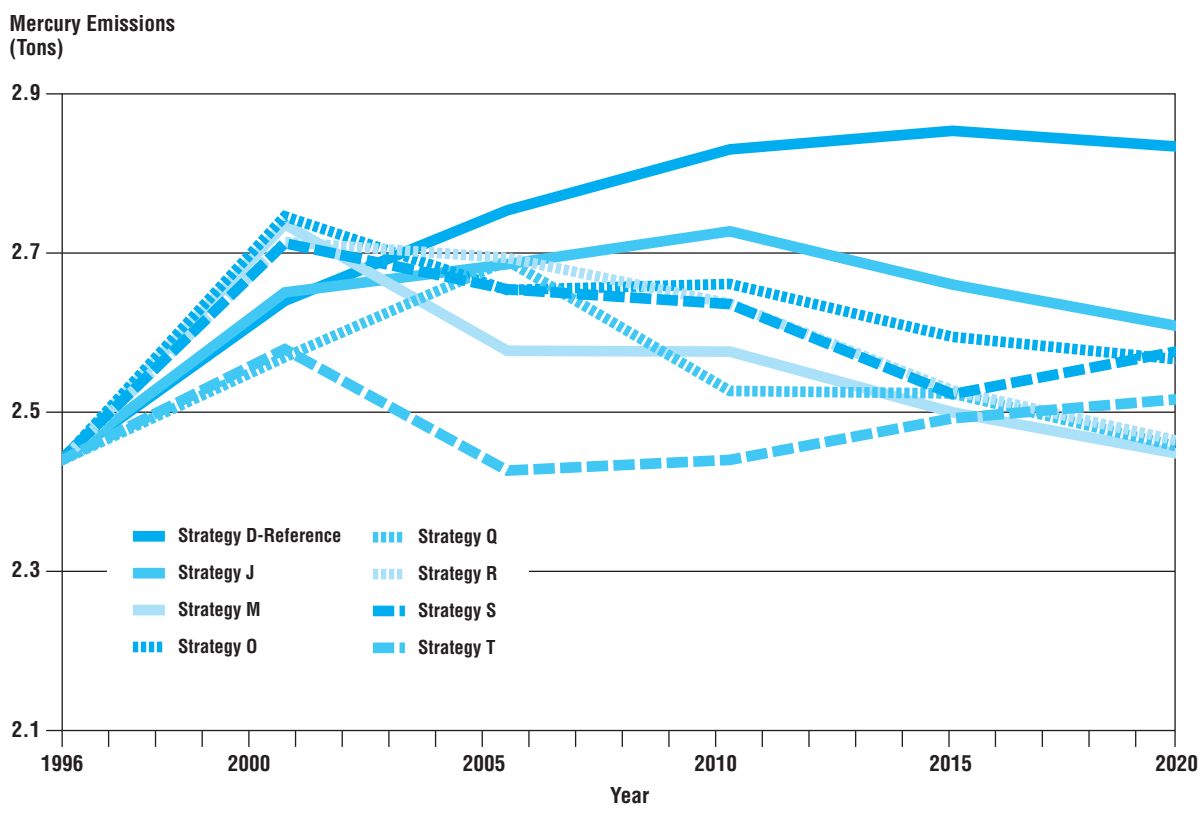
which is a voluntary program to manage United States electric utility greenhouse gases through reduction, avoidance, or sequestering of greenhouse gases.

On April 20, 1994, the Climate Challenge Memorandum of Understanding was signed by the Department of Energy, four utility organizations, and TVA. Subsequently, 104 individual Climate Challenge Participation Accords have been signed with the Department of Energy that represent 487 utilities including TVA. The efforts taken by TVA and the other 450 plus Climate Challenge participants will mitigate possible negative effects utility emissions may have on global climate in a more cost-effective manner than other control measures such as emissions regulations or carbon taxes. A 22.7 million ton reduction in carbon dioxide by the year 2000 is committed to in TVA's Climate Challenge Participation Accord. These reductions are projected from TVA's 1987 to 1990 baseline emissions and the emissions projected by a year 2000 modified reference case. Primarily, TVA greenhouse gas reductions by the year 2000 come from increased use of nuclear power, biomass cofiring, demand-side management programs, fossil-fueled power plant efficiency improvements, transmission system improvements, and hydroelectric power plant modernization.

Although actual carbon dioxide emissions increase under all strategies *(see Figure T2-20)*, the rates of increase have been mitigated by the Climate Challenge actions and are also less than increases under the Energy Vision 2020 reference strategy. Additionally, the carbon dioxide emitted per unit of electric energy produced would be 10 to 15 percent lower than TVA's present power system *(see Figure T2-24)* by the year 2005. This increase in efficiency throughout the planning period is due to: (1) increased production of nuclear power, (2) hydroelectric power plant modernization; (3) addition of more efficient fossil-fired plants, (4) increased use of renewables, and, (5) in some strategies, the repowering of existing coal-fired plants with more efficient energy conversion systems.

The possibility of future carbon dioxide regulation was

FIGURE T2-19. **Yearly Mercury Emissions for Each Strategy**

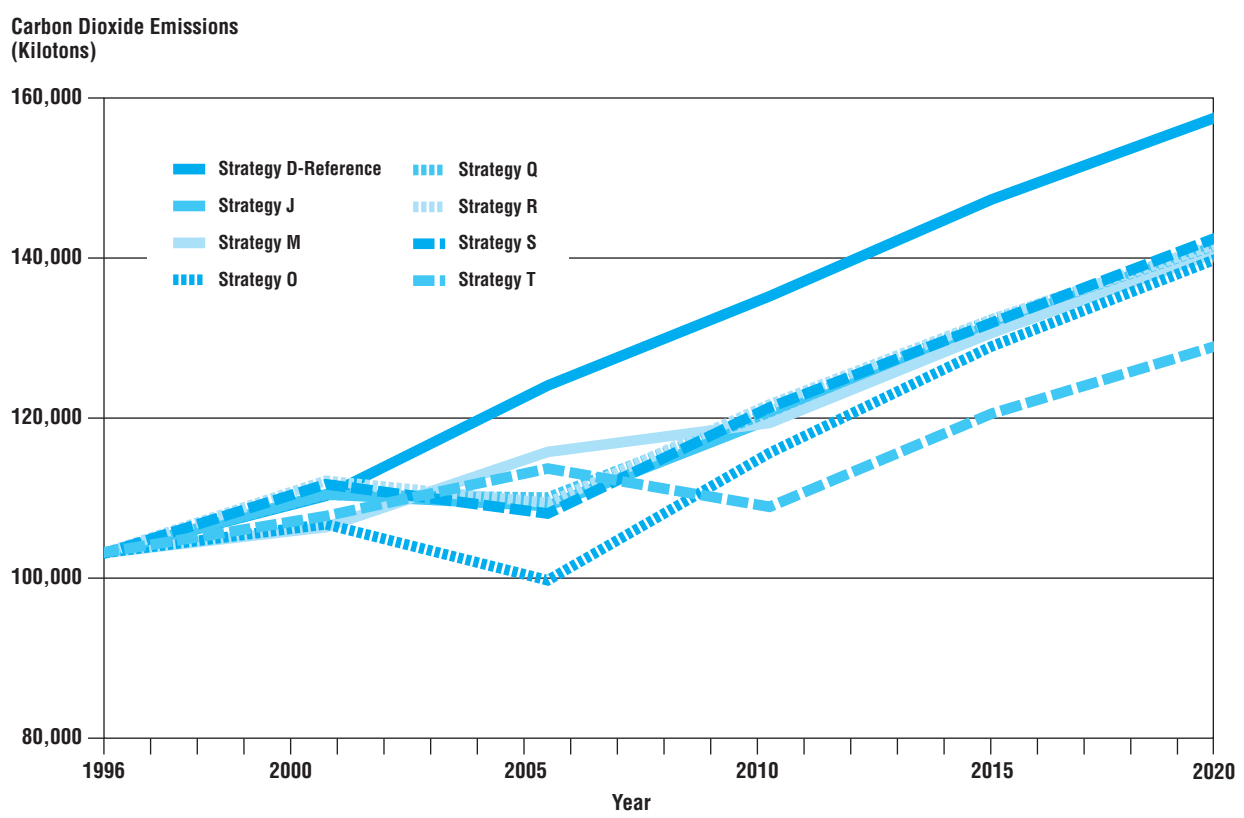


also evaluated in Energy Vision 2020 as an uncertainty. It was assumed for purposes of this uncertainty that there would be a cap on carbon dioxide emissions beginning in the year 2000 at 1990 levels. Any carbon dioxide emissions above this cap could be purchased at $10 per ton of carbon dioxide and any emissions below the cap could be sold for the same price. Because of this cap there would be a direct reduction of carbon dioxide emissions of 2 million to 3 million tons per year on the TVA system. Also, long-term costs were increased sufficiently to reduce emissions to 1990 levels assuming a cost of $10 per ton of carbon dioxide. The cost of this emission reduction averaged $257 million per year for TVA.

Improvements in greenhouse gas emissions (primarily carbon dioxide) for a strategy results from conservation of energy, use of a lower carbon content fuel (e.g., natural gas), the use of noncombustion energy sources, and specific options or measures that offset greenhouse gas releases. Demand-side management programs conserve energy and avoid combustion of fuels, thus reducing the release of carbon dioxide. More efficient power plant cycles also reduce combustion fuel use. Hydroelectric and renewable energy sources, such as wind, supply electricity without combustion of fuels.

Another renewable energy source, landfill methane recovery, has a different advantage. Methane is a greenhouse gas that has 21 times more potential to absorb solar radiation than carbon dioxide. Combustion of landfill methane for energy production releases carbon dioxide, but greenhouse gas impacts are 21 times less than the methane that would have otherwise been released to the atmosphere from the landfill through natural losses. Also, use of wood waste as a cofired fuel at coal-fired power plants recycles carbon dioxide that trees have removed from the atmosphere, rather than the one-way release of carbon dioxide from fuels such as coal and natural gas. Additionally, the methane released to the atmosphere from natural wood waste decomposition in disposal areas is avoided by combustion of the wood waste. Because of the carbon dioxide offsets, equivalent carbon diox-

FIGURE T2-20. **Yearly Equivalent Carbon Dioxide Emissions for Each Strategy**



ide emissions were computed. *Figure T2-25* gives the weightings of various pollutants to obtain the equivalent of carbon dioxide for purposes of considering greenhouse gas emissions.

Greenhouse gas credits and offsets are assigned equivalent carbon dioxide values and are included in the values shown for each strategy, including the index values in *Figure T2-26*.

When comparing emissions at the beginning and end of the study period, equivalent carbon dioxide emissions are projected to increase by 52 percent in the reference strategy (*Figure T2-15*). No strategy provides a decrease in carbon dioxide equivalents when comparing emissions in 1996 and 2020. Carbon dioxide emission trends, including equivalent levels of other greenhouse gases, are projected in *Figure T2-20* for all final strategies.

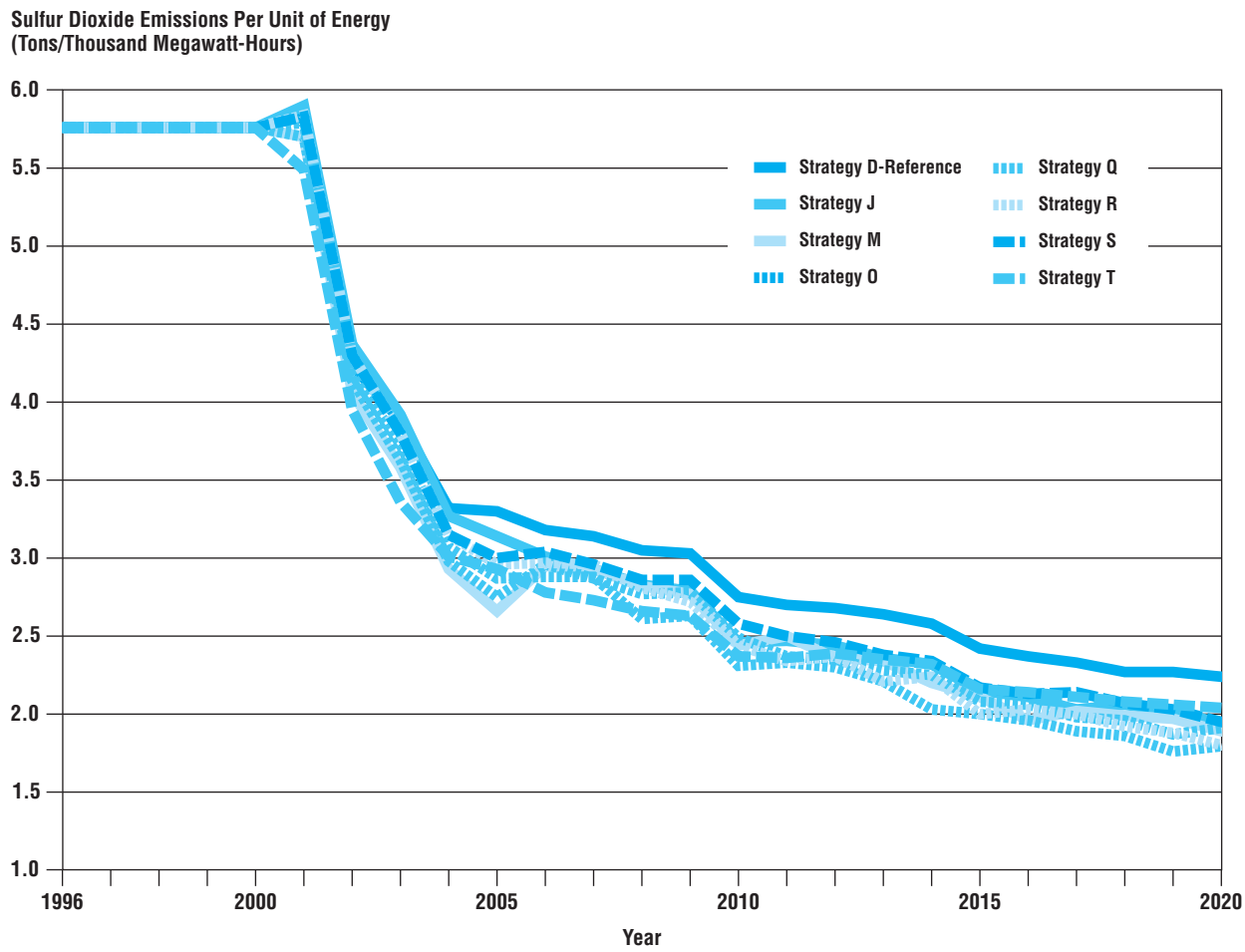
When comparing total emissions averaged over the study period against those for the reference strategy, the smallest increase is forecast for Strategy T with 12 percent lower emissions than the reference strategy (*Figure T2-16*).

Increased use of natural gas-fueled resources, renewables, and demand-side management in Strategy T results in lower levels of greenhouse gas emissions, Gas-fueled resources have 40 percent lower carbon dioxide emissions per unit of energy consumed than the coal-fired plants they re-power. Current scientific understanding is insufficient to project impacts of these increases in the Tennessee Valley.

Emissions Control Efficiencies

The ratio of emissions per unit of electric energy production is a measure of the efficiency of emission controls or the efficiency of energy production itself. All strategies have similar expansion in electric energy production over the planning period so the simple ratio of emissions to unit of electric energy production can be compared. This ratio is shown over the period 1996 to 2020 for sulfur dioxide, nitrogen oxides, mercury, and equivalent carbon dioxide in *Figures T2-21* through *T2-24*. These ratios for sul-

FIGURE T2-21. **Yearly Sulfur Dioxide Emissions for Each Strategy per Unit of Energy Generated**



fur dioxide, nitrogen oxides, and mercury improve over the planning period. These improvements reflect increased plant efficiency, increased use of natural gas, and environmental controls.

As shown in *Figure T2-24*, all strategies have small improvements in efficiencies of carbon dioxide emissions by the year 2000. After 2000, the reference strategy maintains a near-constant ratio of carbon dioxide equivalent emissions to energy production while all other strategies further decrease the ratio. Strategy T has the lowest ratio during the last 10 years of the planning period. These ratios indicate that the projected increases in carbon dioxide equivalents are a function of increased generation.

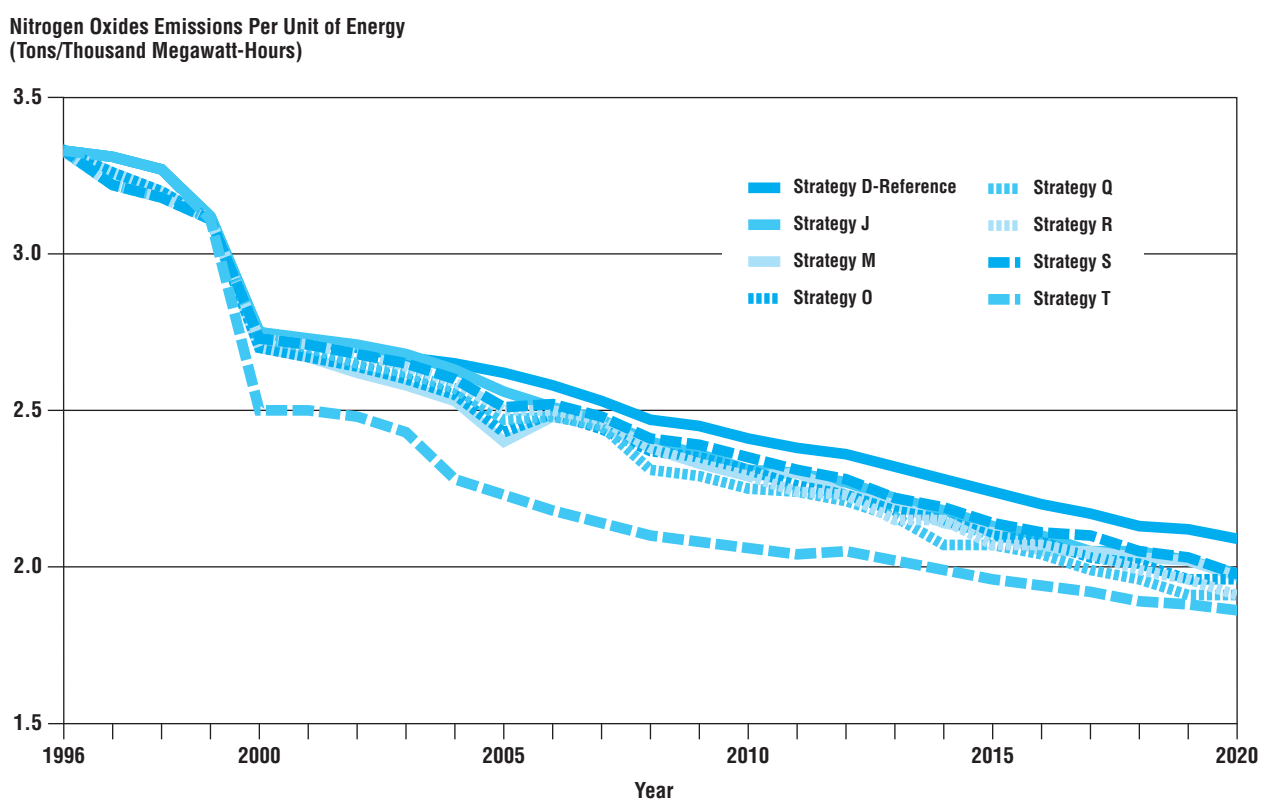
STRATEGY-BY-STRATEGY COMPARISON OF AIR IMPACTS

Air quality impacts related to each energy strategy are addressed separately in this section. *Figures T2-1* to *T2-3* describe each strategy in terms of proposed energy production facilities. Pollutants from all energy resources are considered, including those from purchased power. Levels of TVA emissions of primary particulate matter and volatile organic compounds are negligible compared to emissions from other sources and are not considered in the discussions of specific strategies.

One of the most important conclusions to be drawn from TVA's Energy Vision 2020 evaluation is that TVA's existing coal-fired units are responsible for most of TVA's contribution to the identified environmental impacts. TVA's coal-fired plants produce air pollution, water pollution, and solid waste. These environmental outputs are associated with a number of environmental problems.

TVA's contribution to many environmental problems has been substantially reduced over the years and is being reduced still further. For example, TVA's sulfur dioxide emissions from its coal-fired units have been reduced by over 60 percent since the mid-1970s and will be reduced still further to comply with the

FIGURE T2-22. **Yearly Nitrogen Oxides Emissions for Each Strategy per Unit of Energy Generated**



Clean Air Act Amendments of 1990. These reductions lessen TVA's contribution to such impacts as acid rain and visibility impairment. However, compared to most new energy resource options, TVA's existing coal-fired units are significantly worse environmental performers.

Energy Vision 2020 focuses primarily on what additional energy resource options, if any, should be added to TVA's system in the future. Consequently, repowering of selected less-efficient coal-fired units is one of the better options for reducing emissions.

Any new sources that are constructed, regardless of the type, will meet all applicable federal, state, and local air quality regulations. Thus, new sources will have minimal air quality impacts on the local (within 50 kilometers) scale. Construction of facilities creates temporary local impacts, such as fugitive particle emissions and volatile organic compound emissions from construction equipment. Regional impacts are difficult to project without site-specific information on emissions.

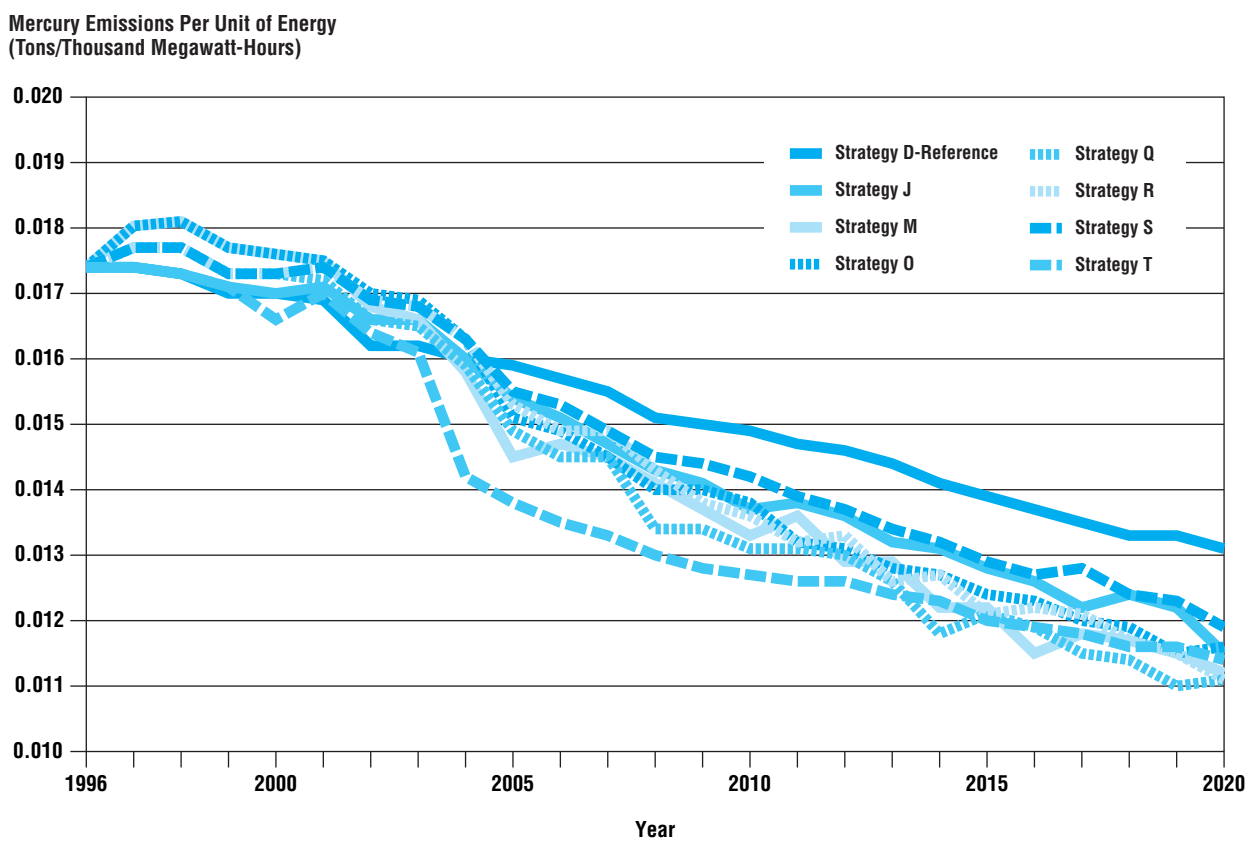
Strategy D – Reference, or "No Action" Strategy

Under Strategy D, existing facilities would continue to operate, although emissions would be reduced from those in 1996 in response to the 1990 Clean Air Act Amendments. New capacity would come primarily from gas-fired turbines fueled by natural gas or gas from coal-gasification facilities.

Sulfur Dioxide

The reference strategy has the highest average annual sulfur dioxide emissions of all the final strategies, greater than 560,000 tons, as shown in *Figure T2-16*. However, all final strategies, includ-

FIGURE T2-23. **Yearly Mercury Emissions for Each Strategy per Unit of Energy Generated**

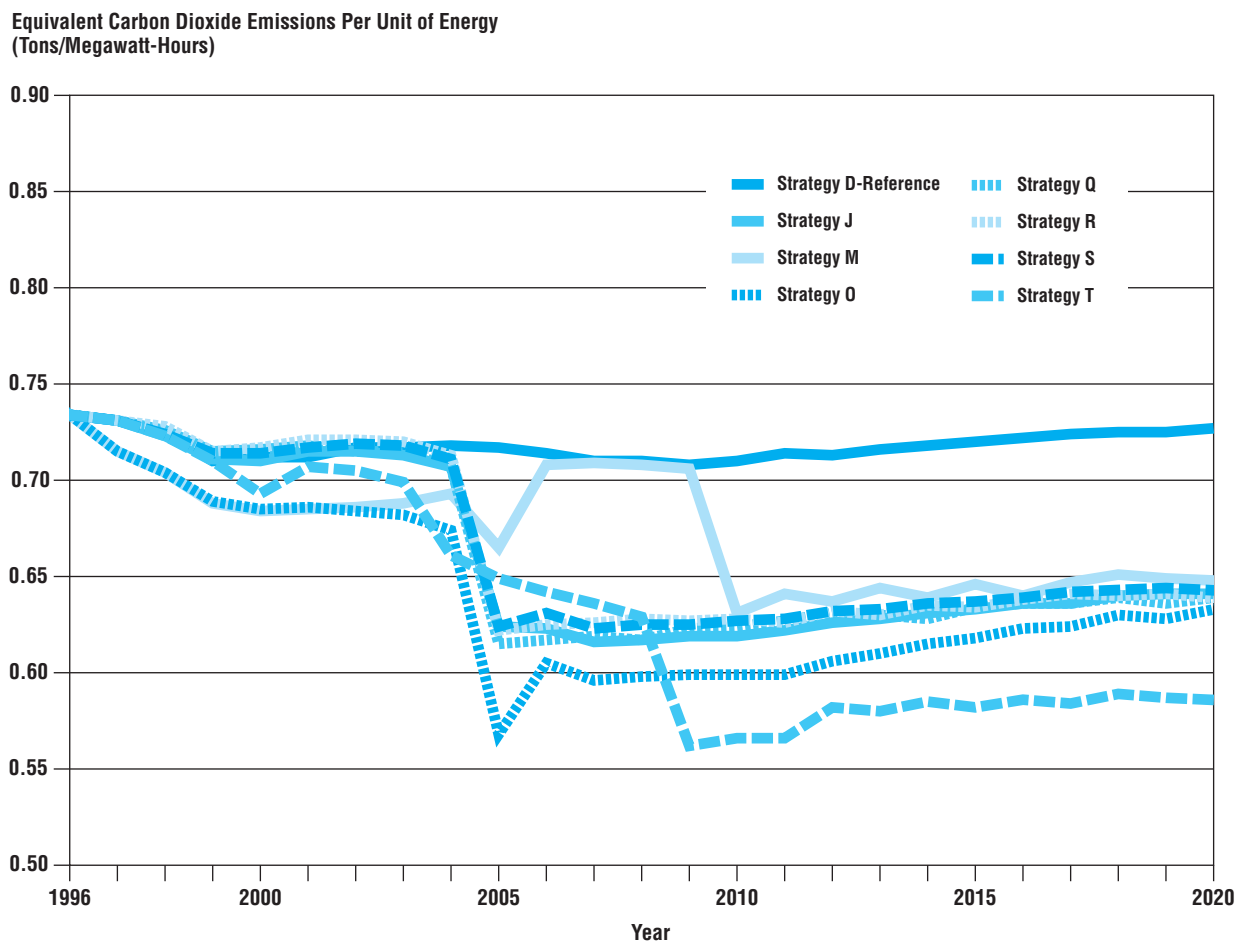


ing the reference strategy have large reductions in sulfur dioxide emissions compared to current emissions (*Figure T2-15*). These reductions would result in a proportional decrease (varying for each facility) in ambient sulfur dioxide concentrations around TVA plants where the reductions occur. This would also be expected to benefit air quality in areas that are sensitive to acid deposition and visibility impairment. However, the magnitude of the benefit is not directly proportional to the emission reductions. For example, a 50 percent reduction in sulfur dioxide emissions would yield less than a 50 percent reduction in acid deposition in the southern Appalachian Mountains. This is due to the fact that TVA emissions are only a fraction of the total sulfur dioxide emissions affecting the southern Appalachians. In addition, some of the proposed emission reductions would be at TVA plants too close to the southern Appalachians to have substantial effect in terms of acid deposition or visibility impairment. Locations further downwind to the east/northeast would derive the most benefit from emission reductions at TVA plants in east Tennessee.

Likewise, because the relationship between "light extinction" and atmospheric particle concentration is highly non-linear, there would be a less than 50 percent improvement in visibility. ("Light extinction" refers to reduced atmospheric light due to the absorption and scattering of light by gas molecules and particles.) If TVA emissions are assumed to be 20 percent of total sulfate loadings at sensitive receptors in southern Appalachia, then a 50 percent reduction in TVA emissions would result in a 10 percent improvement in sulfate loadings. That improvement should be detectable in improved visibility and reduced sulfate in deposition.

Strategy D represents the smallest reduction in sulfur dioxide; therefore, all other strategies should have greater benefits.

FIGURE T2-24. **Yearly Carbon Dioxide Emissions for Each Strategy per Unit of Energy Generated**



Nitrogen Oxides

The reference strategy has the highest average annual nitrogen oxides emissions of all the final strategies, greater than 455,000 tons, as shown in *Figure T2-16*. However, all final strategies, including the reference strategy, have reductions in nitrogen oxides emissions compared to current emissions (*Figure T2-15*). Any changes in ozone exposures resulting from this strategy are likely to be small because proposed nitrogen oxide reductions are small. Also, other sources of nitrogen oxides are projected to increase (e.g. vehicular traffic) and could offset any reductions by TVA. Assuming TVA contributes 25 percent of total nitrogen oxides contributing to ozone formation, and that nitrogen oxide levels limit ozone formation, a 10 percent reduction in TVA contribution would result in a 2.5 percent reduction in ozone exposures, depending on the location. Improvement could be much greater than this average for individual episodes or specific receptors when TVA emissions contribute more than 25 percent of total nitrogen oxides emissions. Within 20 kilometers of TVA power plants, ozone levels could actually increase. (Ozone is consumed in the conversion of nitric oxide to nitrogen dioxide.)

Lower nitrogen oxides emissions would also lead to a slight decline in regional levels of nitrate aerosols. Because nitrogen oxides contribute to ozone and because ozone facilitates the conversion of sulfur dioxide to sulfate, lower nitrogen oxide emissions could also lead to slightly lower sulfate levels. However, the effect on visibility would probably be difficult to perceive. In addition, small improvements of nitric acid in acid deposition could also result.

Mercury

The reference strategy has the highest average annual mercury emissions, almost 5,500 pounds, as shown in *Figure T2-16*. All final strategies, including the reference strategy, represent the same or an increase from current mercury emissions (*Figure T2-15*).

The quantity of mercury emissions is a function of the quantity of coal burned and whether flue gas desulfurization devices (scrubbers) are installed that are partially effective in removing mercury. TVA emissions increases may be detectable in the Tennessee Valley if other sources remain constant or decrease. However, because impacts of atmospheric mercury deposition to natural resources in the Tennessee Valley are small, impacts of increases in TVA emissions are likely to be very small. TVA emissions may contribute to total mercury deposition at sensitive receptors outside the Tennessee Valley. Specific atmospheric modeling would be required to determine if TVA's contribution and increases in TVA emissions would be detectable at sensitive receptors, but this is not likely.

Carbon Dioxide

The reference strategy has the highest average annual equivalent carbon dioxide emissions of all final strategies, over 130,000 tons, as shown in *Figure T2-16*. All final strategies, including the

FIGURE T2-25. **Weighting Factors to Obtain Carbon Dioxide Equivalents for Considering Greenhouse Gas Emissions**

Environmental Measure	Units	Greenhouse Gases Total Equivalent Carbon Dioxide
Carbon Dioxide Emission	Annual Average Thousands of Tons	1
Coalbed Methane Emissions Avoided	Annual Average Tons	-21
Natural Gas Methane Emissions	Annual Average Tons	21
Landfill Methane Recovered	Annual Average Tons	-21
Wood Waste Methane Avoided	Annual Average Tons	-21
Wood Waste Carbon Dioxide Avoided	Annual Average Thousands of Tons	-1
Short Rotation Woody Crops Carbon Dioxide Avoided	Annual Average Thousands of Tons	-1

FIGURE T2-26. **Equivalent Carbon Dioxide Index**

Strategy	Total Equivalent Carbon Dioxide (Millions of Tons)
D-Reference	1.00
J	0.93
M	0.91
O	0.90
Q	0.93
R	0.93
S	0.93
T	0.87

reference strategy, represent an increase from current equivalent carbon dioxide emissions (*Figure T2-15*). The greenhouse gas index for the reference strategy includes effects from existing demand-side management programs.

Strategy J – Bellefonte Coproduct and Renewables Strategy

The resource option differences between Strategy J and the reference, or "No Action," strategy lie in converting Bellefonte Nuclear Plant to an integrated gasification combined cycle plant and relying more on renewable fuel sources.

Because the integrated gasification combined cycle at Bellefonte is proposed in Strategy J, there would be nitrogen oxides emissions from the site that would not have existed under Strategy D. Thus, nitrogen oxides concentrations would increase within about 20 kilometers of Bellefonte and ozone concentrations would likely decrease. Beyond this distance, ozone concentrations would increase at a rate dependent on plant size, design, and other factors. However, the Bellefonte site is not sufficiently near any ozone non-attainment areas to materially affect attainment efforts. Also, the nitrogen oxides emissions from gasification are very low. Emissions from such a Bellefonte facility could theoretically contribute to ozone levels in the southern Appalachians, but this contribution would probably be small. The reason is the distance (about 210 kilometers) and the complex topography between Bellefonte and the southern Appalachians. Both factors act to increase pollutant dispersion and keep low the concentrations that could eventually reach sensitive receptor sites. Moreover, any new facility at Bellefonte would coincide with nitrogen oxides emission reductions in other parts of the TVA system. Detailed site-specific ambient air quality modeling may be required if a non-nuclear Bellefonte option were proposed to be implemented.

Strategy J has the least average annual sulfur dioxide, nitrogen oxides, and mercury reductions (with Strategy O also having the least mercury reductions) compared to the reference strategy (*Figure T2-16*).

For all impact areas other than greenhouse gases, this strategy produces the smallest air quality benefits of all the final strategies relative to Strategy D (the "No Action" strategy) because the fuels mix is so similar. (Air quality indices of 0.98 or 0.97 compared to 1.0 for Strategy D, see *Figure T2-14*).

The greenhouse gases index rating for equivalent carbon dioxide is 0.93, lower than the 1.00 for the reference strategy, Strategy D. The equivalent carbon dioxide emission decrease results from demand-side management (517 megawatts), hydroelectric improvements (163 megawatts), landfill methane capture (500 megawatts), coalbed methane capture (1000 megawatts) and 0.3 percent biomass co-firing for coal-fired facilities.

Strategy M – Combined Demand-Side Management and Off-System Sales Strategy

Strategy M emphasizes natural gas and demand-side management early in the planning period. It includes a new coal-fired unit at the Shawnee plant site, and additional power purchases from independent power producers. Sulfur dioxide and nitrogen oxides emissions from the new Shawnee unit would be more than offset by reductions elsewhere in the TVA system under this strategy. Changes in local air quality impacts around Shawnee and regional air quality impacts, including health impact changes, of this strategy are expected to be small. Site-specific environmental evaluations would be performed before putting a new coal-fired unit at Shawnee in place.

Among the final strategies, Strategy M offers neither the smallest nor the largest average annual emissions reductions for any pollutant when compared to the reference strategy (*Figure T2-16*).

For all impact areas other than greenhouse gases, air quality indices range between 0.93 to 0.95, neither the smallest nor the largest impacts, compared to 1.0 for the reference strategy *(Figure T2-14)*.

The greenhouse gases index rating for Strategy M is 0.91, lower than 1.0 for the reference strategy. The equivalent carbon dioxide emission decrease results from demand-side management (958 megawatts), hydroelectric improvements (163 megawatts), landfill methane capture (500 megawatts), coal field methane capture (1000 megawatts), and 0.3 percent biomass co-firing for coal-fired facilities.

Strategy O – Bellefonte Coproduct, Demand-Side Management Blocks One and Two, and More Off-System Sales Strategy

Strategy O is similar to Strategy M, but includes an integrated gasification combined cycle plant at Bellefonte rather than the Shawnee coal-fired unit. Among the final strategies, Strategy O offers the smallest average annual emissions reductions (along with Strategy J) when compared to the reference strategy (*Figure T2-16*).

For all impact areas other than greenhouse gases, index values range from 0.94 to 0.96, neither the smallest nor the largest impacts, compared to the reference strategy of 1.0 (*Figure T2-14*).

The greenhouse gases index rating for Strategy O is 0.90, the second best rating for all final strategies. The decrease in equivalent carbon dioxide emissions results from use of the resource options identified in the discussion of Strategy M.

Strategy Q – Flexible Strategy with External Options

Strategy Q is similar to Strategy O, but with more emphasis placed on off-system power purchases. This strategy (along with Strategies R and S) produces the smallest average annual

reduction in carbon dioxide compared to the reference strategy. It has, however, the greatest annual reductions in average annual sulfur dioxide emissions compared to the reference strategy (*Figure T2-16*).

For all air impact areas other than greenhouse gases, air quality indices range from 0.92 to 0.95, neither the largest nor the smallest impacts, compared to the reference strategy of 1.0 (*Figure T2-14*).

The greenhouse gases index rating for Strategy Q is 0.93, neither the largest nor the smallest impacts, compared to 1.00 for the reference strategy. The decrease in equivalent carbon dioxide emissions results from use of demand-side management (492 megawatts), hydroelectric improvements (163 megawatts), landfill methane capture (500 megawatts), coal field methane capture (1000 megawatts), and 0.3 percent biomass co-firing for coal-fired plants.

Strategy R – Flexible Strategy with Internal Options

Strategy R is similar to Strategy Q, except that one gas-fired combined cycle unit is added and off-system purchases are de-emphasized. Among the final strategies, Strategy R (along with Strategies Q and S) has the smallest average annual equivalent carbon dioxide emissions reduction compared with the reference strategy (*Figure T2-16*).

For all impact areas other than greenhouse gases, air quality indices range from 0.94 to 0.96, neither the smallest nor the largest impacts, compared to the reference strategy *(Figure T2-14*).

The greenhouse gases index rating for Strategy R is 0.93 as compared to 1.00 for the reference strategy. The equivalent carbon dioxide emission decrease results from demand-side management (492 megawatts), hydroelectric improvements (163 megawatts), landfill methane capture (500 megawatts), coal field methane capture (1000 megawatts), and 0.3 percent biomass co-firing for coal-fired plants.

Strategy S – Low Cost, Low Rates, and Improved Environment Strategy

Strategy S is similar to Strategy O, with the exception that off-system purchases are increased short-term and coal-gasification, mid-term. Among the final strategies, Strategy S (along with Strategies Q and R) have the smallest average annual emission reductions for equivalent carbon dioxide when compared with the reference strategy (*Figure T2-16*).

As shown in air quality indices in *Figure T2-14*, impacts from this strategy are neither the largest nor the smallest impacts when compared to the reference strategy.

The greenhouse gases index rating for Strategy S is 0.93 compared to 1.00 for the reference strategy. The equivalent carbon dioxide emission decrease results from demand-side management (492 megawatts), hydroelectric improvements (163 megawatts), landfill methane capture (500 megawatts), coal field methane capture (1000 megawatts), and 0.3 percent biomass co-firing for coal-fired plants.

Strategy T – Low-Cost Renewables, Low Price Demand-Side Management, Repowering, and Bellefonte Coproduct Partnership Strategy

Strategy T relies heavily on renewable energy sources, new gas-fired turbines (natural gas or coal-gasification), and natural gas repowering at some coal-fired units. Also included is a small amount of new coal-fired capacity and an integrated gasification combined cycle plant at the Bellefonte site. Impacts from the integrated gasification combined cycle plant are addressed under Strategy J. This strategy projects the lowest average annual nitrogen oxides, mercury, and equivalent carbon dioxide emissions compared to the reference strategy (*Figure T2-16*). A large shift to natural gas combustion is an important factor. (Gas combustion produces only about 60 percent as much nitrogen oxides as coal combustion per unit of heat energy produced.) Low mercury emissions correlate with a low reliance on coal combustion.

Because the air quality indices are tied strongly to system-wide nitrogen oxides and sulfur dioxide emissions, this strategy has the best ratings (0.91) for all impact areas compared to the reference strategy of 1.0. The reduction in potential air quality impacts as a result of implementing this strategy would be the largest of all strategies considered. (See *Figure T2-14.*)

The greenhouse gases index rating for Strategy T is 0.87, the best rating of all final strategies when compared to the reference strategy with 1.0. The equivalent carbon dioxide emission decrease results from demand-side management (517 megawatts), hydroelectric improvements (162 megawatts), compressed air energy storage (1011 megawatts), landfill methane capture (500 megawatts), coal field methane capture (1000 megawatts), wind (2000 megawatts), and 0.3 percent biomass co-firing for coal-fired plants.

SECTION 4: WATER RESOURCE IMPACTS OF ALTERNATIVE STRATEGIES

Understanding Water Resource Impacts

This section summarizes the differences among TVA's final strategies with respect to potential impacts on water resources. Three water-quality impacts were considered: (1) human health impacts by ingestion, (2) impacts on water supply and waste assimilation, and (3) impacts on fish, aquatic life, and aquatic biodiversity. Volume 2, Technical Document 1, Comprehensive Affected Environment, provides an overview of water quality issues, existing water quality impacts, sources of pollutants, water pollution trends, and regulations.

All new TVA generating resources included in the strategies assume certain constraints:

- Cooling towers will be constructed as necessary to deal with significant amounts of waste heat.
- All applicable water quality standards will be met through compliance with state-issued permits under the National Pollutant Discharge Elimination System, as is the case with existing facilities.

Prior to the development of a new energy resource, a site-specific environmental review would be done that examined direct and indirect water quality effects. For major facilities, water and aquatic life systems would be carefully monitored during construction and initial operation to identify adverse effects. Possible effects of construction and operation of new facilities on sensitive environmental resources such as wetlands or threatened or endangered aquatic species would be addressed in these site-specific reviews.

FUTURE REGULATORY TRENDS

The U.S. Congress is in the process of reauthorizing the Clean Water Act (P. L. 92-500, as amended), the Safe Drinking Water Act (P. L. 93-523, as amended), the Endangered Species Act (P. L. 93-205, as amended), and Superfund (P.L. 96-100, as amended). Changes proposed for all of these laws have the potential to affect the regulation of water resources (surface water and groundwater). Proposed changes to the Clean Water Act include clearer delineation of what constitutes a wetland, repeal of the current stormwater permitting program, greater latitude for the states in reducing nonpoint pollution sources, and the use of risk assessments and cost-benefit analysis in the Environmental Protection Agency rule- making process. These changes have the potential to affect the permits currently held by operating TVA power plants as well as the siting of new facilities, including transmission lines.

Most of the debate surrounding reauthorization of the Safe Drinking Water Act centers around the issue of risk. Currently the Environmental Protection Agency's rulemaking policy is one of zero risk. Opponents argue that the stringent drinking water standards resulting from this policy are too costly and without justifiable health benefits. How drinking water standards are set can affect the environmental siting process and ultimately the level to which contaminated groundwater must be cleaned.

The Endangered Species Act is under review. Opponents believe it goes too far in protecting the habitats of threatened and endangered species, infringes on property rights, and adversely affects federal land management policies. Loosening of the Act's provisions could affect the siting of new plants and transmission lines.

Almost everyone involved in the Superfund debate believes reform is needed. Some want major changes to the law's liability structure and cleanup standards while others favor more modest changes. The result of this debate in the Congress has the potential to significantly affect the cost of cleanup of contaminated sites associated with power production and transmission facilities.

Analysis of Energy Vision 2020 Strategies

WATER QUALITY INDICES FOR ALTERNATIVE STRATEGIES

TVA developed water quality indices to help characterize how alternative energy resource strategies may contribute to:

- Human health
- Water supply and waste assimilation
- Fish and aquatic life and biodiversity

The final strategies are described in *Figures T2-1* through *T2-3*. *Figure T2-27* shows the values for the water indices. Volume 2, Technical Document 1, Comprehensive Affected Environment (Section 4, Water Resources), contains detailed information about the measures used in deriving these water quality indices and a discussion of how they were weighted.

In developing the indices, TVA used eight weighted measures to evaluate the three impact areas above. There were three direct measures:

- Heat released
- Water consumed, (i.e., when water is not returned to the originating source)
- Water used (i.e., when water is returned to the originating source)

FIGURE T2-27. **Water Quality Impact Environmental Indices for Each Strategy and Impact Area**

	IMPACT AREAS		
Strategy	Health-Ingestion	Water Supply and Waste Assimilation	Fish and Aquatic Life and Biodiversity
D - Reference	1.00	1.00	1.00
J	1.00	1.00	0.99
M	1.01	1.00	1.00
O	1.00	0.99	0.99
Q	1.01	0.99	0.99
R	1.01	1.00	1.00
S	1.01	1.00	1.00
T	0.92	0.99	0.96

Water indices have been developed for health-ingestion, water supply and waste assimilation, and fish and aquatic life and biodiversity.

Surrogate measures were also used. (A surrogate measure is one that moves in the same direction as another that is more difficult to measure.)

- Coal burned
- Power produced by nuclear, coal, and hydroelectric plants
- The number of new power plants constructed

Three of the measures received most of the weighting for the impact areas:

- Hydroelectric peaking power production
- Coal power production
- Coal burned

The water health-ingestion index uses three weighted measures:

- Power production from nuclear
- Coal-fired
- Peaking hydro

Hydro peaking and nuclear power production are constant for all final seven strategies as well as the reference strategy. As a result, differences in coal-fired (existing plants) power production governs the index. Strategies M, Q, R, and S all have increased coal-fired power production from existing plants compared to the reference strategy. This results in index values slightly greater than 1.0.

SUMMARY OF FINDINGS

TVA's final strategies are compared to the "No Action" strategy or the reference strategy for Energy Vision 2020 (Strategy D). As indicated, there are only slight differences among TVA's final seven strategies and Strategy D for most water resource effects. Because less coal is burned under Strategy T (low-cost renewables) and coal use produces some water resource-related consequences, only this strategy shows a noticeable improvement. The following major conclusions have been reached:

- The effects of damming rivers, including operation of existing hydroelectric units, is responsible for the more important water resource impacts. However, since no new dams are proposed in the final strategies or the reference strategy, this impact is the same across all strategies.
- Increasing the capacity of TVA's existing hydroelectric plants is environmentally beneficial. This produces new capacity without constructing new plants. New plant construction, particularly a new hydroelectric dam, is more environmentally damaging. Also, new turbine designs used in increasing the capacity of existing hydroelectric plants may also incorporate technology that introduces oxygen and helps combat the low dissolved oxygen problem that exists today below a number of TVA dams.
- TVA's existing coal-fired plants are responsible for most of TVA's contribution to water pollution. As described in the section on Air Resource Impacts, cost-effective repowering of selected less-efficient coal-fired units provides some of the best options for water quality.
- Repowering or adding capacity at any existing facility is preferable from a water resource perspective because it lessens the risk of impacts to those resources. Generally, from a water quality viewpoint, repowering of existing units is preferable to construction of new plants because the repowered units would have less of an impact on aquatic resources than the older units they replaced. Also, there is a risk of adverse effects from construction runoff and the disturbance of small streams associated with construction of new plants at sites that have not yet been developed. Construction of additional transmission lines on new rights of way could affect aquatic communities in small streams crossed by the lines. However, these construction effects can be greatly reduced or avoided through the use of construction best management practices that properly control contaminated runoff.
- Strategies that include increased use of coal, either for combustion or gasification, will result in increased risk of environmental impacts on water resources. This is due primarily to adverse effects in the fuel cycle, including those resulting from sediment runoff from strip-mined land and acid mine drainage. Streams in Appalachia and western

Kentucky are currently degraded by coal mining and increased use of coal may, without proper mitigation, result in continued degradation. However, various regulatory processes are in place to reduce the risk of adverse impacts and to require the appropriate use of mitigative measures. This includes the regulations implementing the Surface Mining Control and Reclamation Act.

- Unlike coal combustion, coal gasification does not produce large quantities of ash, which can adversely affect surface and groundwater during handling and disposal. Coal gasification produces an inert glass-like slag that can be used as a construction material.
- Generally, new capacity from demand-side management will result in few, if any, negative water resource impacts.
- The production and disposal of contaminated groundwater during the collection of coalbed or coal seam methane can pose problems and unless handled appropriately could affect water quality and aquatic communities.

STRATEGY-BY-STRATEGY COMPARISON OF WATER IMPACTS

Strategy D: Reference, or "No Action" Strategy

Strategy D is considered the "No Action" strategy, or TVA's most likely course of action for adding new capacity during the next 25 years had the Energy Vision 2020 process not been undertaken. Well over half of the new capacity added during that time would come from new gas-fired simple-cycle combustion turbines and combined cycle combustion/steam turbines. More than a third would be produced by integrated gasification combined cycle and coal gasification systems. Seven percent would be purchased from independent power producers using gas-fired simple and combined cycle cogeneration systems. Demand-side management, as a percentage of new capacity, would steadily decrease from 30 percent in 2000 to 3 percent in 2010. Since this reference strategy would not involve decommissioning or repowering existing facilities, any operational or fuel cycle aquatic effects from existing facilities would remain unchanged.

Under the "No Action" strategy, effects on water quality and aquatic communities would tend to be localized and associated with construction and operation of new facilities at undeveloped sites. Fuel cycle effects from drilling and mining at remote locations could be expected, albeit the significance of such effects would be reduced through the operation of various regulatory processes. Localized or site-specific effects would be addressed in subsequent reviews of specific resource options that are proposed.

Construction impacts are generally associated with the erosion/runoff of disturbed soil during storm events. The suspended soil entering a stream or river can carry contaminants (e.g., cleaning solvents, fuels) spilled during construction activities. Suspended material in a stream or river can also absorb heat and increase ambient temperature. Discharges of small amounts of chemicals used in cleaning of equipment and sewage treatment plant effluents (wastewater) could also have minor impacts. New gas pipelines would be required for some options and possibly barge unloading facilities for the coal gasification options.

Siltation can affect aquatic life by clogging fish gills, smothering fish eggs and benthic organisms, and reducing photosynthesis of phytoplankton and aquatic plants. Dredging destroys benthic (i.e., bottom-dwelling) organisms in dredged areas, and chemicals can cause direct toxic effects or indirect effects through bioaccumulation in the tissues of aquatic organisms. Sewage effluents (wastewater) contain human pathogens and oxygen-demanding substances. However, all of these potential effects on the aquatic environment can be minimized or avoided through the use of appropriate site management practices and proper treatment of effluents.

Operational aquatic effects in receiving waters can be caused by thermal discharges, process discharges, coal and ash handling, and small amounts of chemical and sanitary wastes. This reference strategy and nearly all the strategies being considered envision a large portion of new power from integrated coal gasification combined cycle technologies. While integrated coal gasification combined cycle plants are an attractive alternative to conventional power production methods, a number of challenges remain, one of which is water and wastewater management.

Overall, there is very little information generally available on the treatment of integrated coal gasification combined cycle wastewater, and only a limited amount of commercial experience in treating such wastewater. Gasifier design and type of coal used are the principal variables that determine the composition of gasification wastewater. Gas treatment after gasification produces wastewater that may contain organic material, phenolics, cyanides, sulfides (and other reduced forms of sulfur), and ammonia. These are not present in wastewater from conventional coal-fired power plants. Many of these compounds are highly toxic to aquatic life and would pose a significant threat without adequate treatment and removal.

However, technology is available to treat integrated coal gasification combined cycle wastewater to meet the most stringent standards. All operational impacts would be mitigated through the states' National Pollutant Discharge Elimination System permitting processes. In most, if not all, cases these facilities would be considered "new sources" under the Clean Water Act. As such, they would be subject to effluent limitations under New Source Performance Standards for steam electric power plants and chemical manufacturing plants where co-production is planned.

These would be more stringent standards than those at existing plants.

Possible effects of heated effluents on aquatic life that have been suggested include mortality, advanced fish spawning, increased toxicity of certain pollutants, and shift of phytoplankton populations toward less desirable species. Since any new facilities would likely dissipate waste heat through cooling towers, the possibility of these impacts occurring at new TVA facilities is minimized. However, if cooling systems at new facilities are operated in closed cycle, elevated levels of dissolved solids (including metals) will occur in discharged recirculation water through evaporative concentration of solids (including metals). The significance of this would depend on site-specific factors such as speed of mixing, degree of dilution, and metal concentrations in intake water.

National Pollutant Discharge Elimination System permits strictly regulate chemical and sanitary wastes. The use of various oxidizing and non-oxidizing chemicals for control of biofouling organisms can be expected to increase at existing power facilities due to the recent introduction of the zebra mussel *(Dreissena polymorpha)* into surface waters in the TVA service area. The permitting process will establish appropriate limits on biofouling control chemicals to protect aquatic resources, but increased use of such chemicals poses an increased risk of adverse effects. Such controls will also be required at new facilities, but careful advance planning can reduce the threat of zebra mussels and minimize the need for control chemicals.

Aquatic life could be affected by killing or injuring adult fish by impinging (colliding) on intake screens and entraining (drawing through equipment) plankton and fish larvae contained in intake cooling water. Factors such as the location and design of intake structures, the volume of water used, and other site-specific factors would alter the magnitude of such effects. Careful attention during the planning and design phases of facility construction can reduce these potential impacts to acceptable levels.

Aquatic effects associated with coal ash disposal at existing coal-fired units would be minimized in the proposed coal gasification schemes. The process would convert ash to an inert glass-like slag that is non-leachable and suitable for use as a construction material. Mining of high sulfur coal used to fuel the integrated coal gasification facilities could result in some aquatic environmental effects from acid and chemical drainage, land destabilization, and erosion. This would occur both inside and outside the TVA service area. Coal deposits are usually accompanied by pyretic materials that, when exposed to air and water, form sulfuric acid. This and other chemical compounds from mining can pollute water and affect aquatic organisms. There are, however, regulatory processes that are formulated to reduce or eliminate such possible effects. Similarly, activities associated with drilling for natural gas can cause localized aquatic effects, primarily from physical disturbance of habitats and disposal of co-produced groundwater, which may be high in salinity.

Measurements for surface and groundwater environmental evaluation criteria relating to (1) human health (ingestion), (2) water supply and waste assimilation, and (3) fish and aquatic life and biodiversity have been combined and summarized into indices for each of these areas. The score of 1.00 represents the effects of Strategy D, the "No Action" strategy. Based on this analysis, the water impacts of all of the alternatives presented vary only slightly from the reference, or "No Action," strategy, except Strategy T, which is somewhat better in all three areas. The reference, or "No Action," strategy and the final seven strategies analyzed are described in *Figures T2-1* to *T2-3*.

Strategy J – Bellefonte Coproduct and Renewable Strategy

In this strategy, about half of the new capacity in 2020 would be natural gas-based, from either TVA-owned simple cycle turbines or purchased from combined cycle plants owned by independent producers. About 40 percent would be coal gasification combined cycle, including converting Bellefonte to integrated gasification combined cycle with methyl tertiary butyl ether as a marketable coproduct. The other resource options that make up this strategy include renewables (landfill and coalbed methane) and modernization of hydroelectric plants. There would be no repowering or retiring of existing operating plants. Therefore, there would be no reduction in existing water quality or aquatic life impacts due to selection of this strategy.

Off-site impacts on groundwater related to natural gas drilling operations would have the greatest potential for aquatic resource impacts under this alternative. Some potential surface water effects could occur as a result of gas pipeline construction. Also, the construction of new facilities could cause localized effects from erosion of disturbed soils. These impacts would generally be limited to the transport of adsorbed contaminants during rainfall/runoff events. Contaminants of concern would be those spilled or uncontrolled during construction activities (e.g., solvents, fuels). These impacts would be reduced or avoided through the utilization of appropriate erosion control practices.

Operational effects on water quality can be caused by the discharge of heated cooling water and small amounts of chemical and sanitary wastes. The discharge of these contaminants would be regulated by the state National Pollutant Discharge Elimination System's permitting process and potential impacts would be minimized or avoided.

The primary difference between this and Strategy D (the "reference" strategy) is the conversion of the partially constructed Bellefonte Nuclear Plant to an integrated coal gasification combined cycle plant with a facility for coproduct-production of methyl tertiary butyl ether. As discussed, gasification process wastewaters may contain toxic components not associated with conventional coal-fired power plants and therefore may be potentially more damaging to aquatic life in receiving waters. The specifics of the water and wastewater characteristics of this plant would be detailed in a site-specific environmental analysis that would be prepared if this option were selected. In any case, integrated coal gasification combined cycle wastewater is treatable and discharges would be strictly controlled under National Pollutant Discharge Elimination System permits. That would also be true of wastewater associated with a methyl tertiary butyl ether co-production facility.

The additional hydroelectric generation in this strategy would be obtained by undertaking additional modernization projects at existing hydroelectric plants. No new hydroelectric plant construction is contemplated. Of the renewable options, only coalbed methane poses major wastewater disposal problems. This is primarily due to contaminated coproduced groundwater that could affect surface water resources. Coproduced water is often disposed of by returning it to the source from which it was drawn.

Water quality indices for Strategy J are identical to the reference, or "No Action," strategy except for the fish and aquatic life and biodiversity index. This index is rated 0.99, which indicates a very slight improvement over the reference, or "No Action," strategy. This improvement is due to a reduction in the amount of coal burned, relative to the reference strategy.

Strategy M – Combined Demand-Side Management and Off-System Sales Strategy

Strategy M emphasizes natural gas and demand-side management in the near term with a shift toward more coal combustion and coal gasification options in the long term. Coalbed and landfill methane recovery options also come into play in the later years of the study. Shawnee Fossil Plant would add one new unit to its existing 10 coal-fired units.

Increases in natural gas usage could impact off-site groundwater and surface water. Drilling operations could affect the former, gas pipeline construction the latter. Similarly, additional coal utilization could add impacts from increased mining activities. Aquatic effects from the construction of new facilities would also be a possibility. However, there are regulatory processes and best management practices that would reduce or eliminate the risk of such impacts.

Increased coal usage can affect ground and surface water quality due to coal-ash disposal. The integrated coal gasification combined cycle and related options generate complex and potentially toxic wastewaters. The coalbed methane option also presents a potential threat to aquatic communities because of the possible coproduction of contaminated groundwater that would require disposal. The state discharge permitting process would mitigate or avoid impacts to surface waters. Groundwater impacts, however, are much more difficult to control and costly physical mitigation measures may be required, such as synthetic liners for treatment or holding ponds.

The water quality indices are identical with the reference, or "No Action," strategy, except for the health ingestion index. This index is rated at 1.01, which indicates a slightly higher impact than the reference, or "No Action," strategy. The water health ingestion index uses three weighted surrogate measures: power production from nuclear (5%), coal-fired (60%), and peaking hydro (35%). Hydro peaking and nuclear power production are constant for all final seven strategies as well as the reference strategy. As a result, differences in coal-fired (existing plant) power production governs the index. This strategy, as well as strategies Q, R, and S, have increased coal-fired power production from existing plants relative to the reference strategy which results in index values slightly greater than 1.0.

Strategy O – Bellefonte Coproduct, Demand-Side Management Blocks One and Two, and More Off-System Sales Strategy

This strategy is similar to Strategy M in that it also emphasizes demand-side management in the near term and gas and coal gasification in the long term. It includes converting Bellefonte Nuclear Plant to a coal gasification process with coproduction of methanol and its derivatives. Other resource options include landfill and coalbed methane recovery. Unlike Strategy M, however, no new pulverized coal units are included, and there is a greater emphasis on independent power purchases.

Potential impacts on water quality under this strategy include those listed in Strategy M. Additional impacts could be associated with converting Bellefonte Nuclear Plant to coal gasification as described under Strategy J. Construction effects generally tend to be localized and temporary and can be minimized with appropriate materials handling and erosion controls.

Landfill and coalbed methane utilization could impact water quality through facility and pipeline construction and disposal of coproduced contaminated groundwater.

The water quality index for health-ingestion for Strategy O is identical to the reference strategy. The fish and aquatic life and biodiversity index and the water supply and waste assimilation index are rated 0.99, which is only a very slight improvement over the reference, or "No Action," strategy. The fish and

aquatic life improvement is due to a reduction in the amount of coal burned and the water supply index improvement is due to reductions in thermal discharges and water consumption relative to the reference strategy.

Strategy Q – Flexible Strategy with External Options

This strategy essentially duplicates the options in Strategy O with the addition of purchased power and flexible options that involve the off-system purchase of options to buy power at a certain time and price. Strategy Q includes only about half as much demand-side management as Strategy O.

This strategy differs from Strategy O in its off-system power purchase and management, which do not affect water quality in the Tennessee Valley, but could pose risks to water resources where they are located. The water quality index for health-ingestion for Strategy Q is rated 1.01, which indicates a very slightly increased risk for impacts, for the reasons noted above for Strategy M. The water supply and waste assimilation index and the fish and aquatic life and biodiversity index are rated at 0.99, which indicates a very slight improvement over the reference, or "No Action," strategy. The fish and aquatic life improvement is due to a reduction in the amount of coal burned, and the water supply index improvement is due to reductions in thermal discharges and water consumption relative to the reference strategy.

Strategy R – Flexible Strategy with Internal Options

This strategy contains the same options as Strategy Q with the same capacities, except for one new gas-fired combined cycle unit, and a considerably reduced reliance on off-system power option purchases.

Potential impacts on water quality under this strategy are identical to Strategy Q, except for additional impacts that may be associated with a gas-fired combined cycle unit. These potential ground and surface water impacts could result from off-site drilling operations and facility construction. The water quality indices for Strategy R are the same as for the reference, or "No Action" strategy, except for health-ingestion. This index is rated 1.01, which indicates a very slight increased risk, as discussed under Strategy M.

Strategy S – Low Cost, Low Rates, and Improved Environment Strategy

This strategy contains the same options as Strategy O, with more purchased power in the short term, a higher level of coal gasification generation in the middle years, and about half as much demand-side management overall.

Potential impacts on water quality under Strategy S are indexed identically to the reference, or "No Action," strategy, except for health-ingestion. This index is rated at 1.01, which indicates a very slight increased risk over the reference, or "No Action," strategy, for the reasons outlined under Strategy M.

Strategy T – Low-Cost Renewables, Low-Price Demand-Side Management, Repowering, and Bellefonte Coproduct Partnership Strategy

Much of the new capacity added by 2020 under this strategy would be from new natural gas-fired turbines, natural gas repowering of some existing coal-fired units, and coal gasification. A number of renewable and energy storage options, including wind, landfill and coalbed methane, hydroelectric plant improvement, and compressed air energy storage, make up about 25 percent of all new capacity. A small amount of capacity would result from new pulverized coal units.

This is the most diverse mix of generating options among the strategies under consideration. By virtue of its emphasis on renewables and repowering of old coal-fired units, this strategy is the one likely to result in the least overall impact on aquatic ecosystems. The environmental indices for this mix are 0.92 for health-ingestion, 0.99 for water supply and waste assimilation, and 0.96 for fish and aquatic life and biodiversity. This represents the greatest improvement compared to the reference strategy. The improvement in the health index is due to an 8 percent reduction in total fossil generation, the fish and aquatic life improvement is due to a reduction in the amount of coal burned, and the water supply index improvement is due to reductions in thermal discharges and water consumption relative to the reference strategy.

Under this strategy, water quality effects from the use of natural gas could occur in association with off-site drilling operations (groundwater effects) and potentially from the construction of facilities and pipelines (surface water effects). Construction impacts would tend to be localized, temporary, and generally in association with storm runoff. Mitigation of construction effects could be accomplished with the implementation of best management practices.

Additional coal-fired units could have potential impacts on ground and surface water mainly in association with ash disposal. Chemical contaminants in coal-ash are dependent on the type of coal, and the potential effects are well documented. Mitigation could involve physical measures, such as disposal pond lining to protect groundwater. The repowering of older coal-fired units to natural gas-fired combined-cycle units would tend to have an overall mitigating effect on coal-related impacts because new sources are held to more stringent requirements than the old sources they replace. All surface water discharges from plants would be regulated under state National Pollutant Discharge Elimination System permitting limitations.

SECTION 5: LAND RESOURCE IMPACTS OF ALTERNATIVE STRATEGIES

Understanding Land-Related Environmental Impacts

Volume 2, Technical Document 1, Comprehensive Affected Environment, provides an overview of land resource issues and land use. Because land resource impacts tend to be so site-specific in nature, developing indices for such impacts was not practical. Land resource impacts can be more fully and meaningfully evaluated when proposals to implement specific energy resource options are made in the future. These impacts will be addressed in subsequent environmental reviews.

However, certain conclusions or observations can be made at this programmatic level of review based on the generic attributes of various energy resource options.

Factors such as siting of generation facilities, siting of transmission facilities, fuel sources, and waste disposal, all affect land use. Resulting impacts can include:

- Long-term loss of land use
- Loss of plant and animal habitats
- Long-term aesthetic loss
- Fragmentation of forests
- Electric and magnetic fields exposure

Figure T2-28 gives the estimated total land requirements that would likely be required by TVA's final strategies and Strategy D, the reference strategy. Land use estimates range from 10,300 acres for the reference strategy to 62,000 acres for Strategy T. The larger amount of land used for Strategy T is due primarily to the extensive acreage that is needed to support wind turbines. *Figures T2-1* to *T2-3* describe the final strategies considered in the analysis.

The construction of new power generating facilities has greater potential for directly affecting land resources than does retrofitting or altering power sources for existing generation facilities. A new plant would consume additional land acreage, whereas altering existing facilities would not likely require significant additional acreage.

This section deals primarily with the direct effects to land resources resulting from the implementation of new power generating facilities. Discussion has been restricted to a general level. More detailed analysis and discussions will result from the environmental reviews performed for new facilities as they are sited. Specific issues such as endangered species, wetlands, and other site-specific concerns would be examined in these reviews. Discussion in this section deals with issues such as land consumption, land use changes, and land disturbance.

FIGURE T2-28. **Estimates of Direct Land Use for Plant Siting, Power Transmission, and Plant Access for Each Strategy**

Strategy	Capacity in Year 2020 (Megawatts)	Total Land Use (Acres)
D-Reference	15,520	10,336
J	16,456	17,711
M	14,765	16,299
O	15,406	16,080
Q	16,100	15,335
R	16,720	15,685
S	15,976	16,541
T	17,715	61,957

The analysis of potential impacts on land resources was conducted at two levels:

- Potential effects resulting directly from the siting of the power plant itself
- Potential consequences associated with fuel sourcing, power generation, and waste

This analysis is also based on fuel sources, rather than on specific strategies. Potential consequences of siting various types of generating facilities were analyzed based on fuel source. This approach simplifies comparison of individual strategies. The fuel sources (i.e., fuel cycles) evaluated include:

- Coal
- Natural gas
- Biomass
- Hydroelectric
- Solar and wind
- Nuclear

Environmental consequences from the plant "footprint" (i.e., the area occupied by the plant proper) are difficult to quantify. In general, these "footprint" effects are comparable, but not identical, across fuel options. Potential effects relate to the total acreage required and the acreage occupied by buildings, parking areas,

switchyards, coal piles, and other elements. Additional acreage to provide visual or noise buffers increases overall plant acreage considerably over the actual amount of acreage required for the plant itself. These buffer lands may continue to have uses such as pasture, forest management, or row crops thus reducing impacts.

The construction of new generating facilities can bring with it the construction of a distribution network of transmission lines, substations, and switchyards. Since a distribution network would be necessary regardless of power generation method, potential effects from these facilities would not likely differ by fuel source.

Considerable acreage of land is required for transmission line rights-of-way. A 100-foot wide right-of-way occupies about 12.1 acres per mile of transmission line. Permanent woody vegetation is not permitted within the rights-of-way, but pasture and agricultural land uses are allowed. When rights-of-way cross large forested areas, forest fragmentation can occur. Aesthetic impacts can occur in situations where rights-of-way are especially noticeable or visible.

The following summary sections, which focus on fuel types, describe potential "footprint" effects and operational effects resulting from fuel sourcing, power generation, and waste.

SUMMARY OF DIRECT LAND-USE IMPACT FINDINGS

- Resource options that involve expansions at existing plants or the repowering of existing units may have little or no land resource impacts. These include options at the Bellefonte Nuclear Plant site, co-generation options, some option purchase agreements, hydroelectric plant improvements, repowering that makes existing plants more efficient, and generating units added at existing coal plants.
- Coalbed methane may require a network of access roads to install and maintain the gas wells, collection rights-of-way piping, and smaller generating units distributed over larger areas. Factors such as the remoteness of the area, distance between wells, size and distribution of power plants, and installation of transmission lines to connect the power plants to the TVA power system influence land use. Five acres per megawatt was assumed for the analysis as a conservative estimate of land use for access and transmission. However, coalbed methane recovery from existing mines would impact land resources less.
- The 2,000 megawatts of wind energy capacity in Strategy T is estimated to require 50,000 acres of land at high elevations. Wind turbines have a lower power output per acre of land use compared to most generation options. Groups of wind turbines, termed a wind farm, are interconnected to a common switchyard. These turbines are often located in remote regions because wind is best at higher elevations on ridgelines and bluffs. Large-scale use of wind energy would require extensive tracts of land for locating hundreds of visually prominent wind turbines. Since wind resources are limited in the Tennessee Valley, the likelihood of disturbing sensitive ecological areas increases with the amount of wind power produced.
- Methane gas collected from landfills is a renewable energy source that prevents the release of this greenhouse gas to the atmosphere. Methane collection and its use as decentralized or distributed power returns these lands to a productive use, but would have effects similar to those associated with the infrastructure needed to support use of coalbed methane. However, landfill methane recovery would have lesser impacts than coalbed methane recovery since roads and transmission lines may already be in place. Landfill methane recovery and coalbed methane recovery are both considered direct land use, since power generation is integrated into the collection activity.
- There is sufficient land in the TVA region to allow energy resource options to be put in place without impacting sensitive land resources such as wetlands or endangered species. Land resources should not be a constraint on the deployment of any of the energy resource options identified in TVA's final strategies, with the possible exception of wind turbines.
- Other land-use conditions potentially impacted are aesthetics, electric and magnetic field exposure, and noise. Conventional power plants, typically located in rural areas, are out of character with their surroundings. Local topography, site layout and natural buffering, plant design, and population density and distribution all determine the kinds of potential site-specific impacts.

SUMMARY OF INDIRECT LAND-USE IMPACT FINDINGS

- Fuel acquisition and waste disposal are involved in power generation and affect indirect land use. Coal mining, particularly surface mining, is a disruptive land use activity. All of TVA's final strategies, including the reference strategy, expand TVA's use of coal. Total coal use rises about 35 percent from present levels for most strategies. Only Strategy T is significantly different, using about 12 percent less coal than the reference, or "No Action," strategy but still 21 percent more coal than current levels.
- Coal-fired plants have a waste stream of combustion byproducts. The byproducts—fly ash, bottom ash, and slag—are all marketable, depending on both their quality and market conditions. Unmarketed byproducts must either be stored or disposed of. This typically requires long-term land use and management.
- Natural gas drilling is typically less environmentally disruptive than coal surface mining activity for equivalent energy supply.

Also, gas-fired plants have no significant solid waste by-product. All the strategies make significant use of natural gas. Strategy T uses the most, 1.7 to 4 times more than the other strategies. Natural gas is used for repowering of existing coal-fired units. This provides additional benefits by eliminating coal byproduct production and increasing plant efficiency.

- Use of residue or waste wood fuel would reduce landfill requirements and some methane production.

SUMMARY OF NATURAL RESOURCE IMPACT FINDINGS

- Most potential impacts on land resources are site or project-specific, and would be assessed in siting studies and environmental reviews for generation and transmission facilities. These potential impact areas include threatened and endangered species, plant and animal habitats, sensitive or important ecosystems, forest fragmentation, and aesthetics.
- There may be air pollution impacts on land remote from a plant site. These impacts are addressed in the air resources section of this document.

Analysis of Fuels Used In Energy Vision 2020 Strategies

FUEL SOURCING

Fuel sourcing for hydroelectric, solar, and wind power plants are not addressed in this section because these power sources create energy from water, sunlight, and wind, respectively, and as a fuel generally do not have land resource impacts. (The creation of hydroelectric dams can have significant land resource impacts but the "fuel," water, is produced by rainfall.) Only the coal, biomass fuel for co-firing, and nuclear sections address waste-related effects, since natural gas, hydroelectric, solar, and wind power plants do not produce waste byproducts.

COAL-FIRED PLANT IMPACTS

The coal-related environmental impacts for the various strategies are affected by the amount of coal used by each strategy. Use of coal by strategy is shown in *Figure T2-29*. The environmental impacts of coal as a fuel are discussed in the following section.

Site Effects

Coal-fired generating plants tend to require relatively large acreage. They need coal-loading facilities, a coal pile, and ash disposal facilities that require many acres of land, and visual screens or noise buffering. Existing TVA coal-fired plants are located along navigable waterways to provide barge access for transporting coal to the plant and/or as a source of boiler and cooling water.

FIGURE T2-29. **Coal Use for Each Strategy (Annual Average)**

Strategy	Tons
D-Reference	52,073,962
J	51,253,835
M	52,163,285
O	51,187,739
Q	51,669,092
R	51,883,575
S	51,847,911
T	45,860,676

Aesthetic effects of a coal plant are difficult to address because such effects tend to be subjective. However, unless the plant is remote or obscured by hills, its facilities tend to be noticed by the public. Tall flue gas stacks, which are typical of coal-fired plants, can be seen from large distances depending on the stack height and surrounding terrain and often result in degradation of aesthetic character. Especially tall stacks may be visible for several miles. Strobe lights mounted on stacks are effective safety measures, but result in further aesthetic effects. Coal-fired plants can also have cooling towers. Natural draft cooling towers may be as tall as the stacks and have visible water vapor plumes during most weather conditions.

Operational Effects

Noise is almost always a concern in power generation from fossil sources. However, plant designs normally accommodate noise concerns. New plant construction would also meet any applicable noise and emission limitations; however, such limitations are rare in the Valley.

Other than potential impacts due to air pollutants, coal-fired generation options do not directly impact land resources as a result of their operation. However, coal plants can have fuel sourcing and waste generation effects. These are described below.

Fuel Sourcing Effects

TVA purchases about 35 to 40 million tons of coal per year to fuel its 11 existing fossil plants. The process of obtaining this coal involves land disturbances. Obviously, coal must be removed from the earth. According to recent figures, about 75 percent of TVA's current coal demands are supplied from subterranean mines (i.e., underground or "deep mines"), while the remainder comes from surface (i.e., strip) mines. Coal supplied from deep mines results in minimum surface land disturbance. Supplying coal from strip mines results in surface disturbance. However, current mining regulations require coal operators to

FIGURE T2-30 **Combustion Byproduct for Each Strategy (Annual Average)**

Strategy	Tons
D-Reference	6,166,437
J	5,809,790
M	6,663,316
O	5,826,405
Q	5,964,794
R	5,929,001
S	5,921,821
T	5,238,745

FIGURE T2-31. **Natural Gas and Methane Recovery Use for Each Strategy (Annual Average)**

Strategy	Landfill and Coalbed Methane (Billions of Standard Cubic Feet)	Natural Gas (Billions of Standard Cubic Feet)	Total (Billions of Standard Cubic Feet)
D-Reference	0	93.5	93.5
J	45.8	64.9	110.7
M	34.8	41.0	75.9
O	44.2	53.9	98.1
Q	48.9	68.4	117.3
R	48.9	63.4	112.3
S	49.4	59.2	108.6
T	23.4	162.0	185.4

restore the land to its original approximate contour, which helps to reduce potential impacts.

The amount of surface acreage affected by supplying coal varies and depends mainly on the thickness of the coal seam. For comparison, a coal seam one foot thick yields about 1,800 tons per acre. Assuming the average TVA coal-fired plant requires 3.4 million tons of coal per year (37 million tons for 11 plants), and that 25 percent of this total comes from surface mines, then about 840,000 tons of coal per year comes from surface mines. At a yield of about 1,800 tons per acre (for a 1-foot thick seam), approximately 465 acres per year would be required. Thicker seams would reduce this acreage accordingly (i.e., a two-foot thick seam would result in approximately 235 acres being disturbed).

The table in *Figure T2-29* gives the annual average coal use for the planning period for each strategy. All strategies use about 35 percent more in an average year than the FY 1994 procurement level of 38 million tons. Compared to the reference strategy, only Strategy T has a significant difference in coal usage, 45 million tons less, or 12 percent less coal.

Once mined, coal must be moved to the power plant. This can require the construction of new roads and/or rail lines and the consumption of additional acreage. From a fuel transportation standpoint, coal removed from existing mines would not likely result in additional effects to land resources. Because much of the coal is currently delivered via rail, construction of any new coal plants at greenfield sites could result in construction of new rail lines to those plants.

Waste

Coal-fired power plants generate various amounts of ash and other solid byproducts. For fiscal year 1995, TVA estimates that existing coal facilities will generate about 3 million tons of fly ash, 1.25 million tons of bottom ash/slag, 1.2 million tons of gypsum (from flue gas desulfurization control equipment - scrubbers), and 1 million tons of coal wash refuse. The amount and type of solid waste depend on the technology used to collect this material, as well as the characteristics of the coal burned. All these plants generate ash of some sort, which must be discarded or used. This material is usually placed in ash ponds, slurried, or dry stacked. Ash disposal areas are typically located on-site or adjacent to the generation facility. The acreage required for disposal depends on the net ash generation rate of the facility and the per-acre storage capacity of the disposal area.

Not all ash must be stored or disposed of on-site. Markets exist for coal combustion or pollution control byproducts. Depending on the ash collection system and the quality of the ash, this material may be used in the manufacture of building materials, mainly gypsum products such as wall board (i.e., sheetrock), or as soil amendments, and as filler in paving and construction materials (e.g., concrete). Some existing coal plants dispose of a large proportion of their ash via commercial markets.

A range of disposal site lifetimes exists at TVA's existing coal-fired plants. The rate of byproduct production and use contributes to the lifetimes of the disposal/storage sites. Additional land acquisition and/or land use may be required over the life of the plants.

The alternative energy strategies have a range of annual average byproduct production from 5,238,745 tons for Strategy T to 6,166,437 tons for the reference strategy during the 1996-2020 planning period shown in the table in *Figure T2-30*. TVA has an average byproduct utilization rate of 25.4 percent. By the year 2000, the rate is projected to be over 33 percent. The current national average is about 21.8 percent.

TVA analyzed a full range of possible byproduct applications based on the chemical and radiological properties and behavior of ash and slag from its plants in an environmental assessment. The assessment concluded that none of the applications examined would create significant environmental impacts. No

significant environmental impacts are anticipated from new storage or disposal areas that are permitted as landfills by the states. However, site-specific environmental reviews would be done for any new disposal or storage area.

NATURAL GAS-FIRED AND METHANE RECOVERY PLANT IMPACTS

The environmental impacts of natural gas for the various strategies vary with the amount of natural gas and methane recovery. (See *Figure T2-31* for strategy use of natural gas and methane recovery.) The environmental impacts of natural gas and methane fuels are discussed in the following section.

Site Effects

Acreage required for natural gas-fueled power generating plants is comparable to that required for a coal-fired plant with similar capacity. The overall facility "footprint" would be somewhat smaller than for a coal-fired facility with the same generating capacity because fuel off-loading facilities (i.e., railyards, etc.) and ash disposal areas are not required. Flue gas stacks are typically the most prominent feature of gas-fired plants but are typically not as tall as stacks for coal-filled plants. Strobe lights mounted on stacks are effective safety measures, but result in further aesthetic detractions. These plants would not have cooling towers if an existing coal-fired plant is repowered. Mechanical draft cooling towers would be used at a new plant and would have a visible vapor plume during most weather conditions.

Operational Effects

The operation of gas-fired generation facilities causes few effects to land resources. Ash disposal areas are not required and there is very little solid waste (e.g., ash), compared to coal-based generation. Power generation by natural gas-fueled facilities also causes minimal potential impact on land resources.

Noise-related effects are similar to those for coal plants. Potential noise effects would be accommodated by plant design and siting criteria.

Fuel Sourcing Effects

Natural gas is a mixture of gaseous hydrocarbons, mostly methane, which occurs naturally in the earth. Natural gas deposits often accompany petroleum deposits and are found in various locations across the United States. An extensive network of pipelines distributes natural gas to users.

Drilling, exploration activities, and delivery systems (pipelines) have the greatest potential for effects to land. This analysis assumes that delivery to the plant site would be by pipeline.

Because there is an abundance of natural gas reserves, including capped wells, the likelihood of additional impacts to land resources from increased demand for natural gas is reduced. Nevertheless, drilling for natural gas is relatively innocuous and is not necessarily detrimental to land resources.

Methane, the major component of natural gas, can be collected from landfills. Energy Vision 2020 considers this option. Landfill-generated methane is typically of lower quality (i.e., less pure methane) and has a lower energy yield than naturally occurring methane. Depending on its quality, landfill-derived methane may have to be purified to meet emission standards before use. Nevertheless, use of methane from this source would provide an alternative natural gas source and would have an overall beneficial environmental effect.

Coalbed methane recovery is another technology for supplying gas-fired plants. Gas wells are drilled into a coal seam to recover the naturally generated methane. A system of wells would feed gas through a network of collection piping to a small generating unit such as a fuel cell or diesel generator. This method of fuel sourcing could be land intensive, requiring access roads to reach well heads, rights-of-way for collection piping, and power transmission lines to decentralized power plants. Methane can also be recovered from existing coal mines. This would require less additional land area.

The need to construct new gas pipelines as a result of building new gas-fired plants or repowering existing plants is difficult to determine. For economic reasons, repowering of existing generating facilities with natural gas would most likely occur at those plants currently near transmission pipelines.

Gas pipelines are usually located underground for safety reasons. On the land surface, a fixed right-of-way is maintained to prevent establishment of permanent woody vegetation. The right-of-way is maintained in a pasture-like condition or used for row crop agriculture; trees are not allowed. This situation does not preclude the use of the right-of-way for productive uses. However, forest fragmentation can occur if the pipeline crosses extensive forest areas. A pipeline requires approximately the same

FIGURE T2-32. **Biomass Cofiring for Each Strategy (Annual Average)**

Strategy	Tons
D-Reference	0
J	184,643
M	187,909
O	184,493
Q	186,227
R	186,956
S	186,903
T	186,903

acreage as a transmission line right-of-way, and potential effects are generally comparable to transmission line rights-of-way.

Figure T2-31 shows the range of natural gas and recovered methane in the alternative energy strategies. Strategy M uses 19 percent less gas than the reference, or "No Action," strategy. Strategy T has the lowest coal use and the highest gas use, 185 billion standard cubic feet, or 98 percent higher than the reference strategy.

BIOMASS-FUEL IMPACTS

Biomass-related environmental impacts of the various strategies vary with the annual average tons of wood co-firing detailed in *Figure T2-32*. Wood co-firing in coal-fired plants is the only type of biomass included in the final strategies analyzed. However, this section discusses the environmental impacts of wood waste as a fuel, as well as other biomass.

Site Effects

Biomass fuels are usually mixed with coal as a supplement, and biomass fuel options typically involve modification of existing coal-fired plants. Therefore, there would be few, if any, additional site-related impacts. Wood waste storage would have to be established, but such a facility would be compatible with the other industrial-type uses found at coal-fired power plants.

Operational Effects

Operational effects of burning biomass fuels are essentially the same as those for coal-firing because biomass fuels would likely constitute only a small or moderate percentage of the fuel burned in the boiler. Thus, any unique emissions associated with biomass fuels would tend to be lost in the much larger emission volumes resulting from burning coal. Potential changes in emissions are one of the issues that would be examined in more detail in site-specific reviews.

Fuel Sourcing Effects

Fuel Types

Wood waste is the primary biomass fuel. Mill and logging residues are byproducts that can be an inexpensive fuel source. Mill residue is the wood discarded either by primary mills, such as sawmills, or secondary mills, such as furniture companies. Residues may be in the form of chips, bark, shavings, or sawdust. The main cost involved is transportation, so residue availability depends on the number of forest product industries in a 50- to 75-mile radius of a power plant. Plants producing these residues do not always produce a consistent volume, as volume changes in response to economic conditions.

Logging residues are the unused growing stock or sawtimber volume of trees cut or killed by logging and left in the woods. Logging residues are generally composed of the tree crown (i.e., branches and limbs that are not large enough to be sold as timber). The volume of timber operations in a 50- to 75-mile plant radius would determine supply availability. Depending on soil conditions, logging residues can provide valuable nutrients to the soil as it decays. Removal of logging residues could therefore negatively impact nutrient cycling capabilities.

Short rotation woody energy crops provide a source of woody biomass. Primary species include eastern cottonwood, sweetgum, sycamore, and black locust. Since short rotation woody crops would be planted to replace conventional agricultural crops such as cotton, corn, and soybeans, a number of potential environmental benefits would result. These include: reduced erosion; reduced runoff of pesticides and nutrients; less risk of contamination of groundwater with nitrates, herbicides, and other pesticides; improved soil physical properties; increased storage of carbon above and below ground; and increased variety of microorganisms, mammals, birds, and other wildlife.

Short rotation woody crops involve intensive forestry operations such as seedling planting and fertilization and herbicide treatments (usually about once per "crop" rotation). Crop plantations would be grown on marginal-to-good former cropland with less than a 5 percent slope. Suitable areas within the Tennessee Valley region include limestone valley soils in northern Alabama, alluvial delta and coastal plain soils in northern Mississippi, and delta lands and loess belt soils in western Tennessee. Production estimates range from 2.3 to 4.3 dry tons per acre per rotation, but tonnage production is projected to double in the next decade due to genetic improvement research. Crop rotation time is expected to be 5 to 6 years.

Switchgrass may be another biomass fuel option. Although switchgrass is not currently produced for commercial sale, it may be a feasible biomass option since farm operators already own the necessary production and harvesting equipment. Production estimates range from 6 to 9 dry tons per acre per year. Energy yield is estimated to be 14.5 million Btu per dry ton.

Amount of Biomass

The amount of biomass required for power generation depends on whether it is the primary fuel or co-fired with coal. When biomass is co-fired with coal, the amount of biomass used will depend on the degree of energy input. Biomass can be a low energy input (1 to 5 percent), moderate energy input (10 to 15 percent), or high energy input (20 to 50 percent). When biomass is the primary fuel, approximately 1,000 acres of short rotation woody crop plantations per megawatt are needed for sourcing. This results in harvests of approximately 200 acres per year per megawatt.

Final strategies examined for Energy Vision 2020 were limited to wood co-firing at coal-fired plants. The reference strategy

uses no co-firing. All other strategies co-fire at a rate of 0.3 percent to the coal energy input for the existing coal-fired system.

Noise and Aesthetics

Biomass harvesting and transportation raise few concerns associated with noise. Also, there are no significant aesthetic considerations associated with mill residues, short rotation woody crops, and switchgrass. Short rotation woody crops would be harvested from recently converted traditional cropland, and would not likely result in the conversion of existing forest lands. Switchgrass is harvested like hay.

Transportation

Transportation costs would dictate that distance from source to power plant be kept to a minimum for mill and logging residues, short rotation woody crops, and switchgrass, which are high-volume, low-value commodities. Transportation costs for wood are approximately three times that for coal on a Btu basis. Current cost projections indicate that biomass sources should be within 50 to 75 miles of power plant locations. Transportation impacts would be those typically associated with large truck uses. These would include some road surface deterioration, possible traffic impediments, and increased risk of accidents. these potential problems would be examined in subsequent, option-specific environmental reviews.

Generation Effects

Most options for biomass fuel usage in Energy Vision 2020 involve co-firing with coal. Wood can be co-fired with coal in various ways:

- For low energy inputs, wood is co-pulverized with coal and fed to the boiler, along with coal.
- For moderate energy inputs, separate wood and coal handling systems and burners are required.
- High wood energy inputs perform best in fluidized-bed boilers. Use of switchgrass as a fuel may require it to be pelletized first.

Co-firing options would not result in any additional plant siting, size, noise, or aesthetic considerations beyond those discussed for coal power plants.

One option for biomass fuel usage is a whole-tree energy boiler power plant. This is a new direct combustion technology that depends entirely on short rotation woody crops as a fuel source. Siting "footprints" of a biomass-fired plant would be similar to that of a coal-fired plant. This option was not, however, included in TVA's final strategies.

Waste

Waste byproducts produced by a biomass co-fired plant are similar to those of a coal power plant, except that ash has a somewhat higher carbon content. Some coal ash byproduct is currently sold as a concrete additive. Research is underway to determine if the carbon content in biomass co-fired ash is too high to be used in concrete manufacturing. Biomass storage areas may also produce an acidic tannin leachate (mainly from wood bark), but common leachate control measures, as well as site best management practices, can satisfactorily reduce the risk of adverse impacts from such leachate.

HYDROELECTRIC PLANT IMPACTS

Only existing hydroelectric plants are included in the final strategies analyzed. The land-related environmental impacts of hydroelectric plants are discussed below.

Site Effects

Of necessity, hydroelectric plants are located at dams. Their actual plant "footprint" is typically small. In most instances, little land is consumed except for transmission facilities (e.g., switchyards), maintenance areas, and parking areas. Their visual impact is minimal, since hydroelectric generating facilities are incorporated into the dam structure. Because no new hydroelectric facilities would be built under any of the strategies considered, there would be no additional site effects.

Operational Effects

Hydroelectric facilities produce no waste materials that affect land resources. They also produce low noise levels compared to coal-fired plants. Power generation from these facilities does not have significant effects on land resources.

Fuel Sourcing Effects

For purposes of discussion, water is considered to be the "fuel" used in hydroelectric production. Hydroelectric plants depend on hydrostatic pressure (i.e., the pressure of deep water) to turn generators. This process produces electricity. A reservoir must be created to produce sufficient pressure and have the recharge capacity to maintain adequate depth at the dam.

Covering land with water to create reservoirs removes it from productive use. Typically, these river bottom lands are fertile and constitute productive forest land, farmland, and wetlands. These uses are lost by flooding. See Volume 2, Document 1, Comprehensive Affected Environment, for additional information about effects of damming rivers. Because no new hydroelectric facilities would be built under the strategies considered, there would be no additional "fuel sourcing" impacts from hydroelectric production.

WIND AND SOLAR IMPACTS

Wind is one of the renewable energy resource options included in TVA's final seven strategies. The land-related environmental impacts of wind and solar power are discussed below.

Site Effects

Wind-powered generation facilities usually have a network of windmills feeding a central switchyard. These windmills are typically located on ridge lines, ridge tops, and along bluffs where ambient wind velocities are capable of providing adequate wind power. Such locations are generally visible from a long distance. Thus, the potential for visual impact from new facilities is high.

Solar facilities require large amounts of relatively flat, open areas in order to collect adequate amounts of solar radiation. Depending on location, the visual impact of new solar facilities could be objectionable. Solar facilities produce very little noise and no waste byproducts. Wind and solar power plants do not use any fuels or produce any emissions; therefore, only generation issues are discussed.

Operational Effects

Wind

Wind-powered generation facilities are composed of a number of wind turbines connected to the utility grid system through one or more interconnections. Turbines produce approximately 0.3 megawatts and are arranged one per 1 to 2 acres. Approximately 1,250 acres would be required for a 50-megawatt power plant. Site requirements are highly specific. The best sites feature a minimum 2,000 to 3,000 foot elevation on abrupt, prominent ridges. Two areas in or adjacent to TVA's Northeast Tennessee Service Area (one on the Cumberland escarpment and another near Johnson City) together have potential for 750 megawatts of economically variable wind capacity. A nearby location in southwest Virginia has potential for another 1,250 megawatts of economically viable wind capacity.

Noise may result from wind power plants. It is caused by air moving over the turbine blades (aerodynamic noise) and by the turbine's mechanical components. However, recent blade design changes have substantially reduced aerodynamic noise. In the past, television interference near wind plants occurred when metal components of older wind turbines reflected broadcast TV signals. Composite materials are now used in many turbine components and reflection of television signals has been diminished. Cable signals are not affected by wind turbines.

Wind power plants may impact wildlife populations. Although mammals do not appear to be affected very much, bird fatalities, especially raptors (birds of prey), have been reported at some plant locations. Avian casualties are caused by several factors including electrocution from exposed contacts on the tops of riser poles and collisions with transmission lines, guy wires, and turbines. Steps can be taken to reduce bird fatalities, including capping all exposed terminals on risers.

Strips of trees cannot be used for visual or noise buffering around wind power plants because of the need for a large acreage of open land free of trees. Turbine blades are high enough to allow multiple uses of land at plant sites. Typical uses include farming, ranching, and some forestry activities. Some land is also left as open space. Typically 85 to 95 percent of the site can be used for nonpower-generating activities, depending on the turbine spacing required.

Solar

Solar-photovoltaic power facilities located in North America are most effective in lower-latitude areas with low cloud cover. In the Tennessee Valley, the Memphis region could have suitable sites. Because the best commercial solar cells operate at about 12 percent conversion efficiency, the maximum power available is about 120 watts per square meter. A typical site size would require 0.5 square mile (320 acres) of land area for a 50-megawatt power plant. There is little noise associated with solar-photovoltaic power plants.

NUCLEAR PLANT IMPACTS

Only existing nuclear plants are included in the final strategies analyzed. Environmental impacts of TVA's nuclear plants are discussed in site-specific environmental impact statements and other environmental documents.

Site Effects

No Energy Vision 2020 strategies call for building new nuclear plants. Therefore, there would be no site effects due to new construction. Some options involve converting partially-constructed nuclear plants, but these options would likely result in few additional site-specific effects.

Operational Effects

Operation of TVA's existing nuclear power plants results in several different kinds of impacts. Small quantities of radioactivity are released to the air and water. Minor quantities of heat and non-radioactive wastewater are released to the Tennessee River and major quantities of heat and water vapor can be released to the atmosphere from plant cooling towers. Because of the size of the sites and their locations, noise is typically not a nuisance. However, because cooling towers are visible, they can be aesthetically objectionable.

Waste

Compared to the wastes or byproducts generated by coal-fired energy processes, nuclear generation produces relatively little waste. Nuclear waste storage is not expected to impact additional land area in the Tennessee Valley. Currently, low-level radioactive waste is disposed at a Barnwell, South Carolina, facility. The states participating in the Southeast Compact Commission have selected North Carolina as the host state to design, license, and construct a new disposal site that is scheduled to open in 1998. TVA plans to continue to use the Barnwell facility for low-level radioactive waste disposal until the North Carolina facility is opened. Should either or both of the disposal facilities close unexpectedly, low-level radioactive waste will be stored in on-site facilities at the TVA nuclear plants. These facilities are sized to handle any anticipated storage needs for the foreseeable life of the plants. Operation of TVA's five nuclear units will produce about 115 metric tons of used fuel each year. High level radioactive waste, known as "spent fuel," is stored on-site in pools or dry storage until the Department of Energy (DOE) accepts physical custody. DOE is required by the Nuclear Waste Policy Act to take responsibility for the management and safe disposal of spent fuel that is generated in this country. DOE is to arrange shipment of spent fuel to a monitored retrievable storage facility or to an underground repository for ultimate disposal by burial. The nation's first underground high-level waste repository is not expected to be in operation until at least 2010. Current spent fuel storage capacity is sufficient at Sequoyah until 2004 and at Browns Ferry until 2007. Based on one unit operating at Watts Bar, spent fuel storage capacity will be sufficient until 2018. Several technologies are available to extend the on-site storage lives.

There are no technological impediments to the safe transportation and storage of high-level radioactive waste. The feasibility of underground waste repositories has been demonstrated in studies and test projects. Waste repositories can be designed with multiple natural and man-made barriers that ensure radioactivity does not escape into the environment. The National Academy of Sciences, the National Research Council, and the Congressional Office of Technology Assessment have endorsed deep geological repositories for storage of high-level waste. High-level waste can also be transported with minimal risk. Specially-constructed casks are used and various regulatory controls apply to such shipments.

Transmission Line Impacts

LAND USE

Construction of new generating resources at greenfield sites would require additional transmission line facilities. Prior to the decision to construct such facilities, more detailed environmental reviews would be conducted. Absent unusual site conditions, construction of transmission lines typically does not result in significant physical environmental impacts. Most vegetation on rights-of-way is removed, but there is some flexibility in locating rights-of-way and in placing structures so that impacts to sensitive resources can be avoided or minimized. The amount of new land committed to rights-of-way would be reduced by the multiple use of existing transmission line rights-of-way.

The construction of new transmission lines and the installation of energy-efficient electrical appliances could result in exposing additional individuals to EMF. Experts disagree on the potential impacts of EMF exposures. Such impacts could depend in large part on proximity to lines and field strength and would be addressed in site-specific environmental reviews.

RIGHT-OF-WAY MAINTENANCE

Safe operation of transmission line rights-of-way requires control of vegetation height. This involves mechanical cutting or mowing or the use of chemical herbicides. The method selected is determined on a case-by-case basis, taking into consideration factors such as terrain, right-of-way accessibility, type of vegetation, land use, wetland status, and economics.

If chemical control is used, only U.S. Environmental Protection Agency-registered nonrestrictive herbicides and licensed applicators would be used. Any use of herbicides must comply with Environmental Protection Agency label restrictions and TVA guidelines for herbicide applications.

"Danger" trees, those outside the right-of-way but tall enough to threaten the safety of the lines if they were to fall, are also periodically identified and selectively cut.

Estimates of Direct Land Use for All Strategies

Generation options directly affect land use. Impacts are caused by siting of the plant and the construction of transmission lines to connect the plant to the power system. Some plants will have little or no additional land requirements because they are located at an existing site. These include options at the Bellefonte Nuclear Plant, cogeneration options, some option purchase

agreements, hydroelectric improvements, and landfill methane recovery. Other options have varying site requirements that are listed in the table in *Figure T2-33*. Transmission right-of-way requirements vary widely, depending on plant location and the number of different plant sites used for an option. For the sake of simplicity, 0.5 acre per megawatt of capacity was assumed for most options not located at an existing plant site with transmission lines in place.

Two notable exceptions to this assumption are coalbed methane recovery and wind turbines. Coalbed methane may require a network of access roads to install and maintain the gas wells, collection piping, and power plants. The remoteness of the area being utilized, the distance between wells, and the size and distribution of power plants would be the primary factors in the resulting land use. Also, transmission lines would be required to connect the power plants to the TVA power system. For these reasons, 5 acres per megawatt was assumed as a conservative estimate of land use for access and transmission. Wind turbines are typically located in remote regions because the wind resource is best at higher elevations on ridgelines and bluffs. Also, wind turbines have a low power density compared to most generation options, so groups of wind turbines are interconnected to a common switchyard. Based on experience in wind turbine siting, 25 acres per megawatt was used to calculate the total of all types of land use.

The resulting land uses for the options making up each strategy are stated in the table in *Figure T2-33*. Land use estimates range from approximately 10,300 acres for the reference strategy to 62,000 acres for Strategy T, which contains 2,000 megawatts of wind turbine capacity using an estimated 50,000 acres.

Aesthetics

Transmission lines and structures are visually intrusive to most people; therefore, the addition of new transmission lines would be aesthetically impactive. The significance of such impacts would depend on the subjective views of each individual and, in part, on the aesthetic setting of a new line. Aesthetic impacts of power plants are discussed in this section under specific types of fuel.

FIGURE T2-33. **Estimates of Direct Land Use for Plant Siting, Power Transmission, and Plant Access for Each Strategy**

Strategy	Type	Capacity in Year 2020 (Megawatts)	Site Land Use (Acres/Megawatt)	Transmission/Access Land Use (Acres/Megawatt)	Total Land Use (Acres)
D-Reference	Combustion Turbines	5,700	0.05	0.50	3,135
	Combined Cycle - Independent Power Producers	750	1.22	0.50	1,290
	Integrated Gasification - Combined Cycle	3,675	0.40	0.50	3,308
	Combined Cycle	2,820	0.07	0.00	197
	Integrated Gasification - Cascaded Humidified Advanced Turbine	2,100	0.40	0.50	1,890
	Combined Cycle - Cogeneration	175	0.00	0.00	0.00
	Coal - Independent Power Producers	300	1.22	0.50	516
	D Total	**15,520**			**10,336**
J	Bellefonte IGCC Conversion with Coproduct	484	0.00	0.00	0
	Coalbed Methane Recovery	1,000	0.03	5.00	5,030
	Combustion Turbines	5,850	0.05	0.50	3,218
	Hydroelectric Improvements	162	0.00	0.00	0
	Integrated Gasification - Combined Cycle	4,410	0.40	0.50	3,969
	Integrated Gasification - Cascaded Humidified Advanced Turbine	2,100	0.40	0.50	1,890
	Independent Power Producers	1,950	1.22	0.50	3,354
	Landfill Methane Recovery	500	0.00	0.50	250
	J Total	**16,456**			**17,711**

FIGURE T2-33. **Estimates of Direct Land Use for Plant Siting, Power Transmission and Plant Access for Each Strategy** *CONTINUED*

Strategy	Type	Capacity in Year 2020 (Megawatts)	Site Land Use (Acres/Megawatt)	Transmission/Access Land Use (Acres/Megawatt)	Total Land Use (Acres)
M	Coal	1,610	1.22	0.50	2,769
	Coalbed Methane Recovery	1,000	0.03	5.00	5,030
	Combustion Turbines	5,550	0.05	0.50	3,053
	Hydroelectric Improvements	162	0.00	0.00	0
	Integrated Gasification - Combined Cycle	3,675	0.40	0.50	3,308
	Integrated Gasification - Cascaded Humidified Advanced Turbine	2,100	0.40	0.50	1,890
	Landfill Methane Recovery	500	0.00	0.50	250
	Shawnee Fossil Plant Unit 11	168	0.00	0.00	0
	M Total	**14,765**			**16,299**
O	Bellefonte IGCC Conversion with Coproduct	484	0.00	0.00	0
	Coalbed Methane Recovery	1,000	0.03	5.00	5,030
	Combustion Turbines	5,700	0.05	0.50	3,135
	Hydroelectric Improvements	162	0.00	0.00	0
	Integrated Gasification - Combined Cycle	4,410	0.40	0.50	3,969
	Integrated Gasification - Cascaded Humidified Advanced Turbine	2,100	0.40	0.50	1,890
	Independent Power Producers	1,050	1.22	0.50	1,806
	Landfill Methane Recovery	500	0.00	0.50	250
	O Total	**15,406**			**16,080**
Q	Bellefonte IGCC Conversion with Coproduct	484	0.00	0.00	0
	Coalbed Methane Recovery	1,000	0.03	5.00	5,030
	Combustion Turbines	4,800	0.05	0.50	2,640
	Flexible Baseload	289	0.00	0.00	0
	Flexible Peakload	0	0.00	0.00	0
	Hydroelectric Improvements	162	0.00	0.00	0
	Integrated Gasification - Combined Cycle	5,145	0.40	0.50	4,631
	Integrated Gasification - Cascaded Humidified Advanced Turbine	2,520	0.40	0.50	2,268
	Independent Power Producers	300	1.22	0.50	516
	Landfill Methane Recovery	500	0.00	0.50	250
	Peak Power Purchases	900	0.00	0.00	0
	Q Total	**16,100**			**15,335**
R	Bellefonte IGCC Conversion with Coproduct	484	0.00	0.00	0
	Combined Cycle	470	0.07	0.50	268
	Coalbed Methane Recovery	1,000	0.03	5.00	5,030
	Combustion Turbines	4,950	0.05	0.50	2,723
	Flexible Baseload	289	0.00	0.00	0
	Hydroelectric Improvements	162	0.00	0.00	0
	Integrated Gasification - Combined Cycle	5,145	0.40	0.50	4,631
	Integrated Gasification - Cascaded Humidified Advanced Turbine	2,520	0.40	0.50	2,268
	Independent Power Producers	300	1.22	0.50	516
	Landfill Methane Recovery	500	0.00	0.50	250
	Peak Power Purchases	900	0.00	0.00	0
	R Total	**16,720**			**15,685**

FIGURE T2-33. **Estimates of Direct Land Use for Plant Siting, Power Transmission and Plant Access for Each Strategy** *CONTINUED*

Strategy	Type	Capacity in Year 2020 (Megawatts)	Site Land Use (Acres/Megawatt)	Transmission/Access Land Use (Acres/Megawatt)	Total Land Use (Acres)
S	Bellefonte IGCC Conversion with Coproduct	484	0.00	0.00	0
	Coalbed Methane Recovery	1,000	0.03	5.00	5,030
	Combustion Turbines	5,850	0.05	0.50	3,218
	Hydroelectric Improvements	162	0.00	0.00	0
	Integrated Gasification - Combined Cycle	4,410	0.40	0.50	3,969
	Integrated Gasification - Cascaded Humidified Advanced Turbine	2,520	0.40	0.50	2,268
	Independent Power Producers	1,050	1.22	0.50	1,806
	Landfill Methane Recovery	500	0.00	0.50	250
	S Total	**15,976**			**16,541**
T	Bellefonte IGCC Conversion with Coproduct	484	0.00	0.00	0
	Compressed Air Energy Storage	1,011	0.04	0.50	546
	Coal	710	1.22	0.50	1,221
	Coalbed Methane Recovery	1,000	0.03	5.00	5,030
	Combustion Turbines	4,800	0.05	0.50	2,640
	Hydroelectric Improvements	162	0.00	0.00	0
	Integrated Gasification - Cascaded Humidified Advanced Turbine	1,260	0.40	0.50	1,134
	Independent Power Producers	450	1.22	0.50	774
	Landfill Methane Recovery	500	0.00	0.50	250
	Repowering Existing Coal-Fired Plants	5,170	0.07	0.00	362
	Shawnee Fossil Plant Unit 11	168	0.00	0.00	0
	Wind Turbines	2,000	5.00	20.00	50,000
	T Total	**17,715**			**61,957**

Injuries, Accidents, and Illnesses

There can be accidental injuries, deaths, and illnesses, both occupational and non-occupational, associated with power system activities. These activities include the direct effects of constructing and operating power system facilities and indirect effects from activities such as fuel procurement and its transportation. Accidental injury or death to the public (non-occupational) from power facility construction or operation are especially unlikely because the public is isolated from these facilities, which are generally secured from public access. One exception is boating and other water recreation near hydroelectric facility discharges where the public must take precautions and heed warnings to avoid unnecessary risk. The risk of accidental injuries and deaths and illnesses are examined for TVA's nuclear plants and pumped storage facilities in site-specific environmental impact statements (TVA 1971, 1972, 1974, 1976).

As decisions are made to add resources to the power system, project-specific environmental reviews will examine these issues to ensure that mitigation measures are considered. Because all strategies expand the power system to meet anticipated increases in power demand and energy use, it is reasonable to conclude that there may be some increase in accidental injuries, deaths, and illnesses.

SECTION 6: ENVIRONMENTAL EVALUATION OF THE PREFERRED PORTFOLIO ALTERNATIVE

Rather than selecting a discrete strategy as its long-term energy plan, TVA has identified as its preferred alternative a portfolio approach. The options in this portfolio are the options identified in the final strategies that TVA developed during the IRP process. In addition, several other options that respond particularly well to certain possible future events ("uncertainties") have been included in the portfolio. TVA believes that this portfolio approach will better achieve TVA's goals and the Energy Vision 2020 criteria than any discrete strategy.

Rationale for Portfolio Approach

After carefully analyzing 2,000 long-term energy resource strategies, TVA used the multi-attribute tradeoff technique to identify seven strategies that achieve reasonably well all of the Energy 2020 criteria, including environmental criteria. The mix of energy resource options in these seven strategies help mitigate the potential adverse environmental impacts associated with meeting the energy needs of the TVA region and result in comparably low environmental impacts.

One approach that TVA could use is to choose one of these strategies as its long-term energy plan and proceed to implement it. As events unfold, elements of the plan would be revised to account for the events (for example, an unexpected rapid increase in natural gas prices). Options in the plan would be Implemented differently than initially contemplated in the plan, or other options would be substituted for those in the plan that were better able to respond to the new event.

One of the important conclusions that TVA has reached in Energy Vision 2020 is that no strategy is likely to be robust enough to adequately respond to all of the uncertain events of the future. The world has become too uncertain. Competition in the utility industry is likely to produce far-reaching changes. Events will happen that will require changes in a chosen, discrete strategy.

This explains the importance of another conclusion that TVA reached in Energy Vision 2020. Flexibility is the key to responding to future uncertainties. The ability to alter long-term plans as events unfold (the definition of flexibility) will be critical. The final seven strategies provide hedges against key uncertainties and this allows TVA to better manage risk.

A second approach that provides more flexibility than choosing a single strategy is to maintain as many good resource options as possible for as long as possible. This would allow TVA to better respond to future events and needs. TVA's portfolio of resource options contains all of the options that make up the final set of seven strategies, as well as a few other options that respond particularly well to certain uncertainties. Much like a portfolio of stocks is chosen to manage risk and accomplish specific objectives, the portfolio approach to energy resource planning enables TVA to meet customer needs while hedging risks and balancing costs, rates, environmental impacts, debt, and economic development.

(In the broadest sense, the portfolio approach is itself a strategy. However, unlike a traditional, discrete Energy Vision 2020 strategy, TVA would not be purporting to decide to implement all of the options in the portfolio if it chooses the portfolio approach. The Short-Term Action Plan discusses the specific actions TVA will be taking in the short-term. The specific options that would actually be implemented from the portfolio would depend on future events, and would be decisions that are made later.)

Analysis of Impacts

The Energy Vision 2020 evaluation was summarized beginning on page 1 of this document. Because of the nature of the evaluation process (how strategies were developed, modified, and reanalyzed), the final seven strategies share many common characteristics, especially environmentally-important characteristics. These strategies and their potential environmental impacts are described in detail earlier in this document.

Because they share many important environmental characteristics, all of the final strategies, except Strategy T, have very similar potential environmental impacts. Strategy T would perform noticeably better environmentally than the other six strategies, except for potential land resource impacts. It has the lowest (best) air and water indices in all seven environmental impact categories. This occurs primarily because some of TVA's existing coal-fired units would be repowered with natural gas under this strategy and natural gas has fewer environmental impacts

than coal. How TVA's existing coal-fired plants are operated in the future under each strategy largely dictates how well the strategies perform environmentally.

The other important strategy presented in detail in Energy Vision 2020 is the reference strategy (TVA's "No Action" strategy, Strategy D). This strategy assumes a typical coal-based expansion of the TVA system to meet future energy needs. Because it relies heavily on coal, it would have worse air quality impacts and worse or only slightly better water quality impacts compared to any of the other final strategies.

The potential impacts associated with the portfolio approach (TVA's preferred alternative) depend on which resource options are eventually implemented, when they are implemented, and how they are implemented. Future events will dictate this. Prior to implementation of resource options, for the future, any needed additional environmental reviews would be conducted. At the implementation stage, TVA will be able to identify potential impacts on a site-specific basis, if appropriate.

Although the impacts of the portfolio approach cannot be assessed definitively at this time, the impacts identified for the final seven strategies likely bound those impacts. Because the portfolio contains all of the options that make up TVA's best seven discrete strategies, it is highly unlikely that implementation of the portfolio approach would achieve better or worse environmental performance than these discrete strategies. At best, implementation of the portfolio approach would produce the same environmental results as Strategy T if future events led TVA to deploy only the options contained in that strategy. At worse, the portfolio approach would have the worst environmental impacts associated with the other six final strategies.

All of the final strategies are expected to generally perform better environmentally than the reference, or "No Action," strategy. Unlike the seven best strategies, the "No Action" Strategy (Strategy D) was not formulated to achieve the best possible results across the Energy Vision 2020 criteria. Consequently, Strategy D performs poorly on a number of criteria, including environmental concerns. Because Strategy D contains resource options that have worse environmental impacts than the resource options contained in the portfolio, it is highly unlikely that implementation of the portfolio would produce impacts that are worse than those that would result from Strategy D.

In conclusion, the potential environmental impacts of TVA's preferred alternative (the portfolio approach) would likely be somewhat worse than those identified for Strategy T but would be no worse than those impacts identified for the other six final strategies. In all likelihood, the portfolio approach would perform better (probably much better) environmentally than Strategy D for most impacts. However, the subsequent environmental reviews that will be done at the implementation stage will more definitively identify potential impacts. The TVA decision-makers and the public can consider these impacts before implementation decisions are made.

Environmental Control Options

TVA's Energy Vision 2020 also addresses the potential environmental impacts of alternative environmental control strategies (the ways TVA could comply with Phase 2 sulfur dioxide acid rain control requirements of the Clean Air Act Amendment of 1990 and achieve greenhouse emission goals). The proposed portfolio of options contain a number of control options that could be implemented to achieve these specific environmental objectives.

The environmental control options contained in the portfolio include fuel switches, sulfur dioxide scrubbers, natural gas repowering, system improvements, and biomass cofiring. The actual implementation of specific control options depend on a number of factors that are specific to the issue of environmental controls. This includes such things as the price of sulfur dioxide emission allowances in the future, the enactment of new environmental legislation, and the promulgation of control-related environmental regulations.

Implementation of specific control options also depends in part on the energy resource options that are eventually implemented. As indicated in *Figure 9-3*, Volume 1, Chapter 9, environmental control options vary somewhat across the final seven strategies because the energy resource mix varies somewhat, particularly in Strategy T. For example, the repowering of several existing coal units with natural gas, which is an option in Strategy T, would obviate the need to add scrubbers at several existing units.

As with the process of implementing energy resource options, the implementation of specific environmental control options would be preceded by appropriate environmental reviews. These reviews would examine the site-specific impacts of proposed control.

SECTION 7: RELATIONSHIP BETWEEN PRODUCTIVITY AND RESOURCES

Relationship Between Local Short-Term Uses of the Environment and Enhancement of Long-Term Productivity

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 that are implemented. Site-specific or option-specific environmental reviews will be conducted before final decisions are made to use certain resources and will examine potential environmental consequences in more detail.

In both the short and long term, TVA would continue to generate electric energy to serve its customers and the public. The availability of electric energy will continue to sustain the economic well-being of the region and allow it to grow. Although the demand for electricity has slowed from the 7 percent annual increases experienced in the 1960s and the early 1970s, customers in both the TVA region and nationally continue to add more electric appliances and equipment to their homes and businesses. Some of these energy uses can be met with alternative sources, such as natural gas, but most require electricity. Electricity has contributed and will continue to contribute to the enhancement of the quality of life in the Tennessee Valley both in the short and long term.

However, the production of electric energy may have both short- and long-term environmental impacts. In the short term, the public may be exposed to elevated concentrations of various air pollutants that are emitted by coal-fired power plants or radioactive releases from nuclear units. The operation of hydroelectric units can release water with low-dissolved oxygen and produce conditions detrimental to aquatic life. Other examples of potential short-term impacts are identified in this document.

Potential long-term impacts have also been identified in the environmental consequences sections of the document. These include potential decreases in the productive capacity of some agricultural lands, degradation of some building materials, and possible adverse effects on forest health. The exposure of some members of the public to certain air pollutants and electric and magnetic fields (EMF) may also have long term, adverse health consequences. Continued generation of nuclear waste will require that waste be stored safely for an indefinite period. This will require that some location or locations be devoted to long-term nuclear waste storage.

Irreversible and Irretrievable Commitments of Resources

The continued generation of electricity by TVA will irreversibly consume various amounts of fuels (natural gas, oil, coal, and uranium). Continued maintenance of TVA's existing energy resources and the construction of any new energy resources will irreversibly consume certain amounts of energy and materials. The siting of most new energy resources will essentially irretrievably commit the sites used to an industrial use because of the substantial disruptions to the sites that would occur and the relative permanence of the structures themselves. The continued generation of nuclear power will produce nuclear waste; therefore, some site or sites will have to be devoted to the safe storage of such wastes. Any such site would essentially be irretrievably committed to long-term storage of nuclear waste.

A number of resource options included in TVA's preferred portfolio strategy are demand-side management and renewable energy resources such as wind or landfill or coalbed methane. Reliance on these resources would lessen the irreversible commitment of other energy fuel sources, but would still involve the irreversible commitment of materials and sites to such resources.

SECTION 8: MITIGATION OF ADVERSE ENVIRONMENTAL AND UNAVOIDABLE IMPACTS

TVA will mitigate site-specific environmental impacts from the construction and operation of new power facilities through a combination of planning, pollution prevention, and environmental controls. However, one of the most important mitigative measures associated with Energy Vision 2020 is the multi-attribute tradeoff method used for the evaluation. This method allowed proposed strategies to be reformulated in order to reduce potential impacts.

Planning

Planning allows assessment (and possible avoidance) of direct construction impacts of the site, community infrastructure, environmental justice, and local economy. An effective planning analysis requires detailed and comprehensive knowledge about the natural resources, infrastructure, economy, and demographics in and around the site. These are the same factors that would be assessed for an environmental review under the National Environmental Policy Act. The table in *Figure T2-34* contains a partial listing of factors and information requirements in these two areas. Population growth and demographic changes, expected urbanization, and/or industrialization in the vicinity of a proposed site would also be considered.

Site selection can affect both temporary construction impacts and the long-term, cumulative impacts of operation. Also, the extent of the impacts requiring mitigation can be controlled and reduced. The site screening and selection process used by TVA evaluates the natural resources and socioeconomic factors both in the immediate plant site vicinity and the larger area of influence of the plant. The area of influence for the plant would be governed by:

- Extent of air pollutant fate and transport at non-negligible concentrations
- Extent of water effects due to thermal rejection and wastewater effluents
- Extent of fuel procurement and use of transportation modes
- Other similar factors that occur off-site

These planning data allow assessment (and possible avoidance) of direct construction impacts on the site, community infrastructure impacts, environmental justice effects, and effects on

FIGURE T2-34. **Environmental Planning Factors and Information Required for Mitigation Analysis**

Plant Site and Vicinity	Area of Influence
NATURAL RESOURCES	NATURAL RESOURCES
• Hydrogeologic Survey	• Survey of Terrestrial and Aquatic Life
• Meteorology	• Threatened and Endangered Species
• Ambient Air Quality	• Sensitive Habitat/Important Ecosystems
• Water Resources	• Air Quality Data
• Water Quality	• Meteorological Data
• Survey of Terrestrial and Aquatic Life	• Fuel Availability
• Threatened and Endangered Species	
• Sensitive Habitat/Important Ecosystems	
• Prime Farm Land	
• Wetlands	
• Recreation Resources	
• Cultural Resources Survey	
• Aesthetic Resources	
• Ambient Noise	
SOCIOECONOMIC	SOCIOECONOMIC
• Population Demographic	• Population Demographic
- Age, Race, Sex, etc.	- Age, Race, Sex
- Income	- Infrastructure
• Infrastructure	- Transportation
- Transportation	• Economy
- Housing	
- Solid Waste Disposal	
- Wastewater Treatment	
- Other Utilities, Fire, Police, etc.	
• Economy	

the local economy. Proper planning can play an important role in minimizing long-term receptor exposure and the potential cumulative effects of air and water pollutants.

Pollution Prevention

Pollution prevention results from process design. That is, the selection of fuel type, energy conversion technology, and other plant features provides inherent pollution reduction. For example, some fuels such as hydro, wind, and solar have no direct air pollution. The final seven strategies continue the use of regional hydroelectric resources, and one strategy makes significant use of wind energy. Other fuels such as natural gas offer little potential for emission of some pollutants such as metals and sulfur dioxide. Energy conversion cycles that require wet cooling towers to be economical must address concentration and disposal or discharge of water pollutants as cooling tower recirculation water discharge or cooling pond concentration. Other technologies may have no such potential for pollution.

Increased process efficiency reduces fuel requirements and offers inherent reductions in all related waste streams since less fuel is consumed for a given amount of electric energy produced. Energy Vision 2020 evaluated a wide range of efficient thermodynamic cycles including combined cycle, integrated gasification combined cycle, and integrated gasification with cascaded humidified advanced turbine, all of which were resource options in the final seven strategies.

Efficiency through load conservation (demand-side management) also reduces the fuel use and related pollution because of reduced electric production requirements. A number of demand-side management programs are a feature of the final Energy Vision 2020 strategies.

Environmental Controls

Environmental controls have commonly been used on new and existing plants to meet regulatory standards that protect human health and the environment. The most prominent use of controls are for air pollution and waste heat release into surface water. Air pollution controls in particular have been costly to construct and operate and have either reduced plant efficiency or have significant power requirements themselves. Cooling towers prevent thermal release to surface waters but have cost and operational penalties, as well as wastewater effluent. Nevertheless, these controls are effective mitigation measures that can be engineered to meet regulatory requirements.

Adverse Environmental Effects That Cannot Be Mitigated

The mere adoption of a long-term energy strategy has no adverse environmental effects, but the implementation of that strategy would. The nature and potential significance of the environmental effects will depend on the energy resource options eventually implemented under the strategy. However, there are resource options that are common in each strategy, including TVA's portfolio strategy, and these have associated adverse effects that cannot be realistically avoided.

Under every strategy, TVA would continue to operate most of its existing energy resources (its coal-fired units, nuclear units, hydroelectric units, combustion turbines, and hydroelectric pumped storage units). The operation of these units can result in the release of various air and/or water pollutants, depending on the kind of unit. Although the emissions and discharges from electric generating units are relatively well-controlled, certain residual emissions and discharges will continue to be released from TVA's existing units for the duration of Energy Vision 2020. As has been discussed, these residual emissions and discharges can contribute to a variety of environmental impacts such as visibility impairment, acid rain, crop and forest impacts, or low-dissolved oxygen. The operation of coal-fired and nuclear units will continue to expose adjacent populations to small residual quantities of radioactivity and other toxic pollutants.

The implementation of new generating resources would unavoidably result in a change in land use unless new resources are located at existing generating sites. The conversion of land from a non-industrial use to an industrial use will either unavoidably result in the loss of agricultural capabilities or the destruction of wildlife habitat.

The generation and transmission of electric energy unavoidably produces electric and magnetic fields (EMF). Although the health significance of EMF exposures is uncertain, such exposures could have adverse health consequences.

SECTION 9: ENVIRONMENTAL CONSULTATION, REVIEW, AND PERMIT REQUIREMENTS

A number of environmental consultation, review, and permit requirements would apply to the energy resource options that TVA eventually implements. The nature of these requirements vary depending on the kind of option. Fairly substantial requirements would apply to the more environmentally impactive options. This has the effect of substantially reducing the potential significance of impacts and protecting human health and other environmental values. Many of these requirements have associated opportunities for public review and comment. The following identifies and briefly discusses the more important requirements.

National Environmental Policy Act

The National Environmental Policy Act (NEPA), 42 U.S.C. 4321 et seq., requires all federal agencies, including TVA, to consider the potential environmental impacts of proposed actions before deciding whether to proceed with the actions. Under TVA's National Environmental Policy Act procedures and the regulations promulgated by the Council on Environmental Quality, there are three levels of environmental review: (1) categorical exclusions, (2) environmental assessments, and (3) environmental impact statements (EIS). The significance of the potential impacts associated with a proposed action dictate which of these types of review are to be used. Analysis become more detailed and public involvement more extensive as an agency moves from a categorical exclusion review to an environmental impact statement. Energy Vision 2020 has been prepared as both an integrated resource plan and an environmental impact statement. Actual implementation of options identified in the plan would be "tiered" off of Energy Vision 2020 and, as appropriate, would be preceded by more site-specific National Environmental Policy Act reviews.

Air Pollution Reviews

All of the states in which TVA operates require potential major sources of air pollution to obtain construction and operating permits. A major source is generally a source that emits 100 tons or more of pollutant but smaller sources can be major sources if they are located in a nonattainment area (an area that does not comply with a National Ambient Air Quality Standard) or if they emit hazardous air pollutants. Depending on the kind of source, its location, and the pollutants it emits, the source would be required to employ the best available control technology to reduce its potential emissions or even more stringent controls. Other requirements also can apply, such as the need to offset emissions (obtain a better than one-to-one reduction from existing sources) in some areas. The U.S. Environmental Protection Agency (EPA) has the opportunity to review and comment on permits for proposed sources, and there are usually multiple opportunities for public review and comment.

Wastewater Discharge Reviews

All of the states in which TVA operates require potential dischargers of wastewater to obtain a National Pollutant Discharge Elimination System (NPDES) stormwater permit before site preparation and construction activities can commence. A National Pollutant Discharge Elimination System permit must also be obtained for the direct discharge of pollutants to surface waters during facility operation. National Pollutant Discharge Elimination System permit limits are set to protect water quality and water uses. The Environmental Protection Agency has an opportunity to review and comment on proposed permits, as does the general public.

Solid and Hazardous Waste Management

A number of local, state, and federal laws and regulations govern how solid and hazardous wastes are to be managed. Typically, before solid waste can be disposed of on a plant site, state solid waste disposal permits must be obtained. This permitting process controls the design, monitoring, operation, and closure of disposal areas. The requirements for management of hazardous waste are even more stringent. Hazardous waste is regulated from "cradle to grave" (from the point of generation to ultimate treatment or disposal). During the permitting of solid or hazardous waste disposal sites, the public typically has one or more opportunities to comment.

Protection of Wetlands and Floodplains

Because of their biological value, wetlands receive special protection under federal law. Before most wetlands can be disturbed, a permit must be obtained from the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act. The Environmental Protection Agency and the public typically have opportunities to review and comment on proposed permits. As part of the permitting process, the pertinent state is asked to determine whether the proposed action would violate state water quality standards. Federal agencies are required to avoid impacting wetlands with new construction to the extent practicable and to otherwise minimize potential wetland impacts under Executive Order No. 11990 (Protection of Wetlands). Federal agencies are also directed to avoid occupying or modifying floodplains to the extent practicable and to otherwise minimize potential impacts to floodplain values under Executive Order No. 11988 (Floodplain Management).

Endangered Species

Under the Endangered Species Act, 16 U.S.C. 1536 et. seq., federal agencies are to ensure that their actions are not likely to jeopardize the continued existence of any endangered or threatened species or adversely modify any critical habitat of such sensitive species. If a proposed action may affect one of these species, the agency must consult with the U.S. Fish and Wildlife Service and obtain that agency's determination of the potential for impacting these species.

Cultural Resources

A number of federal laws protect cultural and archaeological resources, including the National Historic Preservation Act and the Archaeological Resources Protective Act. Before disturbing cultural and archaeological resources that have historical significance, an agency is required to consult with the State Historic Preservation Officer and in some circumstances, the Federal Advisory Council on Historic Preservation.

Farmland Protection

Under the Farmland Protection Policy Act, federal agencies are required to identify and take into account potential adverse effects of a proposed action on farmlands. Typically, analysis and review are undertaken as part of a National Environmental Policy Act review.

Other Review and Permit Processes

A number of other review and permit processes may be important, depending on the nature of the proposed option and its potential environmental effects. These include reviews under or involving:

- Structures in navigable waters (Rivers and Harbors Act of 1898)
- The Safe Drinking Water Act
- The licensing and monitoring of nuclear facilities (Atomic Energy Act)
- The Toxic Substances Control Act
- The Noise Control Act
- The Federal Insecticide, Fungicide, and Rodenticide Act
- The Comprehensive Environmental Response, Compensation, and Liability Act

Although the actual implementation of an energy resource could require the approval and involvement of other federal or state agencies, the selection of an energy resource plan, which is programmatic in nature, does not have review or consultation requirements. The selection of an energy resource plan for TVA is left to the discretion of TVA's Board of Directors.

SECTION 10: RELATED ENVIRONMENTAL DOCUMENTS

The following documents are related to TVA's Energy Vision 2020 planning process. They can be found in TVA's Corporate Library.

Final Environmental Impact Statement, Bellefonte Nuclear Plant Units 1 and 2, Volumes 1 and 2, 1974.

Final Environmental Impact Statement, Browns Ferry Nuclear Plant Units 1, 2, and 3, 1974.

Final Environmental Impact Statement, Policies Relating to Electric Power Rates, 1974.

Final Environmental Impact Statement, Policies Relating to Sources of Coal Used by the Tennessee Valley Authority for Electric Power Generation, 1971.

Final Environmental Impact Statement, TVA Raccoon Mountain Pumped Storage Project, 1976.

Final Environmental Impact Statement, Sequoyah Nuclear Plant Units 1 and 2, 1971.

Final Environmental Impact Statement, Tennessee River and Reservoir System Operation and Planning Review, 1990.

Final Environmental Impact Statement, Watts Bar Nuclear Plant Units 1 and 2, 1972.

Final Supplement 1 to NUREG-0439, Final Environmental Impact Statement related to the operation of Watts Bar Nuclear Plant Units 1 and 2, (Nuclear Regulatory Commission, April 1995) (Adopted by the Tennessee Valley Authority, June 1995).

Supplemental Environmental Review (Final), Operation of Watts Bar Nuclear Plant Units 1 and 2 (Tennessee Valley Authority, June 1995).

Glossary

The development of Energy Vision 2020, using TVA's interactive planning process, requires the careful, consistent use of certain key terms and phrases. Below are definitions of terms used often in Volume 2, Technical Document 2, Environmental Consequences. (Terms in definitions which are themselves defined in the Glossary are printed in *italics*.)

A

Acid Deposition—The wet or dry deposition of acid chemical compounds from the atmosphere.

Aerosol—A gaseous suspension of ultramicroscopic particles of a liquid or a solid.

Aesthetics—The perception or appearance of visual features in relation to the sense of beauty.

Air Toxins—Various man-made and naturally occurring materials that are known or suspected of causing serious public health impacts, but for which no *National Ambient Air Quality Standards* exist.

Ambient—Surrounding.

Ambient Air Quality Standards—National standards set by the U.S. *Environmental Protection Agency* that are permissible concentration levels of certain pollutants (new *ozone, carbon monoxide, particulates (PM 10), sulfur dioxide, nitrogen dioxide,* and *lead*) in the *ambient* air.

Aquatic—Characteristic of and/or pertaining to water.

Archaeological Resources—Material remains of past human activity.

Ash—The noncombustible component of coal or other fuels.

Attainment Areas—Those areas that meet all *National Ambient Air Quality Standards* as determined by monitoring of air pollutant levels.

B

Benthic Invertebrates—An animal lacking a backbone or spinal column and living on lake bottoms.

Benthos—Organisms that live on or in the first few inches of mud, sand, gravel, or other materials that make up the bottom of streams and lakes, e.g. worms, snails, crayfish, mussels, clams.

Biomass—Organic material. Often involves the harvesting of stands of close-growing whole trees, truck transport, tree storage, and drying using air heated by boiler *flue gas* and combustion of whole trees in a special deep-bed burner at the bottom of the furnace.

Biomass Cofiring—The use of *biomass* as a secondary fuel supplement in a coal-fired plant.

BLN—Bellefonte Nuclear Plant

Bottom Ash—Heavier ash (noncombustible component of coal or other fuels) that settles in the bottom of the boiler rather than being carried out with *flue gas*.

C

Carbon Dioxide (CO_2)—A colorless, odorless, nonpoisonous gas that results from fossil fuel combustion and is normally a part of the *ambient* air. Increasing levels of carbon dioxide in the atmosphere are contributing to the *greenhouse effect*.

Carbon Monoxide (CO)—A colorless, odorless, poisonous gas produced by incomplete fossil fuel combustion.

Cascaded Humidified Advanced Turbine (CHAT)—An advanced Ericson cycle that employs intercooling, recuperation, reheat, and humidification of a combustion *turbine* with a cascaded topping *turbine*.

CHAT—*Cascaded Humidified Advanced Turbine.*

Class I Areas—Areas designated by the Prevention of Significant Deterioration section of the *Clean Air Act Amendments of 1977* that includes national parks and wilderness areas, providing special protection for air quality and air quality-related values.

Clean Air Act Amendments of 1970—Enabling legislation which instructs the *Environmental Protection Agency (EPA)* to set air quality standards for pollutants of concern.

Clean Air Act Amendments of 1977—Legislation that provides greater regulatory authority and sets specific provisions to protect national parks and wilderness areas designated as *Class I areas*.

Clean Air Act Amendments of 1990—Legislation that adds additional regulatory authority to enforce compliance in *non attainment areas*. Also sets new requirements for *acid rain, hazardous air pollutants*, and monitors and reports air *emissions*.

Coal Gasification—Process of converting coal into gas.

Coal Plant—A generation plant using coal as its main source of *energy*.

Coalbed Methane—A gas that is present in all coal seams throughout the United States.

Cogeneration—The sequential production of electricity and useful thermal *energy* (generally steam or hot water) from a single fuel source.

Coproduction—A secondary product that is produced usually in an industrial process in addition to the primary product.

Cradle-To-Grave—System including the generation (e.g., mining), transportation, storage, treatment, and disposal of a fuel or wastes.

Criteria—Measuring rods used in integrated resource planning. They are derived from issues or concerns. Examples include concerns over future rates, acceptable levels of environmental impacts, etc.

Cultural Resources—Any prehistoric or historic district, site, building, structure, or object that may yield information regarding past human endeavors.

D

Delta—In load forecasting, the increase or decrease in the forecast sales caused by the high or low levels of any of the assumptions in the forecast.

Demand—The amount of electric *energy* used at a specific point in time, measured in watts (or multiples thereof, such as *KW, MW,* or *GW*). Demand is measured for individual customers, for groups or classes of customers, and for TVA's system as a whole.

Demand-Side Management (DSM)—Activities which influence electricity use on the customer's side of the meter. Examples include home weatherization, use of compact fluorescent lighting, etc.

DSM—*Demand-Side Management.*

E

Ecosystem—Any unit that includes all organisms (i.e., the community) in a given area interacting with the physical environment. The flow of energy leads to a clearly defined trophic structure, biotic diversity, and material cycles (i.e., exchange of materials between living and nonliving parts within the system).

Effects—These include: (a) direct effects caused by an action and occur at the same time and place; (b) indirect effects caused by an action and are later in time or further removed in distance, but still reasonably foreseeable. Effects and impacts as used in this document are synonymous.

Effluent—Wastewater—treated or untreated—that flows out of a treatment plant, sewer, or industrial outfall. Generally refers to wastes discharged into surface waters.

EIS—Environmental Impact Statement.

Electric and Magnetic Fields (EMF)—Two types of energy fields which are emitted from any device that generates, transmits, and uses electricity.

EMF—*Electric and Magnetic Fields.*

Emission—Pollution discharged into the atmosphere from smokestacks, other vents, and surface areas of commercial or industrial facilities; from residential chimneys; and from motor vehicle, locomotive, or aircraft exhausts.

Endangered Species—Any biotic species formally listed as in danger of extinction throughout all or a significant portion of its range.

Energy—The amount of power consumed over a period of time, measured in watt hours, *kWh, MWh, or GWh.*

Environmental Mitigation—Making environmental pollutants less severe.

Environmental Protection Agency (EPA)—A federal agency established to permit coordinated and effective governmental action for protection of the environment by the systematic abatement and control of pollution through integration of research monitoring, standard setting, and enforcement activities.

F

Flexible Option—An option that can be altered or modified in accordance with TVA needs.

Flexible Strategy—A combination of options that can be easily altered over time to meet TVA's power needs.

Flexibility—The degree to which resource decisions can be changed over time as events unfold and near-term futures become more clearly known.

Flue Gas—Gaseous combustion products from a furnace or boiler.

Fly Ash—The small ash particles that are carried out of a combustor with the existing flue gas. These particles are collected by appropriate equipment prior to discharging the flue gas to the atmosphere.

Fossil Fuel Plant—A plant using coal, oil, natural gas or other fossil fuel as its source of energy.

Fuel Cell—A cell that converts chemical *energy* directly into electrical *energy*, with electric power being produced as a part of a chemical reaction between the electrolyte and a fuel such as kerosene or industrial fuel gas.

G

Gas-fired Combined Cycle—A generating unit consisting of a combustion *turbine* generator and a steam turbine-generator. The primary fuel will be natural gas.

Geographic—Belonging to or characteristic of a particular region.

Gigawatt (GW)—An amount of electric power equal to 1,000 *MW,* or 1 billion watts.

Gigawatt hour—GWh, an amount of *energy* equal to 1,000 MWh, or 1 billion watt-hours.

Greenhouse Effect—The build-up of *carbon dioxide* or other trace gases that allows light from the sun's rays to heat the Earth but prevents a counterbalancing loss of heat.

Greenhouse Gas Emissions—A gas whose presence in the upper atmosphere contributes to the *greenhouse effect* by allowing visible light to pass through the atmosphere while preventing heat radiating back from the Earth from escaping. Greenhouse gases from human produced sources include *carbon dioxide, nitrous oxide,* methane, and *chlorofluoro-carbons* (*CFCs*). There also are even larger quantities of naturally occurring greenhouse gases, notably *ozone* and water vapor, whose concentrations may be affected by interactions with atmospheric pollutants.

Groundwater—Water within the Earth or geologic stratum that supplies wells and springs.

GW—Gigawatt, an amount of electric power equal to 1,000 *MW,* or 1 billion watts.

GWh—Gigawatt hour, an amount of *energy* equal to 1,000 *MWh,* or 1 billion watt-hours.

H

Habitat—The total environmental conditions on a unit of land including food, cover, and water within the home range.

Hazardous Waste—A byproduct of society that can pose a substantial or potential hazard to human health or the environment when improperly managed. Possesses at least one of four characteristics (ignitability, corrosivity, reactivity, or toxicity) or appears on special *Environmental Protection Agency* lists.

Herbicide—Any substance or mixture of substances intended to prevent the growth of or destroy unwanted plants or vegetation.

Hg—Mercury.

High-Level Waste—Material that is highly radioactive. In a nuclear power plant high-level waste is *spent fuel*.

Historic Site—Cultural sites more than 50 years old.

Hydroelectric Power Generation—The movement of water from a higher to lower elevation. The difference between the two elevations establishes potential *energy* that is used to generate electricity by allowing water to flow through a hydro *turbine*.

I

Independent Power Producer (IPP)—Any person who owns or operates, in whole or in part, one or more new independent power production facilities.

Integrated Gasification Combined Cycle (IGCC)—Integration of a coal gasification plant with a combined cycle plant. A coal gasification plant is a facility that converts coal into a synthetic fuel gas.

Integrated Resource Planning (IRP)—A utility planning process that evaluates *supply-side resources* and *DSM resources* on a level playing field to reliably meet the future *energy* needs of customers.

Integration—As used in this document, integration means combining options to become strategies and uncertainties to become futures. Strategies are combined with futures to create scenarios.

IPP—*Independent Power Producer.*

IRP—*Integrated Resource Planning.*

K

Kilowatt—kW, which is the amount of power equal to 1,000 watts.

Kilowatt-hour—kWh, which is the amount of *energy* equal to 1,000 watt-hours.

KM—Kilometer, unit of length equal to 1,000 meters.

kW—Kilowatt, which is the amount of power equal to 1,000 watts.

kWh—Kilowatt-hour, which is the amount of *energy* equal to 1,000 watt-hours.

L

Lignite—An imperfectly formed coal, usually dark brown and often having woody texture.

Low-Level Waste—Radioactive material that is only slightly or moderately radioactively contaminated. Low-level radioactive waste consists largely of ordinary trash and

other items that have come into contact with radioactive materials.

M

Megawatt—MW, the amount of power equal to 1,000 KW or 1,000,000 watts.

Meteorology—The science dealing with weather and weather conditions.

µg/m³—Micrograms per cubic meter.

Mitigation—Measures taken to reduce adverse impacts on the environment.

Mobile Sources—Transportation air pollution sources, primarily automobiles and trucks.

Monitored Retrievable Storage (MRS)—A temporary (40 years) collection and storage facility for *spent fuel* rods until a permanent waste repository is available.

Multi-Attribute Tradeoff Analysis/ Technique—An approach designed for interactive participation by a group to make dual comparisons among different attributes for many strategies. It provides an open framework for public involvement to investigate different attributes, futures, and strategies.

MW—Megawatt, the amount of power equal to 1,000 KW or 1,000,000 watts.

MWh—Megawatt hour, the amount of power equal to 1,000 kWh or 1,000,000 watt hours.

N

National Ambient Air Quality Standards (NAAQS)—Uniform, national air quality standards established by the *Environmental Protection Agency* that restrict *ambient* levels of certain pollutants to protect public health (primary standards) or public welfare (secondary standards). Standards have been set for *ozone, carbon monoxide, particulates PM (10), sulfur dioxide, nitrogen, nitrogen dioxide,* and *lead*.

Natural Resources—The elements of the natural environment that are evaluated as resources (i.e., water resources, forests).

NEPA—National Environmental Policy Act.

New Construction—Buildings and facilities that are constructed during the current year; it may also include major renovations of existing facilities.

Nitrogen or Nitrous Oxides (NO_X)—A product of combustion by mobile and stationary sources and a major contributor to the formation of *ozone* in the troposphere and *acid deposition*.

Nonattainment Area—A geographic area that does not meet one or more of the *National Ambient Air Quality Standards* for the *criteria* pollutants designated in the Clean Air Act.

O

Off-System Sales—Sales by TVA to utilities outside the TVA service area.

Option—Actions TVA can take to resolve an issue. For example, if TVA forecasts an energy deficit, it has the option to meet it with *DSM* programs or other resources.

Ozone (O_3)—A substance found in the stratosphere and the troposphere. In the stratosphere (the atmospheric layer beginning 7 to 10 miles above the Earth's surface) ozone is a form of oxygen found naturally that provides a protective layer shielding the Earth from ultraviolet radiation. In the troposphere (the layer extending up 7 to 10 miles from the Earth's surface), ozone is a chemical oxidant and a major component of photochemical smog.

Ozone can seriously affect the human respiratory system and is one of the most widespread of all the *criteria* pollutants. Ozone in the troposphere is produced through complex chemical reactions of nitrogen oxides, which are among the primary pollutants emitted by combustion sources; hydrocarbons, released into the atmosphere through the combustion, handling, and processing of hydrocarbon products; and sunlight.

P

Particulate—Minute separate particles.

Peaking Capacity—Capacity that is available for use and used to meet peak load. Such capacity, usually represented by combustion *turbines* and pumped storage, often has low capital costs and high fuel costs, and is designed to operate for relatively short periods of time.

Pesticide—Chemical materials used to control undesirable insects, animals, diseases, vegetation, or other forms of life.

Pulverized Coal—Crushed coal used to fuel a coal plant. Currently the principal electric generation technology in the United States.

R

Reactor Fuel Cycle—The process of extracting fuels, preparing fuel elements and assemblies for use in a reactor, using these elements in reactor operation, recovering radioactive byproducts from *spent fuel*, and reprocessing remaining fissionable material into new fuel elements.

Renewable Resources—Power plants or other generating devices whose fuel source is generally considered to be renewable. These include generators

fueled by biomass, water, photovoltaics, solar, wave, or wind *energy*.

Renewables—Wind, solar, landfill, methane, and biomass (trees and grasses used for fuel).

Repowering—Replacing or adding to the source of power of an existing electric generating station.

S

Scenario—The combining of one *strategy* with one future.

Scrubber—A device that removes *sulfur dioxide* from *flue gas* using lime or limestone.

Seedling.—Live trees of commercial species less than 1.0 inch in diameter 4.5 feet above ground that are expected to survive and develop.

Short Rotation Woody Crops—Plants grown on a relatively short rotation schedule for the explicit purpose of harvesting for use in power production.

Slag—Ash that has been melted during the combustion process and then solidified as it is removed from the boiler.

Soil—A dynamic natural medium composed of mineral and organic materials in which plants grow.

Species—A class of individuals having common attributes and designated by a common name.

Spent Fuel—Nuclear fuel that can no longer economically sustain a chain reaction.

Strategy—A combination of *options* intended to fulfill a particular resource goal. For example, an energy deficiency in 2007 might be met with a combination of *supply-side resources* and *DSM* resources.

Streams—A continually, frequently, or infrequently flowing body of water that follows a defined course. The three classes of streams are:

Ephemeral: A channel that carries water only during and immediately following rainstorms. Also known as a "dry wash."

Intermittent: A watercourse that flows in a well-defined channel during the wet seasons of the year, but not the entire year.

Perennial: A watercourse that flows throughout the year or nearly so (90 percent of the time) in a well-defined channel.

Sulfur Dioxide (SO_2)—A heavy, pungent, colorless, gaseous air pollutant formed primarily by the combustion of fossil-fuel plants.

Supply-Side Resource—Resources that meet customer needs by increased production of electricity (e.g. hydro, fossil, nuclear, combustion *turbines,* etc.).

Surface Water—Streams, rivers, ponds, lakes, and man-made reservoirs.

Surrogate Measure—A substitute measure that varies in the same way as the pollutant and environmental effects it represents.

T

Threatened Species—Any species which is likely to become an *endangered species* within the foreseeable future.

Topography—The physical features of a place or region. Commonly refers to land forms and variation in elevation.

TSP—Total suspended *particulate* matter.

Turbine—A machine for directly converting the kinetic and/or thermal *energy* of a flowing fluid (air, hot gas, steam, or water) into useful rotational *energy*.

U

Uncertainties—Issues or concerns that may impact energy resources in the future.

V

Visibility Impairment or Degradation—Visibility Impairment or degradation is usually defined as *aesthetic* damage where the ability to discern form, color, or texture is reduced and therefore the scenic value is also diminished. Or, as stated in 40 CFR 51.30(x), visibility impairment is ". . .any humanly perceptible change in visibility (visual range, contrast, coloration) from that which would have existed under natural conditions."

Volatile Organic Compounds (VOCs)—Any organic compound that participates in atmospheric photochemical reactions except for those designated by the *Environmental Protection Agency* administrator as having negligible photochemical reactivity.

W

Watershed—The entire area that contributes to a drainage or stream.

Wetland—Area with soils saturated with water during the growing seasons and supporting plants characteristic of wet conditions.

Wind Farm—Groups of wind *turbines*.

Z

Zebra Mussel—A non-native mussel which fouls, among other things, water intake structures.

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