TVA is committed to becoming one of the nation's leaders in providing cleaner energy.

Resource Plan Development and Analysis

TVA's Integrated Resource Plan is a synthesis of public input and strategic planning and professional analysis.

Process for Identifying the Recommended Planning Direction

6 Resource Plan Development and Analysis

TVA employed a scenario planning approach in the development of the Draft and the final IRP. This approach is commonly used in the utility industry. The goal of this approach was to develop a "no-regrets" strategy that was relatively insensitive to uncertainty. In other words, once strategic decisions were made, the strategy would perform well regardless of how the future unfolds. The processes used in the scenario planning approach, including evaluation methods and strategy selection, are outlined in this chapter.

This chapter describes the following six steps of the Draft IRP process:

1. Development of the scenarios and strategies used to conduct the scenario planning analysis
2. Resource portfolios optimization modeling
3. Development of scenario planning scorecards to measure the performance of the portfolios and strategies developed in the scenario planning analysis
4. Identification of preferred planning strategies for publication in the Draft IRP
5. Incorporation of public input and performance of additional scenario planning analyses
6. Identification of the Recommended Planning Direction

6.1 Development of Scenarios and Strategies

Scenario planning is useful for determining how various business decisions will perform in an uncertain future. Multiple strategies, which represented business decisions that TVA can control, were modeled against multiple scenarios, which represented uncertain futures that TVA cannot control. The intersection of a single strategy and a single scenario resulted in a resource portfolio.[1] A portfolio is a 20-year capacity expansion plan that is unique to that strategy and scenario combination.

Modeling multiple strategies within multiple scenarios resulted in a large number of portfolios. Proper analysis of these portfolios was a challenge. Accordingly, during early stages of the analysis, it was more important to observe trends or common characteristics that strategies exhibited over multiple scenarios rather than focusing on specific outcomes in individual portfolios. If a strategy behaved in a similar manner in most scenarios, the modelers could be confident of its robustness. Characteristics of robustness included increased flexibility, less risk over the long term and the ability to mitigate the impacts of

[1]Portfolios are also referred to as capacity expansion plans or resource portfolios

uncertainty. Conversely, a strategy that behaved differently or poorly in each scenario that it was modeled within was considered more risky and indicated a higher probability for disappointment and future regret.

6.1.1 Development of Scenarios

Most quantitative models focus on what is statistically likely based on history, market data and projected future patterns. The scenarios developed for the planning approach operated differently by utilizing assumptions that the future evolves along paths not suggested by history. They were not assigned a probability that one particular future is more likely to occur than another. Using this approach, scenarios identified and framed plausible futures that were studied in the development of the long-range resource plan.

The following three-step process was used to develop scenarios used in this IRP:

1. Identification of key uncertainties
2. Development of scenarios
3. Determination of scenario uncertainty values

> Scenarios represent future conditions that TVA cannot control but must adapt to.

Identification of Key Uncertainties

TVA, with input from the SRG, identified uncertainties that were used as building blocks to develop scenarios for this IRP. The key uncertainties are listed in Figure 6-1.

Key Uncertainty	Description
Greenhouse gas (GHG) requirements	• Reflects level of emission reductions (CO_2 and other GHG) mandated by federal legislation plus the cost of carbon allowances
Environmental outlook	Changes in regulations addressing: • Air emissions (exclusive of GHG) • Land • Water • Waste
Energy efficiency and RES	• Reflects mandates for minimum generation from renewables and the viability of renewable generation sources • It includes the percentage of the RES standard that can be met with energy efficiency
Total load	• Reflects variance of actual load to what is forecast • Accounts for benefits of EEDR penetration
Capital expansion viability & costs	For nuclear, fossil, other generation and transmission, includes risks associated with: • Licensing • Permitting • Project schedule
Financing	• Financial cost (interest rate) of securing capital
Commodity prices	• Includes natural gas, coal, oil, uranium and spot price of electricity
Contract purchase power cost	• Reflects demand cost, availability of power and transmission constraints
Change in load shape	Includes effects of factors such as: • Time-of-use rates • Plug-in Hybrid Electric Vehicles (transportation) • Distributed generation • Economics changing customer base • Energy storage • Energy efficiency • Smart grid / demand response
Construction cost escalation	Includes the following for nuclear, fossil and other generation: • Commodity cost escalation • Labor and equipment cost escalation

Figure 6-1 – Key Uncertainties

Development of Scenarios

Scenarios were constructed by utilizing various combinations of the key uncertainties in Figure 6-1. They were then further refined to ensure that the following characteristics for each scenario:

- Represented a plausible, meaningful future “world” (e.g., uncertainties related to cost, regulation and environment)
- Were unique among the scenarios being considered for study
- Reflected a future that TVA could find itself in during the timeframe studied in this IRP

- Placed sufficient stress on the resource selection process
- Provided a foundation for analyzing the robustness, flexibility and adaptability of each combination of various supply- and demand-side options
- Captured relevant key stakeholder interests

A summary of the scenarios selected for the IRP analysis is shown in Figure 6-2. During the scoping phase in summer 2009, Scenarios 1 through 6 were developed for use in the Draft IRP analysis. Scenario 7 was also developed as a reference case in the Draft IRP. It closely resembled TVA's long-term planning outlook at the time the original scenarios were developed. Another reference case, Scenario 8 was added after the publication of the Draft IRP. It captured the impacts of the recent recession and was used in subsequent analysis.

Scenario	Key Characteristics
1 Economy Recovers Dramatically	• Economy recovers stronger than expected and creates high demand for electricity • Carbon legislation and renewable electricity standards are passed • Demand for commodity and construction resources increases • Electricity prices are moderated by increased gas supply
2 Environmental Focus is a National Priority	• Mitigation of climate change effects and development of a "green economy" is a priority • The cost of CO_2 allowances, gas and electricity increase significantly • Industry focus turns to nuclear, renewables, conservation and gas to meet demand
3 Prolonged Economic Malaise	• Prolonged, stagnant economy results in low to negative load growth and delayed expansion of new generation • Federal climate change legislation is delayed due to concerns of adding further pressure to the economy
4 Game-changing Technology	• Strong economy with high demand for electricity and commodities • High price levels and concerns about the environment incentivize conservation • Game-changing technology results in an abrupt decrease in load served after strong growth
5 Energy Independence	• The U.S. focuses on reducing its dependence on non-North American fuel sources • Supply of natural gas is constrained and prices for gas and electricity rise • Energy efficiency and renewable energy move to the forefront as an objective of achieving energy independence
6 Carbon Regulation Creates Economic Downturn	• Federal climate change legislation is passed and implemented quickly • High prices for gas and CO_2 allowances increase electricity prices significantly • U.S. based energy-intensive industry is non-competitive in global markets and leads to an economic downturn
7 Reference Case: Spring 2010	• Economic growth lower than historical averages • Carbon legislation is passed and implemented by 2013 • Natural gas and electricity prices are moderate
8 Reference Case: Great Recession Impacts Recovery	• Economic outlook includes economic recovery, but growth is at a slightly lower rate than Scenario 7 due to lingering recession impacts • Natural gas prices are lower to reflect recent market trends

Figure 6-2 – Scenarios Key Characteristics

Determination of Scenario Uncertainty Values

Once each of the key uncertainties were defined, specific numerical values for each aspect of the scenarios were developed utilizing the following assumptions:

- Climate change uncertainty will be based upon stringency of requirements and timeline required for compliance and cost of CO_2 allowances
- An aggressive EPA regulatory schedule is expected to create additional compliance requirements (e.g., Hazardous Air Pollutants Maximum Achievable Control Technology [HAPs MACT], revised ambient air standards, etc.)
- Command and control regulations for HAPs MACT will likely drive plant-by-plant compliance
- RES will help accomplish GHG reduction required at the federal level
- The spot price of electricity will be correlated with the price of natural gas and coal
- Demand, primarily driven by economic conditions, will be affected by energy efficiency, demand response and other factors
- Schedule risk will be related to demand as well as the uncertainty of permitting and licensing generation and transmission projects
- Economic conditions and associated inflationary pressures will become the primary drivers for changes in financing costs
- Construction costs will be driven by demand as well as availability of labor, equipment, design and raw materials
- Economic conditions will become the primary driver, but the legislative/regulatory environment will apply additional pressure by introducing uncertainty related to potential schedule impacts
- Cost and availability of contract power purchases will be primarily driven by economic conditions and local area demand (i.e., load growth)

A detailed description of each scenario's uncertainty values is shown in Figure 6-3.

Uncertainty	Scenario 1 Economy Recovers Dramatically	Scenario 2 Environmental Focus is a National Priority	Scenario 3 Prolonged Economic Malaise	Scenario 4 Game-changing Technology	Scenario 5 Energy Independence	Scenario 6 Carbon Legislation Creates Economic Downturn	Scenario 7 Reference Case: Spring 2010	Scenario 8 Reference Case: Great Recession Impacts Recovery
GHG requirements	CO_2 price $27/ton ($30/metric ton) in 2014 and $82 ($90/metric ton) by 2030. 77% allowance allocation, 41% by 2030	CO_2 price $17/ton ($19/metric ton) in 2012 and $94 ($104/metric ton) by 2030. 77% allowance allocation, 28% by 2030	No federal requirement (CO_2 price = $0/ton)	CO_2 price $18/ton ($20/metric ton) in 2013 and $45 ($50/metric ton) by 2030. 77% allowance allocation, 41% by 2030	CO_2 price $18/ton ($20/metric ton) in 2013 and $45 ($50/metric ton) by 2030. 77% allowance allocation, 41% by 2030	CO_2 price $17/ton ($19/metric ton) in 2012 and $94 ($104/metric ton) by 2030. 77% allowance allocation, 28% by 2030	CO_2 price $15/ton ($17/metric ton) in 2013 and $56 ($62/metric ton) by 2030. 77% allowance allocation, 39% by 2030	Same as Scenario 7
Environmental outlook	Same as Scenario 7	SO_2 controls 2017 NO_X controls Dec 2016 Hg MACT 2014 HAP MACT 2015	No additional requirements (CAIR requirements, with no MACT requirements)	Same as Scenario 7	Same as Scenario 7	Same as Scenario 7	SCR all units by 2017 FGD all units by 2018 HAPs MACT by 2015	Same as Scenario 7
Energy efficiency and RES	RES – 3% by 2012, 20% by 2021 (adjusted total retail sales) EE can meet up to 25% or requirement	RES – 5% by 2012, 30% by 2021 (adjusted total retail sales) EE can meet up to 25% or requirement	No federal requirement	RES – 5% by 2012, 20% by 2021 (adjusted total retail sales) EE can meet up to 40% or requirement	RES – 5% by 2012, 20% by 2021 (adjusted total retail sales) EE can meet up to 40% or requirement	RES – 5% by 2012, 30% by 2021 (adjusted total retail sales) EE can meet up to 25% or requirement	RES – 3% by 2012, 15% by 2021 (adjusted total retail sales) EE can meet up to 25% or requirement	Same as Scenario 7
Total load	Med grow to High by 2015; High Dist; Alcoa Returns in 2010+; USEC stays forever; Dept Dist same as Scenario 7	Medium case, then 2012 40% rate increase; Low Dist; DS customer reductions (steel/paper plants); USEC stays forever; Dept Dist same as Scenario 7	Low load case; Low Dist; Alcoa not returning, No HSC & Wacker; USEC leaves June 2013; Dept Disc same as Scenario 7	Med-High load growth through 2020, then 20% decrease 2021-2022 including USEC departure, reduced dist sales & extended TOU	Medium case, then 20% rate increase in 2014; unrestricted PHEV included; TOU	Medium load case 2010-2011; 2012 low case then flat w/no growth; USEC leaves 2013; Alcoa not returning, HSC & Wacker not in; TOU	Moderate growth	Moderate to low growth
Capital expansion viability & costs	Moderate schedule risk	High schedule risk	Low schedule risk	Moderate schedule risk	Moderate schedule risk	Low schedule risk	Moderate schedule risk	Moderate schedule risk
Financing	Higher than Scenario 7 – higher inflation due to higher economic growth	Higher than Scenario 7 – higher inflation due to looser monetary policy supporting economic growth	Lower than Scenario 7 – lower inflation due to lower economic growth	Same as Scenario 7 – increased productivity due to technology leads to stronger economic wealth and non-inflationary money growth	Higher than Scenario 7 – higher inflation due to looser monetary policy supporting economic growth	Lower than Scenario 7 – lower inflation due to lower economic growth	Based on current borrowing rate	Based on current borrowing rate
Commodity prices	Gas & coal higher than Scenario 7	Gas higher; coal lower than Scenario 7	Gas much lower & coal much higher than Scenario 7	Gas lower & coal slightly higher than Scenario 7	Gas & coal higher than Scenario 7	Gas & coal much lower than Scenario 7	Gas - $6-8/mmBTU Coal - $40/ton	Gas - $5-7/mmBTU Coal - $40/ton
Contract purchase power cost	Much higher cost & lower availability	Higher cost & lower availability	Same as Scenario 7, then much lower cost with higher high availability	Higher cost & lower availability, then much lower cost with high availability after load decrease	Higher cost & lower availability	Lower cost with high availability	Moderate cost & availability	Moderate cost & availability
Construction cost escalation	Much higher than Scenario 7 – high economic growth causes high demand for new plants and high escalation rate	Somewhat higher than Scenario 7 – due to "construction costs escalating at high rate due to large volume of nuclear, renewables and env controls projects". High regulatory scrutiny adds to project costs	Lower than Scenario 7 – low load growth leads to low escalation	This scenario has two stages of escalation: 1) higher than Scenario 7 due to high load growth early, then 2) lower escalation when game-changing technology hits	Somewhat higher than Scenario 7 – moderately strong economy and load growth leads to somewhat higher than base escalation	Lower than Scenario 7 – negative load growth, very weak economy and high renewables lead to low escalation	Moderate escalation	Moderate escalation

Figure 6-3 – Scenario Descriptions

6.1.2 Development of Planning Strategies

After development of the scenarios, planning strategies were designed to test the various business decisions and portfolio choices that TVA has control over and might consider. Strategies are very different from the scenarios. Whereas, scenarios describe plausible futures and include factors that TVA cannot control, strategies describe business decisions over which TVA has full control. In the end, a well-designed strategy would perform well in many possible scenarios whereas a poorly designed strategy would frequently not perform well.

The following three-step process was used to design the strategies in this IRP:

1. Identification of key components
2. Development of strategies using key components
3. Definition of strategy

Planning strategies represent decisions and choices over which TVA has full control.

Identification of Key Components

To define the planning strategies, nine distinct categories of components were identified. The choice of components was influenced by comments received during the public scoping period and input from the SRG. Comments stated that TVA should challenge its targets for EEDR and renewables beyond the current portfolios. Accordingly, the ranges for both components were significantly expanded. The components for the planning strategies are described in Figure 6-4.

Component	Description	Type
EEDR portfolio	The level of EEDR included in each strategy	Defined Model Input
Renewable additions	The amount of renewable resources added in each strategy	Defined Model Input
Coal-fired capacity idling	A proposed schedule of coal-fired unit idling that will be tested in each strategy	Defined Model Input
Energy storage	Option to include a pumped-storage unit in selected strategies	Defined Model Input
Nuclear	Constraints related to the addition of new nuclear capacity	Constraint
Coal	Limitations on technology and timing for new coal-fired plants	Constraint
Gas-fired supply (self-build)	Limitations on gas-fired unit expansion	Constraint
Market purchases	Level of market reliance allowed in each strategy	Constraint
Transmission	Type and level of transmission infrastructure required to support resource options in each strategy	Constraint

Figure 6-4 – Components of Planning Strategies

As noted in Figure 6-4, there were two types of components, used in the model.

Defined model inputs	These components were scheduled or predetermined. This applied to both the timing and the quantity of specific asset decisions
Constraints in the model optimization	These components constrained the optimization of asset choices such as minimum build times, technology limitations and other strategic constraints including limits on market purchases. The capacity optimization model selected resources that were consistent with these constraints

Development of Strategies Using Key Components

TVA combined these nine components and created five distinct planning strategies for the Draft IRP analysis. Figure 6-5 lists the five distinct planning strategies and their key characteristics.

Planning Strategy	Key Characteristics
A Limited Change in Current Resource Portfolio	• Retain and maintain existing generating fleet (no additions beyond Watts Bar Unit 2) • Rely on the market to meet future resource needs
B Baseline Plan Resource Portfolio	• Allows for nuclear expansion after 2018 and new gas-fired capacity as needed • Assumes idling of approximately 2,000 MW of coal-fired capacity • Includes EEDR portfolios and wind PPAs
C Diversity Focused Resource Portfolio	• Allows for nuclear expansion after 2018 and new gas-fired capacity as needed • Increases the contribution from EEDR portfolio and new renewables • Adds a pumped-storage unit • Assumes idling of approximately 3,000 MW of coal-fired capacity
D Nuclear Focused Resource Portfolio	• Allows for nuclear expansion after 2018 and new gas-fired capacity as needed • Includes an increased EEDR portfolio compared to other strategies • Assumes idling of approximately 7,000 MW of coal-fired capacity • Includes new renewables (same as Strategy C) • Includes a pumped-storage unit
E EEDR and Renewables Focused Resource Portfolio	• Assumes greatest reliance on EEDR portfolio of any strategy and includes largest new renewable portfolio • Assumes idling of approximately 5,000 MW of coal-fired capacity • Delays nuclear expansion until 2022

Figure 6-5 – Planning Strategies Key Characteristics

Definition of Strategy

Once each strategy's key characteristics were defined, specific numerical values for each component of each strategy were defined as shown in Figure 6-6.

Components	Strategy A Limited Change in Current Resource Portfolio	Strategy B Baseline Plan Resource Portfolio	Strategy C Diversity Focused Resource Portfolio	Strategy D Nuclear Focused Resource Portfolio	Strategy E EEDR and Renewable Focused Resource Portfolio
EEDR	1,940 MW & 4.725 annual GWh reductions by 2020	2,100 MW & 5,900 annual GWh reductions by 2020	3,600 MW & 11,400 annual GWh reductions by 2020	4,000 MW & 8,900 annual GWh reductions by 2020	5,100 MW & 14,400 annual GWh reductions by 2020
Renewable additions	1,300 MW & 4,600 GWh competitive renewable resources or PPAs by 2020	Same as Strategy A	2,500 MW & 8,600 GWh competitive renewable resources or PPAs by 2020	Same as Strategy C	3,500 MW & 12,000 GWh competitive renewable resources or PPAs by 2020
Idled coal-fired capacity	No fossil fleet reductions	2,400 MW total fleet reductions by 2017	3,200 MW total fleet reductions by 2017	7,000 MW total fleet reductions by 2017	4,700 MW total fleet reductions by 2017
Energy storage	No new additions	Same as Strategy A	Add on pumped-storage unit	Same as Strategy C	Same as Strategy A
Nuclear	No new additions after WBN2	First unit online no earlier than 2018 Units at least 2 years apart	Same as Strategy B	First unit online no earlier than 2018 Units at least 2 years apart	First unit online no earlier than 2022 Units at least 2 years apart Additions limited to 3 units
Coal	No new additions	New coal units are outfitted with CCS First unit online no earlier than 2025	Same as Strategy B	Same as Strategy B	No new additions
Gas-fired supply (self-build)	No new additions	Meet remaining supply needs with gas-fired units	Same as Strategy B	Same as Strategy B	Same as Strategy B
Market purchases	No limit on market purchases beyond current contracts and extensions	Purchases beyond current contracts and contract extensions limited to 900 MW	Same as Strategy B	Same as Strategy B	Same as Strategy B
Transmission	Potentially higher level of transmission investment to support market purchases Transmission expansion (if needed) may have impact on resource timing and availability	Complete upgrades to support new supply resources	Increase transmission investment to support new supply resources and ensure system reliability Pursue inter-regional projects to transmit renewable energy	Same as Strategy C	Potentially higher level of transmission investment to support renewable purchases Transmission expansion (if needed) may have impact on resource timing and availability

■ Defined model inputs ☐ Optimized model inputs

Figure 6-6 – Strategy Descriptions

Strategy components were utilized in the modeling in several different ways. For example, Strategy A has specific defined constraints, such as including no new coal additions and 1,300 MW of renewable resource additions. Other components specified timing, such as adding nuclear resources no earlier than 2018 and no new coal additions in Strategy B. Reactive constraints were also identified, such as the need to build additional transmission capacity if imports from renewables exceed a certain limit.

6.2 Resource Portfolios Optimization Modeling

The generation of resource portfolios was a two-step process. First, an optimized capacity expansion plan was generated, which was then followed by a financial analysis. This process was repeated for each strategy/ scenario combination and for additional sensitivity runs.

6.2.1 Development of Optimized Capacity Expansion Plan

TVA utilized a capacity optimization model, System Optimizer, which is an industry standard software model developed by Ventyx. This model utilized an optimization technique where an "objective function" (i.e., total resource plan cost) was minimized and subject to a number of constraints by using mixed integer linear programming.

Resources were selected by adding or subtracting assets based on minimizing the present value of revenue requirements (PVRR). PVRR represents the cumulative present value of total revenue requirements for the study period based on an eight percent discount rate. In other words, it is the today's value of all future costs for the study period discounted to reflect the time value of money and other factors, such as investment risk.

In addition, the following constraints were observed:

- Balance of supply and demand
- Energy balance
- Reserve margin
- Generation and transmission operating limits
- Fuel purchase and utilization limits
- Environmental stewardship

System Optimizer uses a simplified dispatch algorithm to compute production costs. The model used a "representative hours" approach in which average generation and load values in each representative period within a week were scaled up appropriately to span all hours of the week and days of the months.

Year-to-year changes in the resource mix were then evaluated and infeasible states were eliminated. The least-cost path (based on lowest PVRR) from all possible states in the study period was retained in the Draft IRP as the optimized capacity expansion plan.

6.2.2 Evaluation of Detailed Financial Analysis

Next, each capacity expansion plan was evaluated using an hourly production costing algorithm, which calculated detailed production costs of each plan, including fuel and other variable operating costs. These detailed cost simulations provided total strategy costs and financial metrics that were used for evaluation of the results.

This analysis was accomplished using another Ventyx product called Strategic Planning (MIDAS). This software tool uses a chronological production costing algorithm with financial planning data used to assess plan cost, system rate impacts and financial risk. It also utilized a variant of Monte Carlo analysis[1], which is a sophisticated analytical technique that varies important drivers in multiple runs, to create a distribution of total costs rather than a single point estimate, which allows for risk analysis. The Monte Carlo analysis in MIDAS utilized 13 key variables.

The following variables were selected by TVA for the analysis:

- Commodity prices – natural gas, coal, CO_2, SO_2 and NO_x allowances
- Financial parameters – interest rates and electricity market prices
- Operating costs – capital as well as operation and maintenance
- Dispatch costs – hydro generation, fossil and nuclear availability
- Load forecast uncertainty

Total PVRR for each resource plan was calculated taking into account additional considerations. These considerations included the cash flows associated with financing. The model generated multiple combinations of the key assumptions for each year of the study period and computed the costs of each combination. Capital costs for supply-side options were amortized for investment recovery using a real economic carrying cost method that accounted for unequal useful lives of generating assets.

[1]Monte Carlo analysis is also referred to as stochastic analysis

Present value calculations are widely used in business and economics to provide a means to compare cash flows at different times on a meaningful basis. It also ensures that assets with higher capital costs and longer service lives are not unduly penalized relative to assets with lower capital costs and relatively shorter economic lives.

The short-term rate metric was also calculated and provided an alternative representation of the revenue requirements for the 2011-2018 timeframe expressed per MWh. This metric was developed to focus on the near-term impacts to system cost in recognition of TVA's current debt cap of $30 billion and the likelihood that the majority of capital expenditures in the short–term[1] may have to be funded primarily from rates.

6.2.3 Development of Portfolio

Portfolios are the output of the modeling process described in Section 6.2 – Resource Portfolios Optimization Modeling, and represent the outcome of choices made for a given view of the future. During the Draft IRP process, an optimized portfolio was developed for each of the five planning strategies within each of the six scenarios and for the Reference Case: Spring 2010. The end result was 35 distinct portfolios. Each portfolio represented a 20-year capacity expansion plan. The portfolios consisted of assets that represented various resource selections and cost characteristics optimized to meet TVA's capacity and energy needs for the IRP study period.

Due to the nature of the analysis, certain elements (i.e., emphasis on EEDR and nuclear energy) of some strategies remained relatively constant across the scenarios. However, other elements (i.e., amount of natural gas-fired capacity and market purchases) were variable and determined by the interplay between each planning strategy and the scenario within which it was analyzed.

6.3 Development of Evaluation Scorecard

The use of a scenario planning approach, combined with multiple strategies to be considered, resulted in a large number of distinct 20-year resource portfolios that required analysis and evaluation. Rather than looking for the best single solution contained within a large number of portfolios, the scenario planning approach looked for trends or characteristics common to multiple portfolios with a focus on outcomes considered to be successful and the strategies that guided those outcomes. Definition of what is considered successful, although difficult, was a key component in the evaluation of the planning strategies. Development of a scorecard to communicate the success or failure of the different portfolios was vital to the success of this evaluation process.

[1]prior to 2018

The following sections describe the creation of the IRP scorecard, including development of the ranking and strategic metrics. Although not part of the scorecard, the development of a technology innovation narrative is also discussed below.

6.3.1 Scorecard Design

Identification of preferred planning strategies in the Draft IRP and development of the Recommended Planning Direction in the final IRP involved a trade-off analysis. The analysis was focused on multiple metrics of cost, risk, environmental impacts and other aspects of TVA's overall mission.

A scorecard was designed for each strategy and was used to facilitate this trade-off analysis. The scorecard template (Figure 6-7) was comprised of two sections – ranking metrics and strategic metrics. A technology innovation narrative was included apart from the scorecard to help identify which strategies would be supported by particular technology innovations.

	Ranking Metrics			Strategic Metrics				
	Financial Impact			Environmental Stewardship			Economic Impact	
Portfolio	Cost	Risk	Ranking Metric Score	Carbon Footprint	Water Impact	Waste Impact	Total Employment	Growth in Personal Income
		Total Score:						

Figure 6-7 – Planning Strategy Scorecard

Ranking Metrics

Ranking metrics were used to quantify the financial impact of each given portfolio. Two metrics, cost and risk, were selected based on their ability to highlight differences between the portfolios. To further highlight differences, the ranking metric score was calculated as a blend of the two metric's scores.

Cost Metric

Production of the financial metrics PVRR and short-term rates was described in Section 6.2.1. The cost metric used in the strategy scorecard combined these two metrics using the following weighted formula:

Cost = 0.65 * PVRR + 0.35 * short-term rates

By considering the expected values for PVRR and short-term rates, TVA was able to better evaluate the cost and rate implications for various portfolios. The inclusion of both short-term rates and total revenue requirements helped to facilitate a trade-off analysis of alternative resource plans. This allowed TVA to explicitly evaluate funding implications, consistent with stakeholder concerns regarding increasing rate pressures.

Risk Metric

The PVRR risk metric was computed using both a risk ratio and a risk/benefit ratio metric for each portfolio, as shown in Figure 6-8.

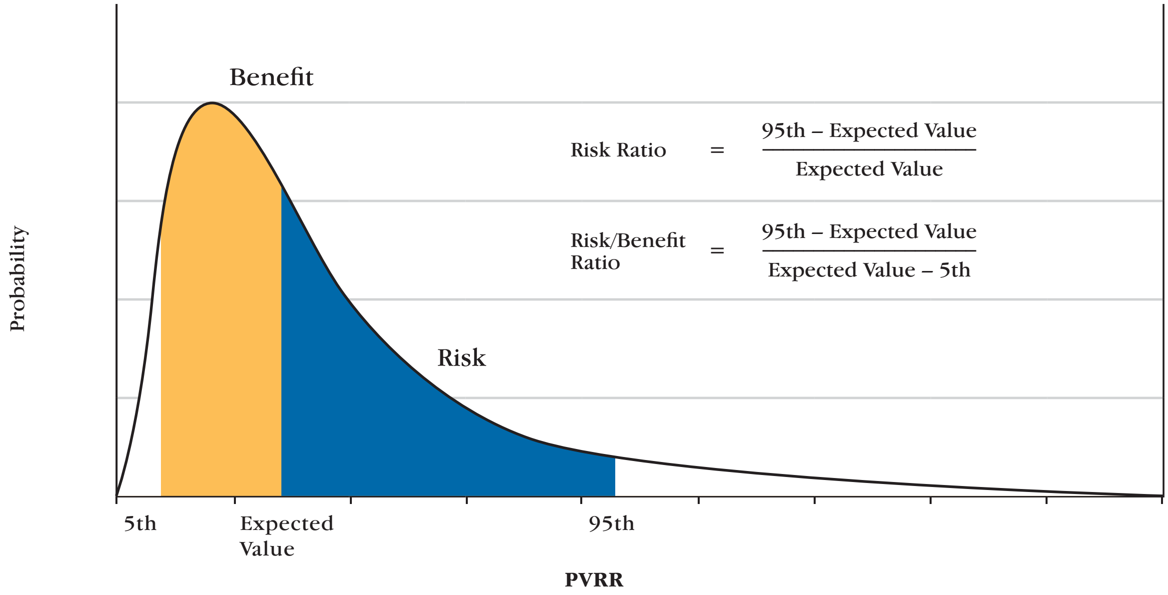

Figure 6-8 – Financial Risk Metrics

The risk metric used in the strategy scorecard combined these two metrics using the following weighted formula.

Risk = 0.65 * risk ratio + 0.35 * risk/benefit ratio

The risk ratio was expressed as the ratio of the difference between the 95th percentile of PVRR from the stochastic analysis and the expected value. It is a measure of the absolute "size" of the risk relative to the expected cost under each strategy within each scenario. A higher value signifies a portfolio with a relatively higher level of risk. The risk/benefit ratio captured the "risk" of a portfolio by examining the potential of exceeding the expected PVRR compared to the benefit of not exceeding the expected PVRR, expressed as a ratio. It compared the potential risks and the potential benefits of a strategy to determine whether or not the "risks and rewards" balance was weighted in favor of the customer.

Ranking Metric Score

The ranking metrics score combined the cost and risk metrics using the following weighted formula.

Ranking metrics score = 0.65 * cost + 0.35 * risk

This metric allowed evaluation of the interaction between financial risks and overall plan cost. For example, desirable low costs may require accepting a greater risk exposure, or to achieve an acceptable level of financial risk may mean selecting a plan with costs that are slightly higher than the least-cost option. The trade-offs required to balance these competing objectives helped identify the preferred planning strategies in the Draft IRP and the Recommended Planning Direction in the final IRP.

Strategic Metrics

Strategic metrics developed to consider other parts of TVA's mission were paired with ranking metrics to complete the IRP scorecard. Two strategic metrics were developed – environmental stewardship and economic impact.

Environmental Stewardship Metric

The environmental stewardship metric was developed to evaluate air, water and waste impacts. In the air metric evaluation, CO_2, SO_2, NO_x and Hg emissions were calculated for each portfolio. Emissions trends for SO_2, NO_x and Hg were steeply reduced because all cases chose large levels of coal-fired unit idling (2,000-7,000 MW) and controlled (90 percent or better emission removal rates) operating units in the future. For simplicity, the air metric was represented as a CO_2 impact footprint factor (annual average tons) because similar trend lines were tracked in all cases for CO_2. No additional significant insight was gained using all air emissions as opposed to using only CO_2. Therefore, the air metric is represented as a CO_2 impact "footprint" factor (annual average tons).

The water component of the environmental stewardship metric represents the thermal load produced through the condenser cooling cycle from steam generating plants to measure thermal impacts to the environment. The water impact was estimated based on the total heat dissipated by the condenser in the generation cooling cycle.

In addition to air and water impacts, certain generation sources produce waste streams that require disposal. The waste component used in this analysis focused on coal and nuclear generation, which are the primary sources of waste streams. The volumetric and disposal costs were used to better normalize differences in mass generated (tons). Waste streams that were estimated included coal ash, flue gas desulfurization/scrubber waste and high- and low-level nuclear waste.

The final evaluation criteria for both water and waste relied on surrogate measures as a proxy for environmental impacts. Both provided a reasonable and balanced method for evaluating planning strategies when compared with other components. Additional detail on the environmental stewardship metrics is in Appendix A – Method for Computing Environmental Impact Metrics.

Economic Impact Metric

Economic impact metrics were included to provide an indication of the impact of each strategy on the general economic conditions in the Tennessee Valley region. The economic metrics were represented by total employment and personal income. These metrics were compared to the impacts of Strategy B – Baseline Plan Resource Portfolio, in Scenario 7.

The IRP study defined economic impact as growth in regional economic activity. Measurement criteria included total personal income in "constant" dollars (i.e., with inflation accounted for) and total employment. These provided measures for the effects of the various planning strategies on the overall, long-term health and welfare of the economy over the next 20 years. This analysis concentrated on changes to the welfare of the general economy due to the strategies. It did not address changes to the distribution of income or employment.

In general, the greater the direct regional expenditures associated with a particular portfolio, the more positive were the effects on the regional economy. This can be offset by the fact that higher rates caused by higher costs have a negative effect on the regional economy. Thus, a resource portfolio that has high expenditures in the Tennessee Valley region may also have high costs and high rates.

The economic impact metrics for a particular planning strategy could be positive or negative depending on the net sum of the expenditure effects and the cost effects. More details about the methodology used to determine the economic impact metrics for the planning strategies is in Appendix B – Method for Computing Economic Metrics.

Scorecard Calculation and Color Coding

The ranking metrics in the scorecard for this IRP were expressed in terms of a 100-point score while ensuring that the relative relationship between the actual values for each portfolio in the strategy was maintained. The following process was used to compute the scores:

- Actual values of ranking metrics (i.e., PVRR, short-term rate impacts) were converted to a relative score on a 100-point scale. This type of scoring helped to assess and prioritize risk and identify the best possible solution
- The highest ranked ("best") value received a 100
- The rest of the scores were based on their relative position to the "best" value (e.g., a value that is 75 percent of the "best" would receive a 75)
- A color-coding method was used to assist in visual comparison of portfolio results. The coding was done within a given scenario. The "best" value for each metric was coded green, the "worst" value was coded red and the values in between were shown with a shaded color that corresponded to the relationship of the score values

An example of the translation from actual values to ranking metric scores is shown in Figure 6-9. The figure shows the conversion for the short-term rate metric.

Raw ranking metric value for short-term rate impacts in Scenario 1 are shown to right

Ranking Metric Scores		
	Strategy	Scenario 1
Average of ST Rates $/MWh (level 2011-18)	A	76.82
	B	78.67
	C	79.95
	D	84.61
	E	80.41

The "best" (in this case lowest) value within a scenario gets a score of 100

Strategy D is 10.13% higher than the "best" value and receives a score of 89.87

Scores are converted from the raw scores as shown and are included in the planning strategy score cards

Converted Ranking Metric Scores		
	Strategy	Scenario 1
Average of ST Rates (level 2011-18)	A	100.00
	B	97.59
	C	95.93
	D	89.87
	E	95.34

All other scores are assigned a value based on their relative position to the "best" score

Figure 6-9 – Ranking Metrics Example

The strategic metrics were included in the scorecard in two ways. First, the environmental stewardship metrics values were translated into a relative scoring system, known as a Harvey Ball rating system. Second, the economic impact metrics were represented by a percent change from a reference case.

For the environmental stewardship metrics, the data was coded in a given scenario so that the relative relationship (rank order) among the strategies was indicated by the amount of the ball that was filled in. Figure 6-10 shows an example of how this translation was done.

- This is an example of how the Harvey Ball ratings were applied to the Carbon Footprint strategic metric
- Expected values for annual CO_2 emissions from stochastic analysis are shown to the right
- Planning strategies were ranked based on their performance within each scenario

  In this example, 1=highest and 5=lowest
- In this example, quantitative data was available to support the ranking, however, other strategic metrics may have required qualitative assessment for ranking
- The appropriate Harvey Ball was assigned based on the rankings

Legend	
●	Better
◕	↑
◑	
◔	
○	

Average Annual CO_2 Emissions (Million Tons)

	Scenario						
Strategy	1	2	3	4	5	6	7
A	2,054	1,719	1,402	1,775	1,723	1,190	1,767
B	1,774	1,461	1,317	1,518	1,480	1,138	1,533
C	1,673	1,418	1,210	1,408	1,422	1,035	1,427
D	1,468	1,170	1,058	1,256	1,204	962	1,249
E	1,613	1,299	1,106	1,410	1,303	959	1,352

Carbon Footprint Rankings Within Scenarios

	Scenario						
Strategy	1	2	3	4	5	6	7
A	5	5	5	5	5	5	5
B	4	4	4	4	4	4	4
C	3	3	3	2	3	3	3
D	1	1	1	1	1	2	1
E	2	2	2	3	2	1	2

Populated Carbon Footprint Strategic Metric

	Scenario						
Strategy	1	2	3	4	5	6	7
A	○	○	○	○	○	○	○
B	◔	◔	◔	◔	◔	◔	◔
C	◑	◑	◑	◕	◑	◑	◑
D	●	●	●	●	●	◕	●
E	◕	◕	◕	◑	◕	●	◕

Figure 6-10 – Example of Draft IRP Scoring Process – Carbon Footprint

For the economic impact metrics, data were included in the scorecard as a percent change from the reference portfolio (Strategy B in Scenario 7). Instead of computing impacts for all 35 portfolios, only the range of possible impacts was evaluated.

The range of possible impacts was evaluated by computing the values for each planning strategy in Scenarios 1 and 6. The changes in employment and personal income in these scenarios relative to the reference portfolio (Strategy B in Scenario 7) indicated the maximum impacts that could result in any of the other scenario/strategy combinations.

6.3.2 Technology Innovations Narrative

In addition to the ranking and strategic metrics, a brief narrative of technology innovations associated with each planning strategy was prepared for the TVA Board of Directors. The narrative gave insight into the technology utilization implicit in each strategy for the Draft IRP.

This narrative was not a metric, but included as a supplement to the fully populated scorecard as background information to consider for selection of a Recommended Planning Direction. The technology innovation narrative discussed which technologies would justify investment to enable the resource mix identified in each strategy (e.g., a planning strategy with extensive EEDR may need smart grid investments for energy savings to be fully realized). A full description of the technology innovation matrix is in Chapter 7 – Draft Study Results.

6.4 Identification of Preferred Planning Strategies in the Draft IRP

Identification of preferred planning strategies was the key deliverable of the Draft IRP. The preferred planning strategies were identified by using the following three steps:

1. Scoring
2. Sensitivity analysis
3. Identification of preferred planning strategies

6.4.1 Scoring

For the Draft IRP, the identification of preferred planning strategies began by computing a score for each of the 35 portfolios evaluated in the study. Scores were based on the expected value for the cost and risk metrics. A total planning score was then calculated by summing the scores (ranking metrics) for each portfolio produced. Strategic metrics were combined with the ranking metrics for each of the selected reference resource portfolios to complete the scorecard. The technology innovation narrative was also utilized to help inform the scorecard. The initial scorecard was publicly shared during the Draft IRP and associated EIS public comment period and helped to facilitate discussion of trade-offs, constraints and compromises by considering the scorecard values of cost, risk and the strategic metrics.

6.4.2 Sensitivity Analyses

Sensitivity analyses were conducted to refine the preliminary results. The results focused on key assumptions in the strategies based on review of the scorecard results. For the

Draft IRP, sensitivity analyses consisted of selected cases intended to assess the robustness of the top performing strategies prior to selecting which strategies would be retained for further analysis for the final IRP.

6.4.3 Identification of Preferred Planning Strategies

By utilizing the ranking metrics, strategic metrics and technology innovation narrative, the preferred planning strategies were identified. Three strategies were retained in the Draft IRP – Strategies C, E and B. Resource portfolios were then identified from the preferred planning strategies. These resource portfolios represented the planning strategies for the purpose of comparative analysis and impact assessment and were used to define the broad range of options considered in the Draft IRP.

6.5 Incorporation of Public Input and Performance of Additional Scenario Planning Analyses

Following publication of the Draft IRP, the data used for analysis was re-evaluated and refreshed for key assumptions like load forecasts and commodity prices. Also during this time, the Scenario 8 reference case was created to better capture the impacts of the recent economic recession. Figure 6-3 has more details on that scenario. In other cases, suggestions received from the SRG and general public were incorporated into the analysis. The modeling and evaluation processes were also carefully examined and changes were made to further improve the quality of the analysis.

6.6 Identification of Recommended Planning Direction

After the Draft IRP public comment period, efforts continued to prepare the final IRP. The primary deliverable for this phase was the identification of the Recommended Planning Direction. This strategy will help define TVA's short- and long-term strategic direction and identify short-term actions that need to be accomplished. The preparation of the final IRP consisted of the following steps:

1. Identification of key components
2. Definition of boundary conditions
3. Development of Recommended Planning Direction candidates
4. Identification of the Recommended Planning Direction

6.6.1 Identification of Key Components

Components of the preferred planning strategies from the Draft IRP were evaluated for characteristics that would likely comprise the Recommended Planning Direction.

The revised approach reduced the number of inputs that were included in model optimization to produce a more focused result while allowing other unique combinations of resources to be tested that were not directly considered in the Draft IRP.

A key variable that was retained as a defined input was the level of idled coal-fired capacity. Idled capacity was not optimally selected within the model runs and required model iterations to test the different levels. This constraint meant that the optimum renewable and EEDR portfolio amounts were then selected for each assumed level of idled coal-fired capacity.

Portfolios for renewable additions and EEDR levels were optimized in the final analysis, along with the components identified in the Draft IRP. The model selected the best renewable and EEDR portfolio from the iterations provided as a part of optimizing all other resource alternatives.

6.6.2 Definition of Boundary Conditions

As described above, the Recommended Planning Direction was identified based on a blended optimization analysis using certain components from Strategies B, C and E. Figure 6-11 outlines the boundary conditions used in this stage of the analysis.

Components	Boundaries
EEDR	The EEDR portfolio will be no less than 2,100 MW & 5,900 annual GWh reduction by 2020
Renewable additions	Renewable additions will be no less than the existing wind contracts
Coal-fired capacity idled	Coal-fired capacity idled will be between 2,400 MW and 4,700 MW
Energy storage	The pumped-storage hydro unit (850 MW) will be included in all cases
Nuclear	Nuclear units cannot be added any earlier than 2018 and large units must be a minimum of two years apart – B&W technology at BLN cannot be added any later than 2020
Coal	New units cannot be added prior to 2025 and must be equipped with carbon capture and sequestration
Market purchases and transmission	If more than 900 MW/year are purchased beyond current contracts and extensions, potential transmission costs should be considered
Transmission	Transmission upgrades will be made to support new supply resources and maintain system readability

Figure 6-11 – Recommended Planning Direction Boundary Conditions

Within these boundaries, the capacity optimization model selected a resource plan that met the study constraints for reliability and least cost. To identify the optimum resource plan, multiple iterations were run within the model using the ranges of EEDR, renewable additions and idled coal-fired capacity as shown in Figure 6-12.

<table>
<tr><th>Components</th><th colspan="60">Range of Options Tested</th></tr>
<tr><td>EEDR</td><td colspan="20">2,100 MW & 5,900 annual GWh reductions by 2020</td><td colspan="20">3,600 MW & 11,400 annual GWh reductions by 2020</td><td colspan="20">5,100 MW & 14,400 annual GWh reductions by 2020</td></tr>
<tr><td>Renewable additions</td><td colspan="12">1,500 MW competitive resources or PPAs by 2020</td><td colspan="12">2,500 MW competitive resources or PPAs by 2020</td><td colspan="12">2,500 MW competitive resources or PPAs by 2029</td><td colspan="12">3,500 MW competitive resources or PPAs by 2020</td><td colspan="12">3,500 MW competitive resources or PPAs by 2029</td></tr>
<tr><td>Coal-fired capacity idled</td><td colspan="15">2,400 MW total fleet reductions by 2017</td><td colspan="15">3,200 MW total fleet reductions by 2017</td><td colspan="15">4,000 MW total fleet reductions by 2017</td><td colspan="15">4,700 MW total fleet reductions by 2017</td></tr>
</table>

Figure 6-12 – Recommended Planning Direction Range of Options Tested

Figure 6-12 also indicates the coal-fired capacity idling levels that were studied. As previously stated, these levels were not selected by the optimization model based on the full incremental costs of retaining these assets as part of the portfolios, but functioned as defined model inputs. As a result, the options shown for renewables and EEDR, along with any other resource options, were available for selection during optimization for each of the four assumed coal-fired idling levels.

6.6.3 Development of Recommended Planning Direction Candidates

Optimization results were produced by testing the four coal-fired idling levels across a subset of the scenarios originally developed for the Draft IRP.

The following scenarios were used to efficiently test the full range of possible futures for a total of 12 optimized cases:

- Scenario 1 – represented the upper bound
- Scenario 8 – represented a mid range of possible futures
- Scenario 3 – represented the lower bound and did not include climate change regulation

The following iterative six-step approach was used to produce the case results for the final IRP:

1. Incremental changes were made to strategy components in an attempt to improve upon the preferred planning strategies identified in the Draft IRP
2. The new strategy was tested in Scenarios 1 – 8 to evaluate new component combinations
3. The results were rescored to build a fully populated scorecard with ranking and strategic metrics
4. The completed scorecard was compared with results in the Draft IRP and previously considered alternatives to identify improvement, if any
5. Components common to strategies that exhibited improvement were selected to describe the proposed Recommended Planning Direction
6. Steps 1-5 were repeated until no further improvements were identified

6.6.4 Identification of Recommended Planning Direction

A Recommended Planning Direction was identified and is fully described in Chapter 8 – Final Study Results and Recommended Planning Direction. The identification of the Recommended Planning Direction was an iterative process that utilized the results of more than 3,000 modeling runs and evaluation of the results. The scorecard, along with stakeholder input and other considerations, was used to identify changes from the preferred planning strategies identified in the Draft IRP.