Integrated Resource Plan

TVA'S ENVIRONMENTAL AND ENERGY FUTURE

Supply Resource Options

External Stakeholder Review

October 22, 2009

Discussion Topics

- Overview
  - Focus of Today's Discussion
  - Supply Side Resources
  - Approach to Estimating Cost and Performance

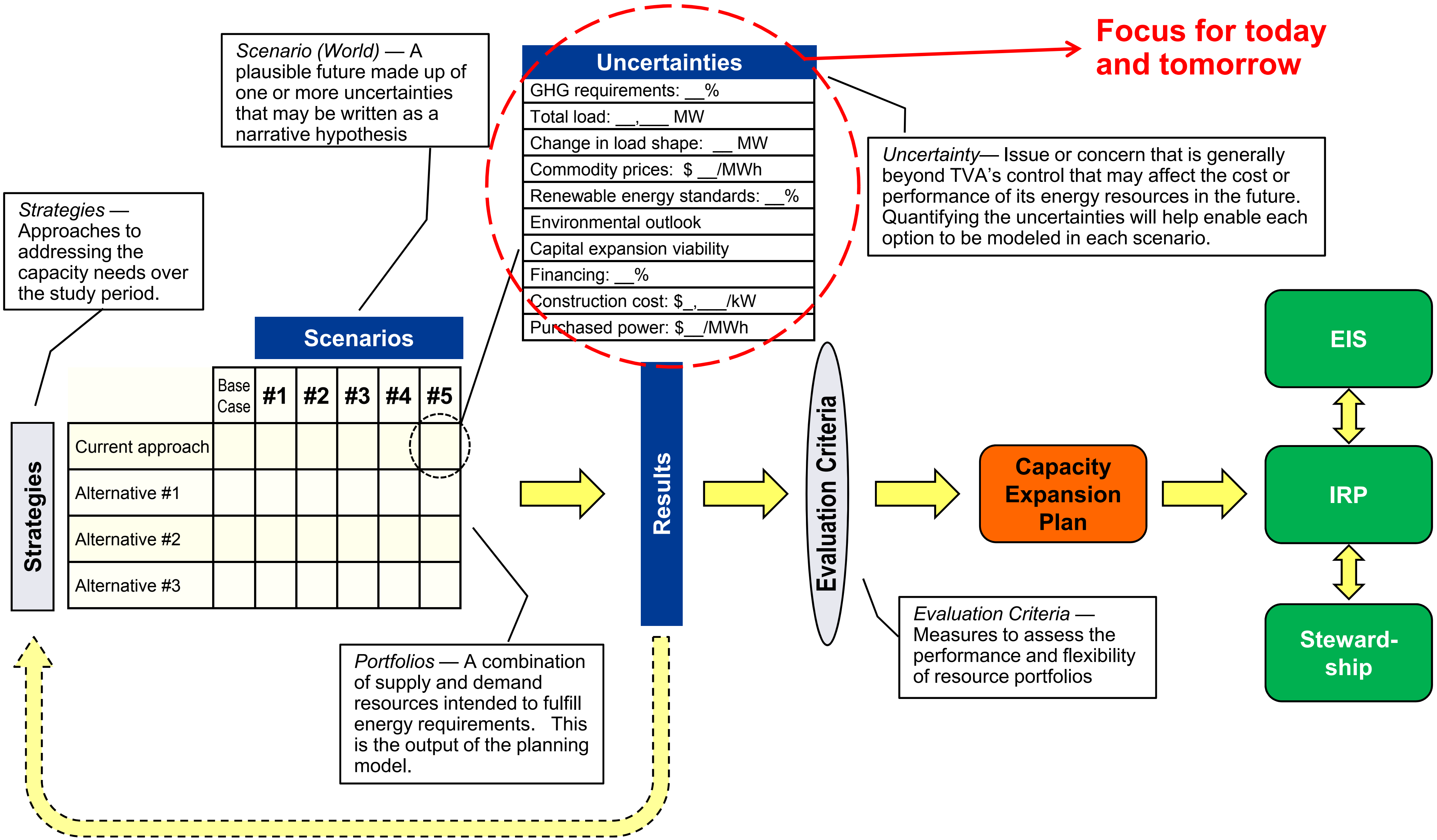
- Technology Discussion
  - Supply Option Characteristics
    - Fossil
    - Nuclear
    - Renewable and Alternative
    - Storage
  - Comparison of Capital Costs
  - Screening Inputs

- Modeling Process for Resource Planning

Today's objective is to enable understanding of TVA's approach for evaluating and screening supply source technologies.

Overview

IRP Summary Process



Focus for today and tomorrow

Scenario (World) — A plausible future made up of one or more uncertainties that may be written as a narrative hypothesis

Strategies — Approaches to addressing the capacity needs over the study period.

Uncertainty— Issue or concern that is generally beyond TVA's control that may affect the cost or performance of its energy resources in the future. Quantifying the uncertainties will help enable each option to be modeled in each scenario.

Portfolios — A combination of supply and demand resources intended to fulfill energy requirements. This is the output of the planning model.

Evaluation Criteria — Measures to assess the performance and flexibility of resource portfolios

Uncertainties

- GHG requirements: __%
- Total load: __,___ MW
- Change in load shape: __ MW
- Commodity prices: $ __/MWh
- Renewable energy standards: __%
- Environmental outlook
- Capital expansion viability
- Financing: __%
- Construction cost: $_,___/kW
- Purchased power: $__/MWh

Scenarios

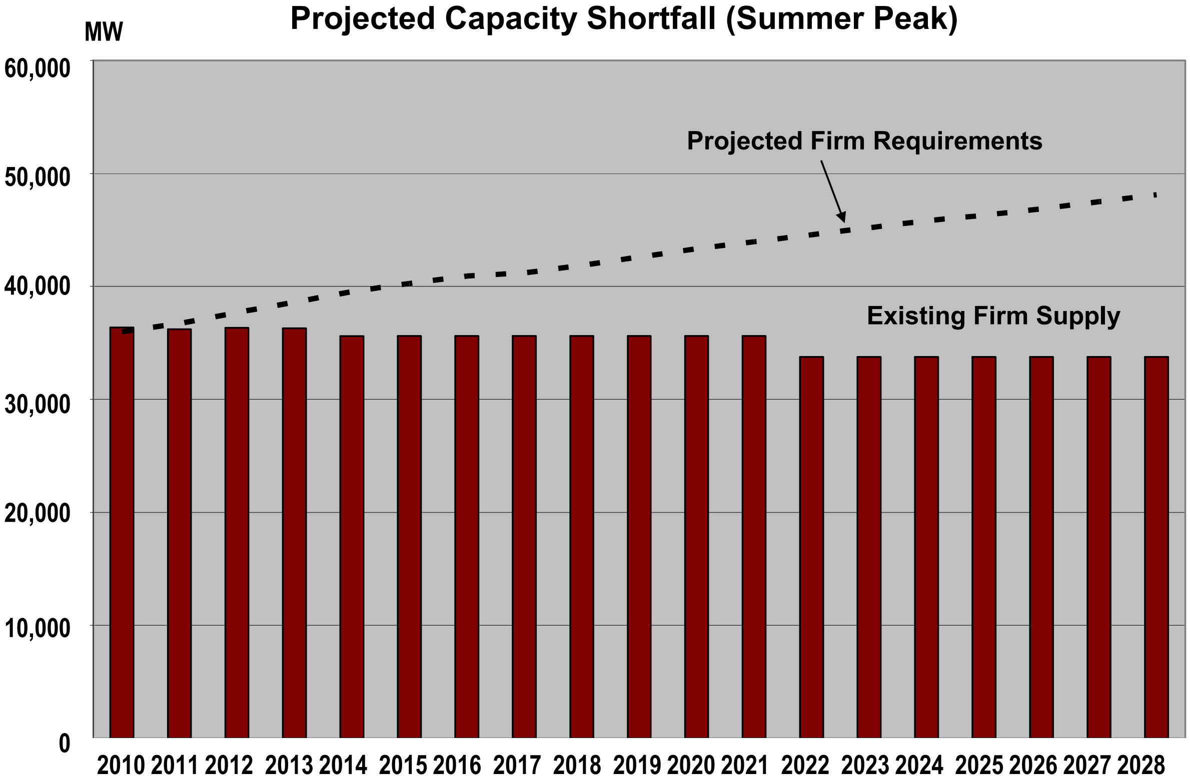
Strategies	Base Case	#1	#2	#3	#4	#5
Current approach						
Alternative #1						
Alternative #2						
Alternative #3						

Overview

Meeting Demand

- Capacity planning is typically about seeking the least cost option to close the gap between projected firm requirements (load + reserves) and existing firm supply consistent with reliability requirements
- The gap can be filled through either:
  - Demand-side resources
  - Supply-side resources
- Demand-side alternatives were discussed in the September 24th workshop
- Assumptions that drive the load forecast and capacity shortfall will be covered tomorrow

Projected Capacity Shortfall (Summer Peak)

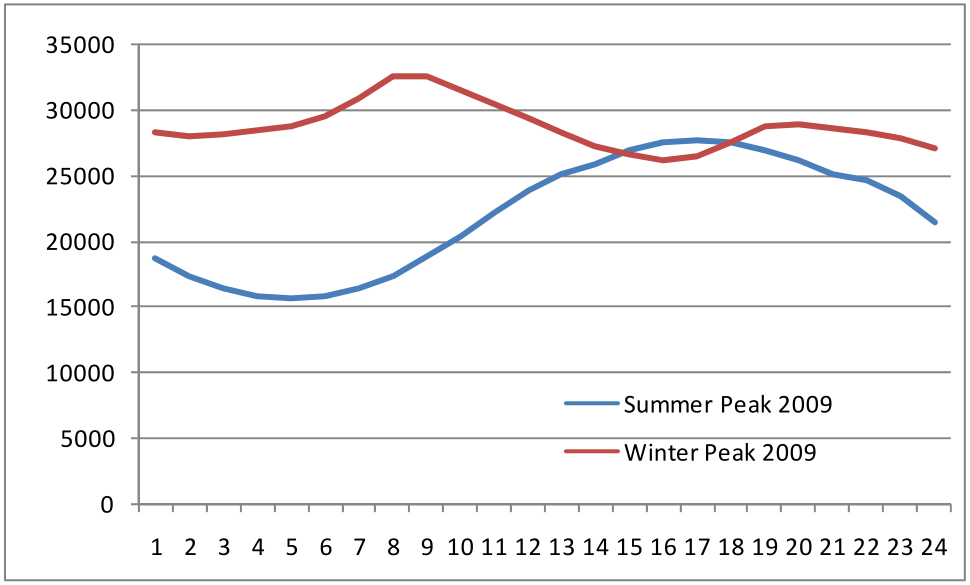


- Today's discussion will focus on the supply-side resources that can be used to close the capacity shortfall

Overview

Identifying the Least Cost Solution

- Capacity need filled with mix of resources that are least cost combination
  - Both capital and operating costs are considered (revenue requirements)
  - Capital cost modeled as cash flow
  - Operating costs based on unit characteristics and load shape
- Load shape dictates the type of resources that will be chosen and how they will be utilized ("dispatched") to meet expected customer demand
- Variables that are key to operating cost projections include
  - Unit operating efficiency or "heat rate" – conversion efficiency of fuel into power
  - Fuel and variable operating costs
  - Commitment/dispatch constraints – factors that limit how/when units can be used
- Resources generally classified according to "duty cycle"



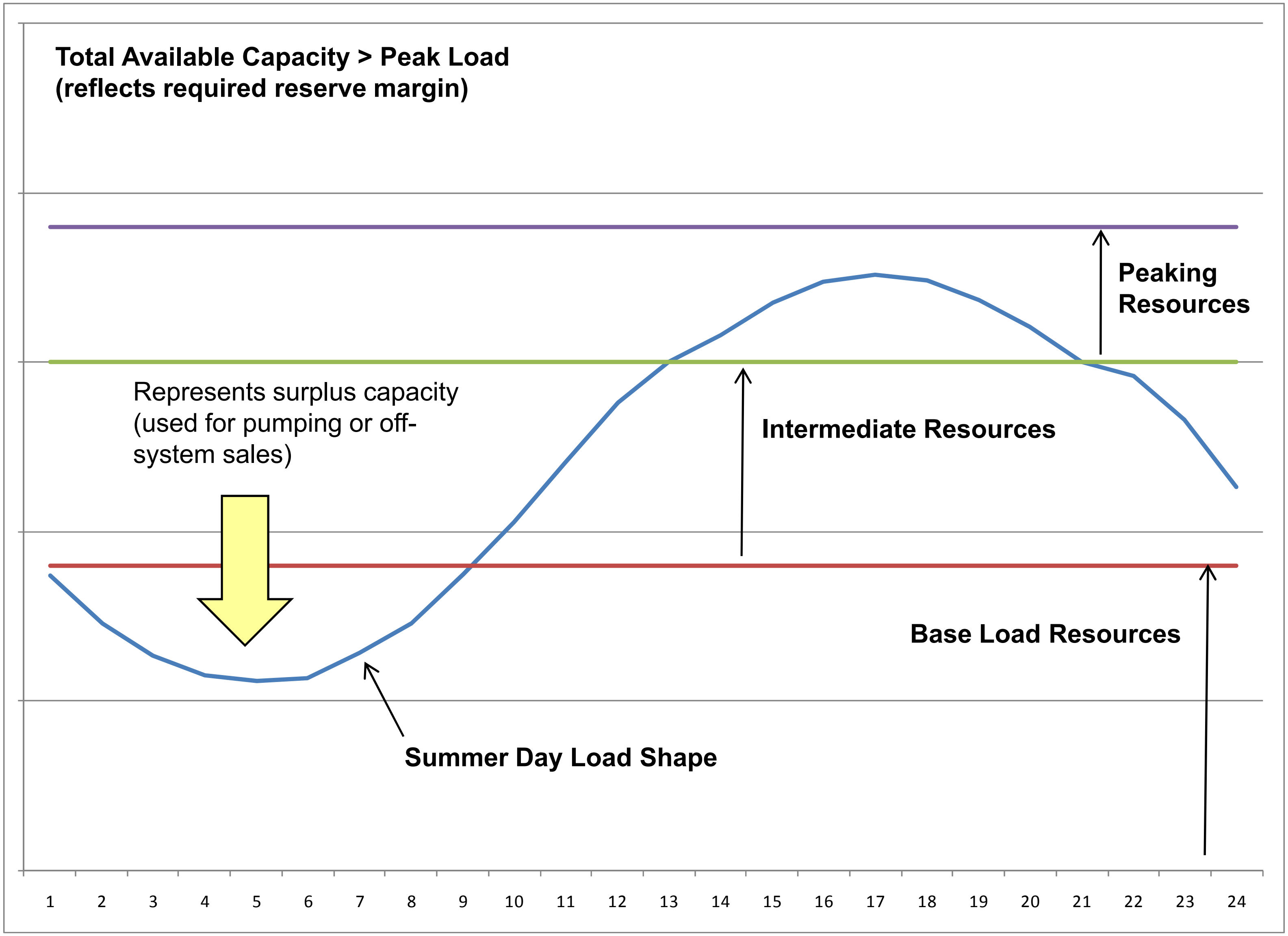
Base load resources – lowest overall operating costs (low heat rate and variable cost), units designed to remain online virtually around the clock

Intermediate resources – moderate operating costs and the ability to "swing" with changes in load

Peaking resources – highest operating costs, designed to be used only when loads are highest and other resources already committed

Overview

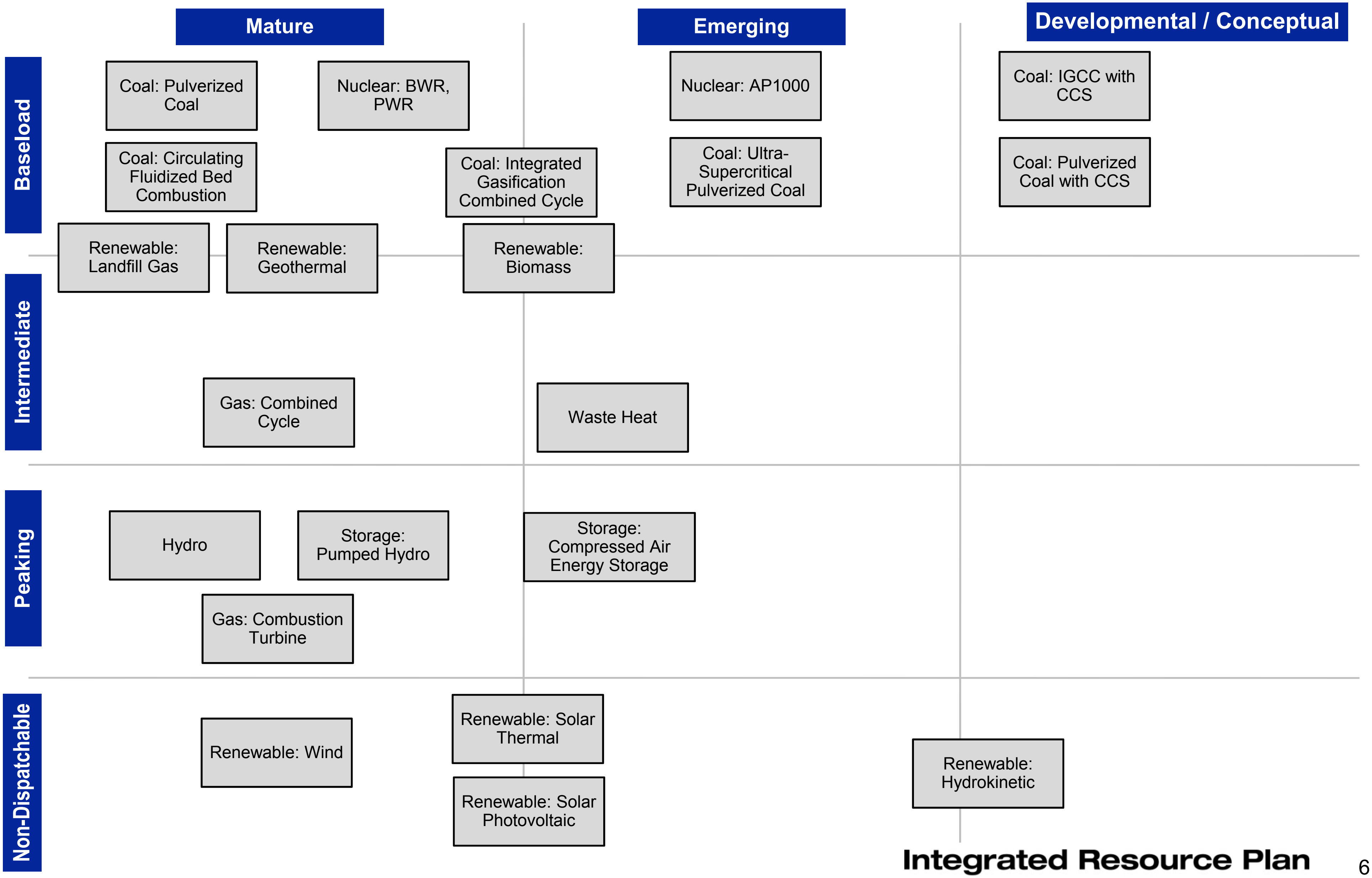
Daily Load Shapes – Understanding Resource Needs



Overview

Supply-Side Resources (Cont’d)

There are many technologies to consider – cost, application, and maturity vary widely. Geography and proximity to supply source are also major factors.



	Mature	Emerging	Developmental / Conceptual
Baseload	Coal: Pulverized Coal Nuclear: BWR, PWR Coal: Circulating Fluidized Bed Combustion Coal: Integrated Gasification Combined Cycle Renewable: Landfill Gas Renewable: Geothermal	Nuclear: AP1000 Coal: Ultra-Supercritical Pulverized Coal Renewable: Biomass	Coal: IGCC with CCS Coal: Pulverized Coal with CCS
Intermediate	Gas: Combined Cycle	Waste Heat	
Peaking	Hydro Storage: Pumped Hydro Gas: Combustion Turbine	Storage: Compressed Air Energy Storage	
Non-Dispatchable	Renewable: Wind	Renewable: Solar Thermal Renewable: Solar Photovoltaic	Renewable: Hydrokinetic

Overview

Approach to Estimating Cost and Performance

Cost Estimates

- Determine required plant size and number of units

- Estimate capital costs
  - Ensure costs are for a complete plant
  - Base costs on 2009 dollars, assuming overnight costs. Overnight costs:
    - Include engineering, procurement, construction, and owner's costs
    - Are net of financing costs and do not account for inflation or escalation
    - Exclude transmission costs
  - Account for technological, environmental, and siting factors, such as
    - Environmental-related costs mandated by permitting or regulatory needs
    - Known technological advancements
    - Significant, widely applicable, siting costs

- Utilize a variety of data sources, such as
  - Discussions with vendors
  - Contract negotiations
  - Comparison to recently completed similar work
  - Budgetary estimates provided
  - Industry research and analyses

Overview

Approach to Estimating Cost and Performance (Cont'd)

Cost Estimates (Cont'd)

- Consider the following when comparing capital cost data
  - Level of the estimate (e.g., conceptual, final, based on bids)
  - Specific plant design (e.g., level of redundancy, amount spent to lower heat rate)
  - Year of the cost data
  - Whether escalation and/or accumulated funds used during construction (AFUDC) are included
    - AFUDC reflects the cost of borrowed funds used during construction and is capitalized when plant is put in service
  - Scope of the project
  - Whether capital spares are included
  - Assumptions for the fuel supply (e.g., distance to gas supply, coal quality)
  - Whether owner's costs are included
  - Whether transmission is included
  - Contingency level

- When comparing cost estimates, it is helpful to remember a quote from an EPRI report:
  - "The cost data presented in this report should not be compared with data from other sources unless all factors that significantly affect cost have been identified and included on a consistent basis"

Approach to Estimating Cost and Performance (Cont'd)

Performance Estimates

- Estimate performance characteristics, in addition to capital costs
    - Heat rate and power output (include long-term degradation)
    - Fixed and variable operations and maintenance (O&M) costs
    - Emission rates (assume best available control technology)
    - Availability
    - Operational characteristics

- Leverage experience with existing plants, vendor input, and industry sources for estimates of performance characteristics

Technology Discussion

Characteristics – Fossil

Natural Gas – Combustion Turbine (CT) Plants

- Low initial capital cost
- Very low O&M cost
- Quick start and low start cost
- Easier to site
- Shorter construction schedule
- Very high operating cost (e.g., fuel, variable O&M, emission)

Natural Gas – Combined Cycle (CC) Plant

- Moderate capital cost
- Low O&M cost
- Good operational flexibility
- Can be higher operating cost
  - Based on natural gas volatility and fuel supply hedging strategy
- Limited pipeline capacity
- Shorter construction schedule

Technology Discussion
Characteristics – Fossil (Cont'd)

All Base Load Coal Plants (coal-fired)

- Low operating cost
- Typically coal prices are low and not very volatile (regulatory risk is increasing – CO_2)
- High initial capital cost
- Siting and permitting challenges, longer schedule

Supercritical Pulverized Coal (PC)

- Mature technology
- Good efficiency
- High solid waste generation
- High CO_2 emissions

Integrated Gasification Combined Cycle (IGCC)

- High efficiency
- Plant complexity
- Not completely mature
- High CO_2 emissions

Circulating Fluidized Bed Combustion

- Flexibility on coal types
- Smaller size than PC plants – higher cost per kW

Ultra-Supercritical Pulverized Coal

- High efficiency
- Not mature
- High CO_2 emissions

Supercritical Pulverized Coal with CCS

- Low CO_2 emissions
- Very high capital cost and poor efficiency
- Not mature (CCS portion)

Integrated Gasification Combined Cycle with CCS

- Low CO_2 emissions and more adaptable to CO_2 removal
- Very high capital cost and poor efficiency
- Not mature (CCS portion)

* CCS = CO_2 Capture and Sequestration

Characteristics – Nuclear

- Provider of baseload generation
- Low operating costs
  - Average fuel price volatility very low (long term fuel purchases)
- Does not create emissions of CO_2, NOx, or SO_2
- Long lead time for licensing and construction
- High initial capital costs
- New nuclear generation being pursued by some utilities in the U.S. (see examples below)

Public Announcements on AP1000 Projects

February 2008 — For two new AP1000 reactors at its Turkey Point site, Florida Power & Light calculated overnight capital costs of $2,444 to $3,582 per kW, which were grossed up to include cooling towers, site works, land costs, transmission costs and risk management for total costs of $3,108 to $4,540 per kW.

March 2008 — For two new AP1000 reactors in Florida Progress Energy announced that if built within 18 months of each other, the cost for the first would be $5,144 per kW and the second $3,376 per kW (total $9.4 billion). Including land, plant components, cooling towers, financing costs, license application, regulatory fees, initial fuel for two units, owner's costs, insurance and taxes, escalation and contingencies the total would be about $14 billion.

May 2008 — For two new AP1000 reactors at the Virgil C Summer Generating Station in South Carolina South Carolina Electric and Gas Co. and Santee Cooper expected to pay $9.8 billion (which includes forecast inflation and owners' costs for site preparation, contingencies and project financing).

November 2008 — For two new AP1000 reactors at its Lee site Duke Energy Carolinas raised the cost estimate to $11 billion, excluding finance and inflation, but apparently including other owners costs.

On April 9, 2008, Georgia Power Company reached a contract agreement for two AP1000 reactors to be built at Vogtle at an estimated final cost of $14 billion plus $3 billion for necessary transmission upgrades.

Characteristics – Nuclear (Cont'd)

MIT Study Update – Understanding the Estimates

Different Estimates Largely Reflect Different Quotation Methods: Illustration

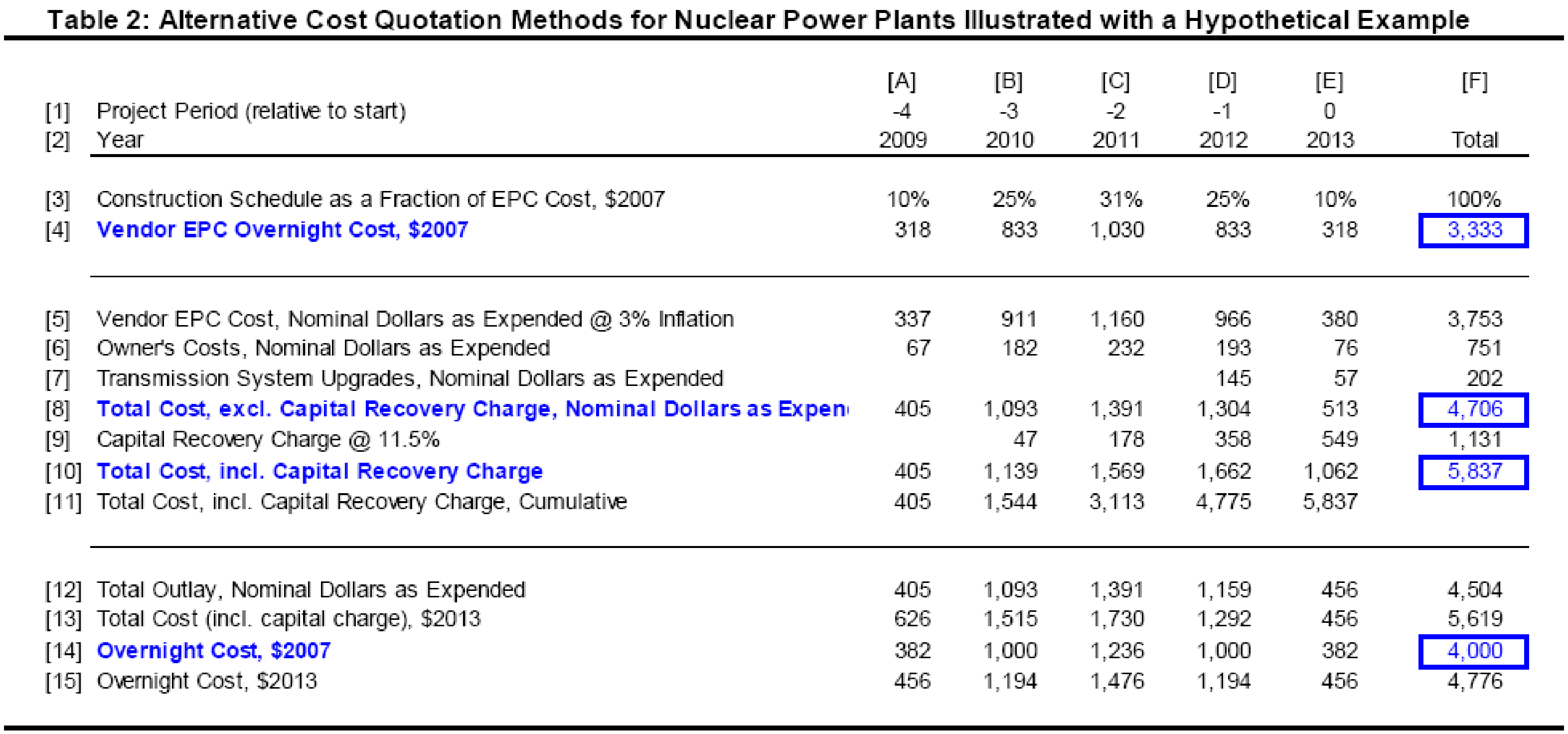


Table 2: Alternative Cost Quotation Methods for Nuclear Power Plants Illustrated with a Hypothetical Example

		[A]	[B]	[C]	[D]	[E]	[F]
[1]	Project Period (relative to start)	-4	-3	-2	-1	0	
[2]	Year	2009	2010	2011	2012	2013	Total
[3]	Construction Schedule as a Fraction of EPC Cost, $2007	10%	25%	31%	25%	10%	100%
[4]	**Vendor EPC Overnight Cost, $2007**	318	833	1,030	833	318	3,333
[5]	Vendor EPC Cost, Nominal Dollars as Expended @ 3% Inflation	337	911	1,160	966	380	3,753
[6]	Owner's Costs, Nominal Dollars as Expended	67	182	232	193	76	751
[7]	Transmission System Upgrades, Nominal Dollars as Expended				145	57	202
[8]	**Total Cost, excl. Capital Recovery Charge, Nominal Dollars as Expen**	405	1,093	1,391	1,304	513	4,706
[9]	Capital Recovery Charge @ 11.5%		47	178	358	549	1,131
[10]	**Total Cost, incl. Capital Recovery Charge**	405	1,139	1,569	1,662	1,062	5,837
[11]	Total Cost, incl. Capital Recovery Charge, Cumulative	405	1,544	3,113	4,775	5,837	
[12]	Total Outlay, Nominal Dollars as Expended	405	1,093	1,391	1,159	456	4,504
[13]	Total Cost (incl. capital charge), $2013	626	1,515	1,730	1,292	456	5,619
[14]	**Overnight Cost, $2007**	382	1,000	1,236	1,000	382	4,000
[15]	Overnight Cost, $2013	456	1,194	1,476	1,194	456	4,776

From Du and Parsons, CEEPR Working Paper 09-004.

CEEPR MIT Center for Energy and Environmental Policy Research

Characteristics – Nuclear (Cont'd)

MIT Study – Basis For $ per kW Construction Estimate

Comparison of Five Nuclear Build Proposals in the U.S.

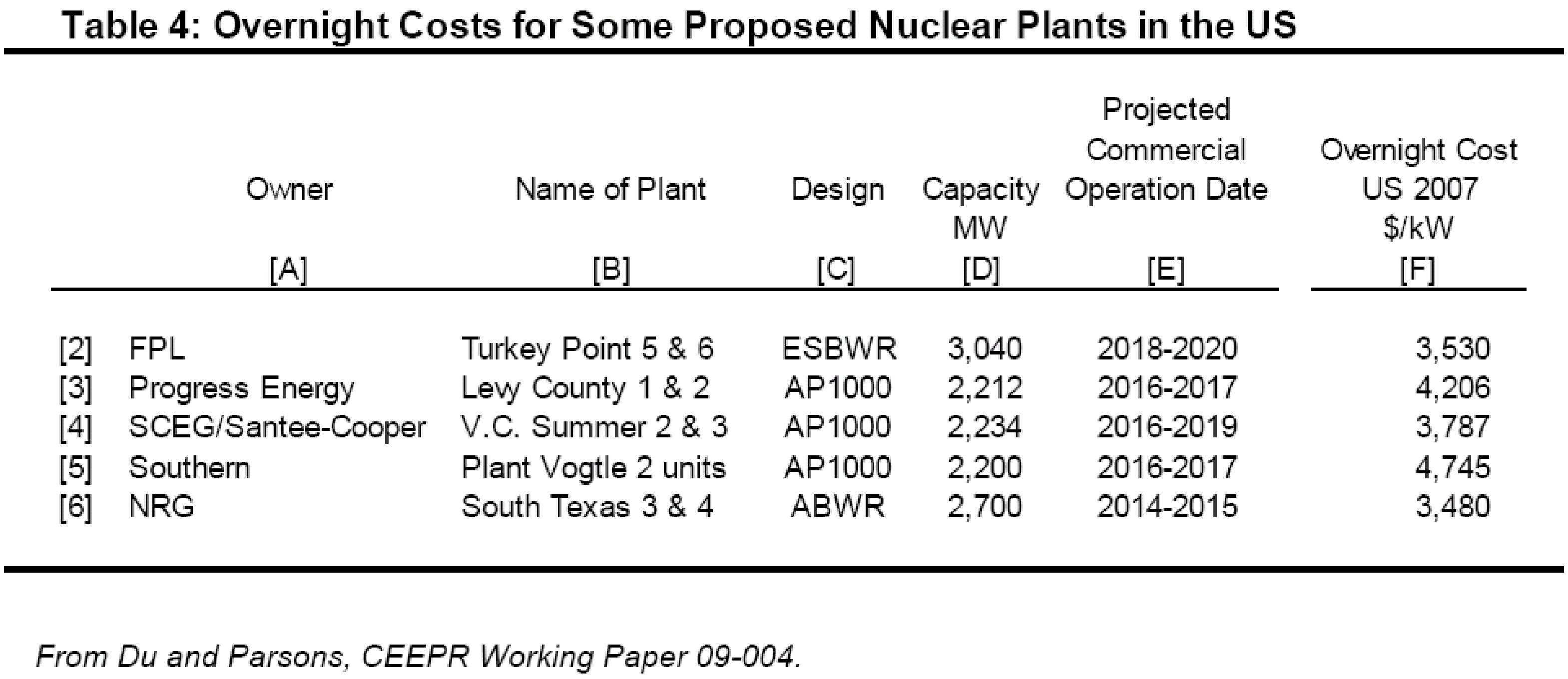


Table 4: Overnight Costs for Some Proposed Nuclear Plants in the US

	Owner	Name of Plant	Design	Capacity MW	Projected Commercial Operation Date	Overnight Cost US 2007 $/kW
	[A]	[B]	[C]	[D]	[E]	[F]
[2]	FPL	Turkey Point 5 & 6	ESBWR	3,040	2018-2020	3,530
[3]	Progress Energy	Lewy County 1 & 2	AP1000	2,212	2016-2017	4,206
[4]	SCEG/Santee-Cooper	V.C. Summer 2 & 3	AP1000	2,234	2016-2019	3,787
[5]	Southern	Plant Vogtle 2 units	AP1000	2,200	2016-2017	4,745
[6]	NRG	South Texas 3 & 4	ABWR	2,700	2014-2015	3,480

From Du and Parsons, CEEPR Working Paper 09-004.

CEEPR MIT Center for Energy and Environmental Policy Research

Technology Discussion

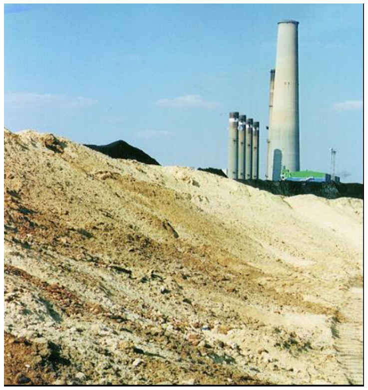
Characteristics – Renewable and Alternative

Wind

- Mature technology, commercially available
- Does not require additional fuel source
- Offsets greenhouse gases
- Relatively simple design, short lead time for construction
- Intermittent generation – <u>not</u> dispatchable
- Best wind resources limited geographically
- Wide range of potential future costs
- Siting resistance due to aesthetic effects of wind turbines

Biomass

- Mature technology, commercially available
- Carbon neutral
- Use of regional resources, local economical development
- Results in less waste sent to landfills
- Co-firing may have potential impact on SCR catalyst
- Significant capital required to upgrade units to achieve high levels
- Uncertain cost, availability, and competition for biomass resources
- Dispatchable



Technology Discussion

Characteristics – Renewable and Alternative (Cont'd)

Landfill Gas

- Mature technology, commercially available
- Practical for a large range of landfill sizes
- Converts a waste material into useable energy
- Capture and productive use of methane – a potent greenhouse gas
- Uncertainty of landfill gas production life
- Transmission line availability
- Can be dispatchable

Solar Photovoltaic

- Mature technology, commercially available
- Continuing research on third generation solar technologies
- Does not require additional fuel source
- Offsets greenhouse gases
- Can help to reduce household or facility electric bill
- Intermittent generation – not dispatchable
- Current high costs
- Incentives necessary to accelerate adoption

Technology Discussion
Characteristics – Renewable and Alternative (Cont'd)

Concentrated Solar

- Parabolic trough technology mature, commercially available
- Other technology types emerging
- Direct, non-diffused solar resources limited to Southwest U.S.
- Intermittent generation
- High capital costs
- Land requirements

Geothermal

- Hydrothermal technologies (geysers) mature, commercial
- High capacity factor (e.g., 80-90%)
- Resources geographically limited
- High pre-development costs
- Siting issues
- Water use

Characteristics – Renewable and Alternative (Cont'd)

Hydrokinetic

- Emerging technology, first licensed project was August 2009
- Varying capacity factors (e.g., ~29-65%)
- Siting and permitting issues
- Potential environmental and navigation impacts
- High cost
- Grid integration issues
- Unknown long-term performance

Waste Heat

- Conventional heat recovery is commercial, mature
- New emerging technologies on the horizon
- Increases industrial process efficiency
- Many industrial opportunities
- Need continuous, predictable flow of waste heat
- No standard plant, applications custom tailored to industry
- Capital cost, O&M cost vary greatly

Technology Discussion

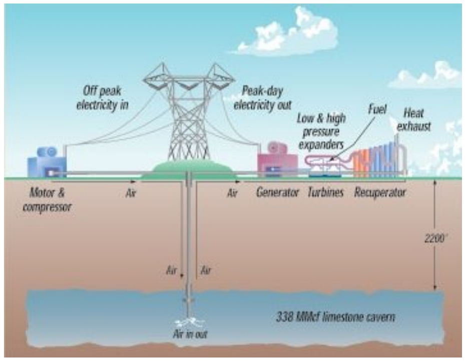
Characteristics – Storage

Pumped Storage

- Extraordinary operational flexibility
- Very low O&M costs
- Almost instant start and low start cost
- Very high initial capital cost, especially for a low capacity factor plant
- Siting challenges

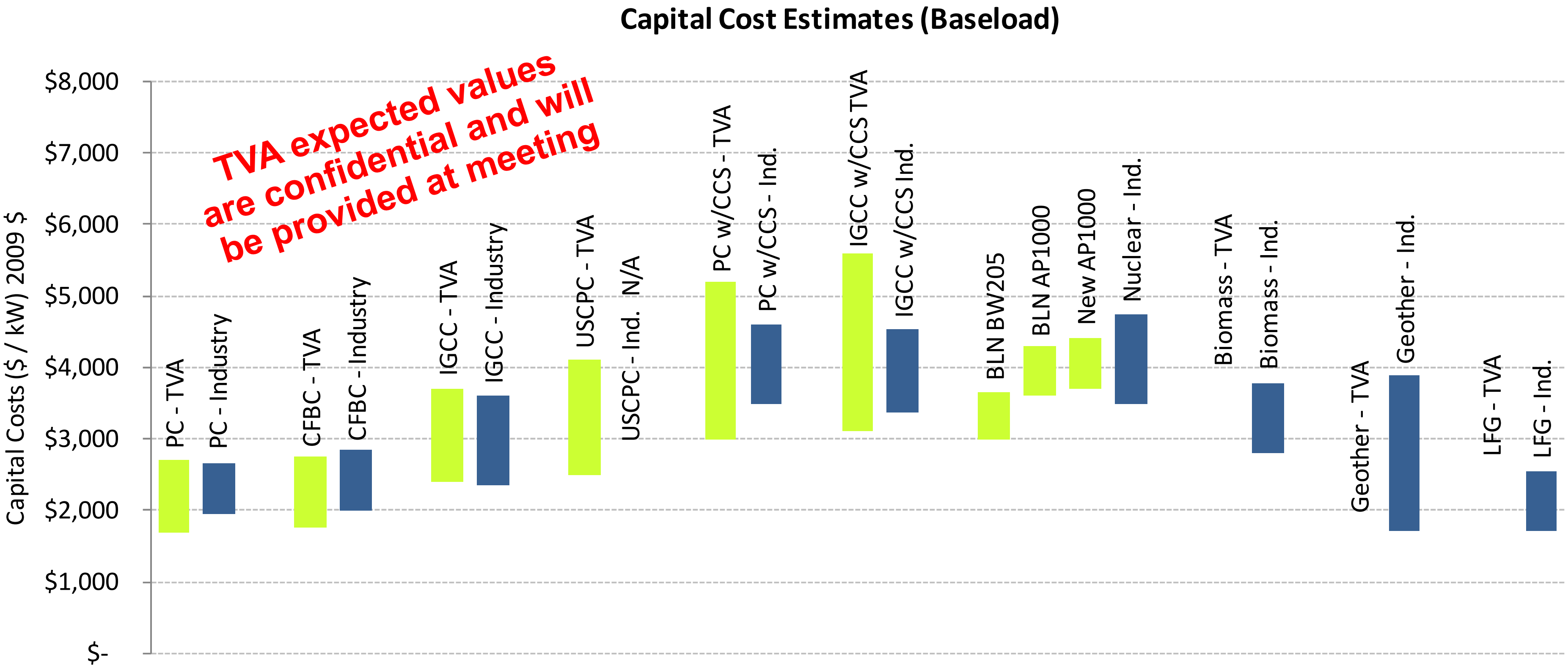
Compressed Air Energy Storage

- Excellent operational flexibility
- Less dependent on volatile natural gas
- High initial capital cost, especially for a low capacity factor plant
- Siting challenges



Technology Discussion

Comparison of Capital Costs



TVA expected values are confidential and will be provided at meeting

- 🟩 TVA cost estimate ranges based on recently completed work, vendor discussions, and/or internal studies
  - These values provide input for screening
- 🟦 Industry values from the following sources:

Technology	Source
Pulverized Coal (PC)	EPRI, EIA, Shaw, NEI
Circulating Fluidized Bed Combustion (CFBC)	EPRI, Shaw
Integrated Gasification Combined Cycle (IGCC)	EPRI, EIA, Shaw, NEI
Ultra Supercritical Pulverized Coal	Not available

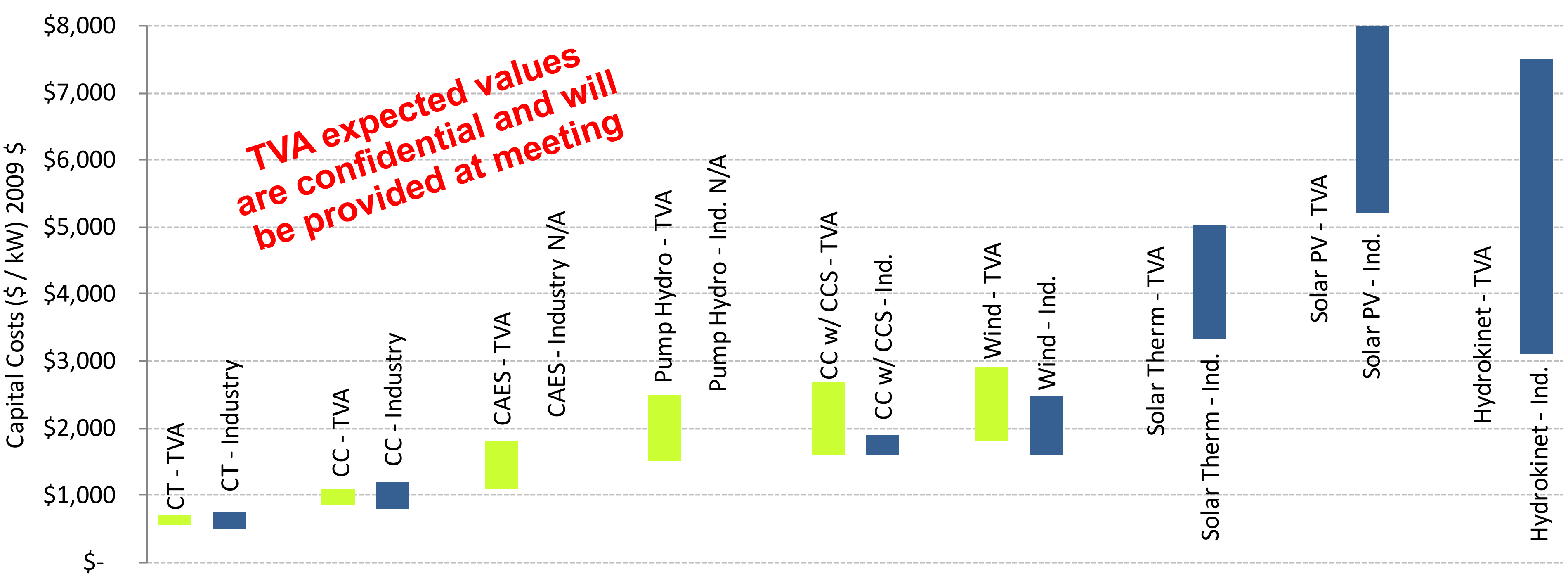
Technology	Source
PC with Carbon Capture & Storage (PC w/CCS)	EPRI, Shaw, NEI
IGCC with CCS	EPRI, EIA, Shaw, NEI
Nuclear	MIT CEEPR and NEI
Biomass, geothermal, landfill gas (LFG)	EPRI, EIA

NOTES:

- Biomass, geothermal, and landfill gas are shown as baseload technologies but are also used as intermediate resources
- Detailed information for industry sources is listed at the end of this section

Technology Discussion

Comparison of Capital Costs (Cont'd)



Capital Cost Estimates (Intermediate & Peaking)

TVA expected values are confidential and will be provided at meeting

🟩 TVA cost estimates based on recently completed work, vendor discussions, and/or internal studies

🟦 Industry values from the following sources:

Technology	Source
Combustion Turbine (CT) and Combined Cycle (CC)	EPRI, EIA, CERA
Compressed Air Energy Storage (CAES)	Not available
Pumped Hydro	Not available
Combined Cycle with Carbon Capture &Storage (CC w/CCS)	EPRI, EIA
Wind, Solar Thermal, Solar Photo Voltaic (PV), Hydrokinetics	EPRI, EIA

Estimates for some technologies depend highly on maturity and proximity to source

TVA cost estimates are generally in line with industry values.

Comparison of Capital Costs (Cont'd)

The following are additional industry sources used by TVA in development of capital costs:

- Recent TVA experience
- Energy Information Administration (EIA) www.eia.doe.gov/oiaf/aeo/
- Environmental Protection Agency (EPA) www.epa.gov
- EPRI Technical Assessment Guide (TAG) www.epri.com
  - Power Generation and Storage Technology Options
  - Renewable Energy Technical Assessment Guide
- Global Insight www.ihsglobalinsight.com/Energy
- IHS Cambridge Energy Research Associates (CERA) www.cera.com
- MIT Center for Energy and Environmental Policy Research (CEEPR) http://web.mit.edu/ceepr/www/publications/index.html
- National Energy Technology Laboratory (NETL) www.netl.doe.gov/technologies/carbon_seq/index.html
- Nuclear Energy Institute (NEI) www.nei.org/resourcesandstats/

Technology Discussion
Screening Inputs

The following table provides detailed input used in supply option screening

Confidential – to be provided at meeting

Technology Discussion

Screening Inputs

After possible resource options are screened on policy and feasibility/maturity, remaining technologies are subjected to economic screening

This screening step compares "busbar costs" for each technology by duty cycle to identify most economic options for base, intermediate or peaking use

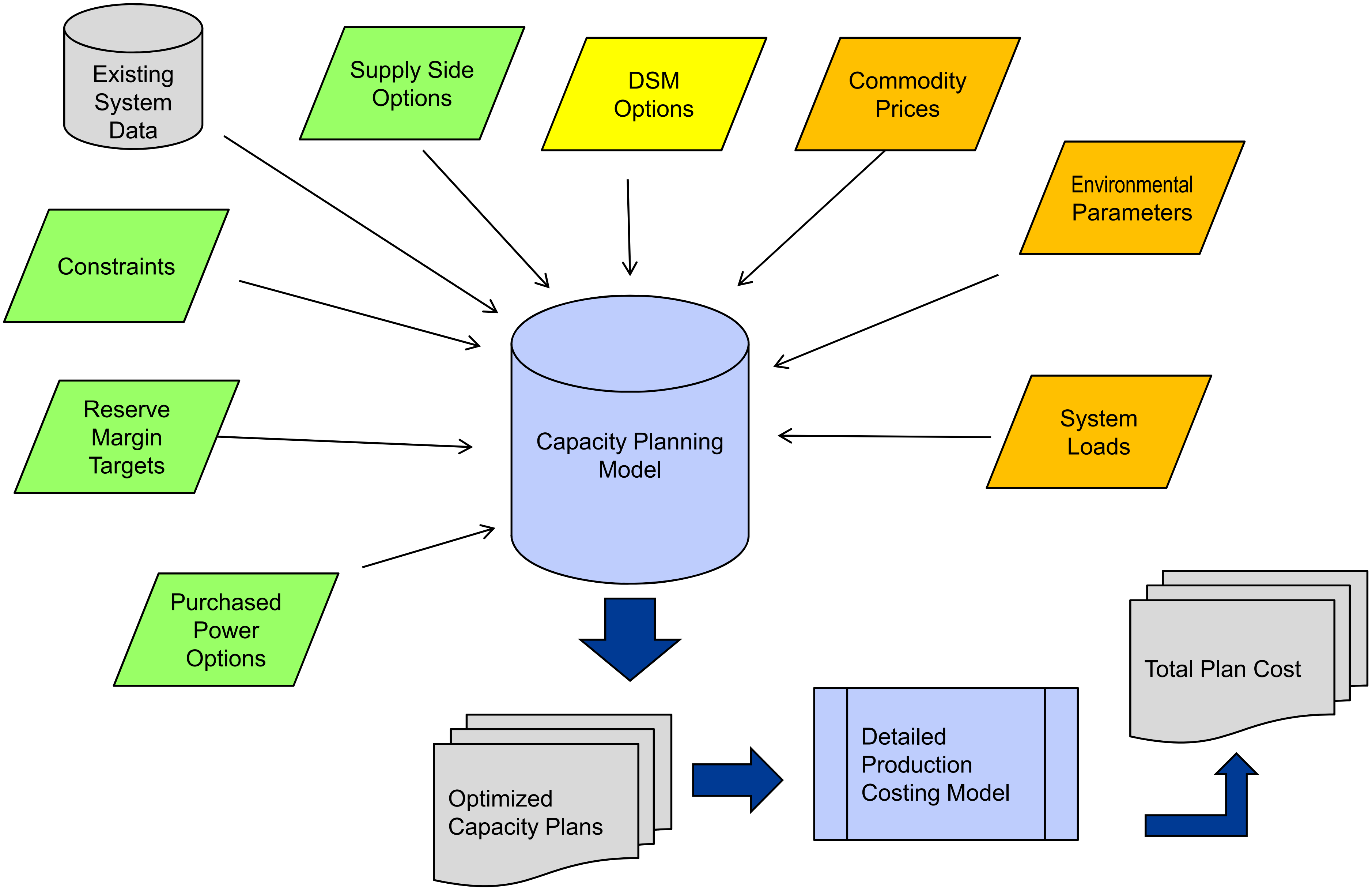
- Busbar cost is based on the cost of the resource only – capital and operating expense – and does not include transmission costs, site costs, etc.
- To properly capture differences among technologies for asset life and to reflect changes in costs over time, busbar costs are usually expressed as levelized $/MWh values
- Input data for busbar cost models usually include unit-specific data (like the data shown in the table on the preceding slide) and system-level data like fuel prices, interest and discount rates, emissions and compliance costs, etc.
- Often busbar costs are reported in graphical form over a range of typical capacity factors, as well as a tabulated $/MWh value, to facilitate identification of candidate resources that will be considered by the capacity planning model

More details about TVA's screening process and a discussion about the preliminary list of candidate technologies selected for use in the capacity planning model will be presented at the next stakeholder meeting

Modeling Process for Resource Planning

Modeling Process

Overview: The Inputs/Outputs of the Planning Process



Existing System Data

Supply Side Options

DSM Options

Commodity Prices

Environmental Parameters

Constraints

Reserve Margin Targets

Capacity Planning Model

System Loads

Purchased Power Options

Optimized Capacity Plans

Detailed Production Costing Model

Total Plan Cost

Modeling Process

Overview: Identify the Resource Options

- Supply side
  - Develop a list of candidate technology options using internal and external sources
  - Apply multiple screening steps to identify likely (candidate) technologies
    - Policy
    - Feasibility/viability
    - Economic
  - Input candidate technologies to the capacity planning model
- Demand side
  - Define one or more DSM portfolios
  - Evaluate DSM portfolios in the capacity planning model two ways
    - Treat DSM options as priority resource: supply-side options selected after DSM impacts considered
    - Model considers DSM bundles as “units” together with supply-side options and chooses the least cost combination
- Purchased power agreements
  - Consider characteristics for conventional and renewable PPA characteristics
  - Capacity schedule (MW amount)
  - Duration of the transaction
  - Price (by season/year, including transmission)
  - Transmission expansion if required (assessed when transaction is selected)
  - Transmission interface capability increases (if required) included in cost of the transaction
  - PPAs included as an alternative to supply-side resource additions

Modeling Process

Overview: Constraints and Reliability Requirements

Include modeling constraints (boundary conditions)

- Set to ensure that possible capacity plans reflect strategic and/or operational constraints
  - Constructability – limit first year resource is available to reflect timeline to bring a unit online and/or set minimum time between multiple units
  - Deliverability – timeline required to ensure transmission system can support unit (or purchase) at full dispatch and consideration of any transmission limits that may affect choice of resources
  - Fuel supply – any limitations in fuel delivery routes or infrastructure
  - Capability changes – incremental adjustments to existing generating fleet and/or planned fleet reductions (retirements, mothball)
  - Strategic – targets for reliance on market purchases, overall resource mix, etc.
  - **More about constraints at a future stakeholder meeting**

Set the reserve margin to ensure an adequate level of reliability

- Capacity expansion modeling optimizes the capacity added to fill the shortfall between existing capability and firm requirements (system load – interruptible loads + reserve margin) at the time of the system peak
  - For TVA, the system peak for capacity planning purposes occurs in the summer
- Reserve margin is comprised of two components: operating reserves and planning reserves
  - Operating reserves are set based on NERC and SERC requirements to ensure system stability under certain contingencies
  - For TVA, this component of the reserve margin is about 3,000 MW and generally remains fixed over the planning study
  - Planning reserves are set to ensure adequate resources are available after accounting for possible unit outages/derates or other system events not reflected in the operating reserve
  - For TVA, this component of the reserve margin is about 8.5% of the net system peak (load – interruptibles) and is based in part on loss of load probability studies

Modeling Process

Capacity Planning: “Optimized” Resource Additions

- Capacity planning is about finding the optimum combination of resources to meet projected demand/energy requirements over the study period
- The computer model is designed to optimize new resource schedule based on one key study parameter (called the objective function) – usually this key parameter is net present value of revenue requirements
  - Results will change as the objective function changes
- Model generates multiple combinations of resource additions for each year of the study period and computes costs for each combination.
- Year to year changes in resource mix are then evaluated and infeasible “states” are eliminated
  - For example, if the total number of resources decreased from one year to the next, that state is deemed infeasible and eliminated from further consideration
- Least cost path through the possible states in the study period is the optimized capacity expansion plan
- Capacity optimization tools use a simplified dispatch algorithm to compute operating costs because of the number of possible states evaluated
- Detailed analysis of operating costs and related characteristics is needed when selecting a preferred resource plan, so an hourly production costing model is used to compute those costs for plan evaluation/comparison
- Once capital expansion and production costing results are obtained, portfolio risk assessment is done using stochastic methods and tools

Wrap-Up Discussion

- Additional comments
- Recap of action items and follow-up questions
- Overall feedback on today’s discussion