2015 Integrated Resource Plan

IRPWG Meeting

Session 7 – Day 2

May 30, 2014

REDACTED VERSION

IRPWG Meeting – May 30th Agenda

	Day 2	
8:30	**Recap from Previous Day/Overview of Day 2**	Randy McAdams
8:45	**Overview of Assumptions on the Planning Strategies**	Gary Brinkworth
	Resources and Planning Assumptions	
9:15	Overview of Capacity Planning	Tom Rice
9:45	Generation Resource Characteristics & Costs	Candy Cooper
10:30	*Break*	
10:45	Generation Resources (con't)	
11:30	Wind / Solar Resource Characteristics & Modeling	Scott Jones
12:15	*Lunch*	
1:00	EE Modeling Update	Ed Colston / Tom Rice
1:30	**Group Feedback – Resources and Planning Assumptions**	Randy McAdams
2:00	**Wrap-up and Next Steps**	Gary Brinkworth
	Adjourn	

Recap from Day 1

The primary comments and suggestions received during yesterday's session can be grouped in two categories:

1. Feedback about the scenario assumptions:

- **Stagnant Economy:**
  - Revisit assumptions around inflation & CO2 price; consider renaming this scenario to clarify intent
- **De-carbonized future:**
  - Revisit the assumptions around the impact on GDP

2. Comments around how to better communicate the scenarios to the public:

- Clarify assumptions, define terms and construct more clearly labeled charts
- Rename DG classification as Industrial Gas and Solar
- Make explicit that renewable growth is an additional driver for electricity price

TVA will review all comments/recommendations and communicate resulting changes in the scenario assumptions to the working group

Overview of Assumptions on the Planning Strategies

Overview of Assumptions on the Planning Strategies

IRP 2015 Selected Strategies

STRATEGY	DESCRIPTION
A - "Traditional" Least Cost Planning	• All resource options available for selection; traditional utility "least cost optimization" case
B- Meet an Emission Target	• Resources selected to create lower emitting portfolio instead of focusing only on a traditional least cost approach • This lower emissions plan will be based on an emission rate target or level using CO2 as the emissions metric (the target will be set as a reduction from current emissions forecast) • Additional existing unit retirements may be included in the plan.
C - Lean on the Market	• Most new capacity needs are met using market resources and/or third-party assets acquired through PPA or other bilateral arrangements • TVA makes a minimal investment in owned assets (deployment of EEDR to meet resource needs will continue)
E - Doing More EEDR	• In order to establish TVA as a regional energy efficiency leader, a majority of capacity needs are met by setting an annual energy target for EEDR (e.g., minimum contribution of 1% of sales) • Renewable energy and gas are secondary options with no coal or nuclear additions permitted
F – Embracing Renewables	• In order to establish TVA as a regional renewable leader, a majority of new capacity needs are met by setting immediate and long-term renewable energy targets (e.g., 20% by 2020 and 35% by 2040), including hydroelectric energy • A utility-scale approach is targeted initially with growing transition to distributed generation as the dominant renewable resource type by 2024 • EEDR and gas are secondary options with no coal or nuclear additions permitted

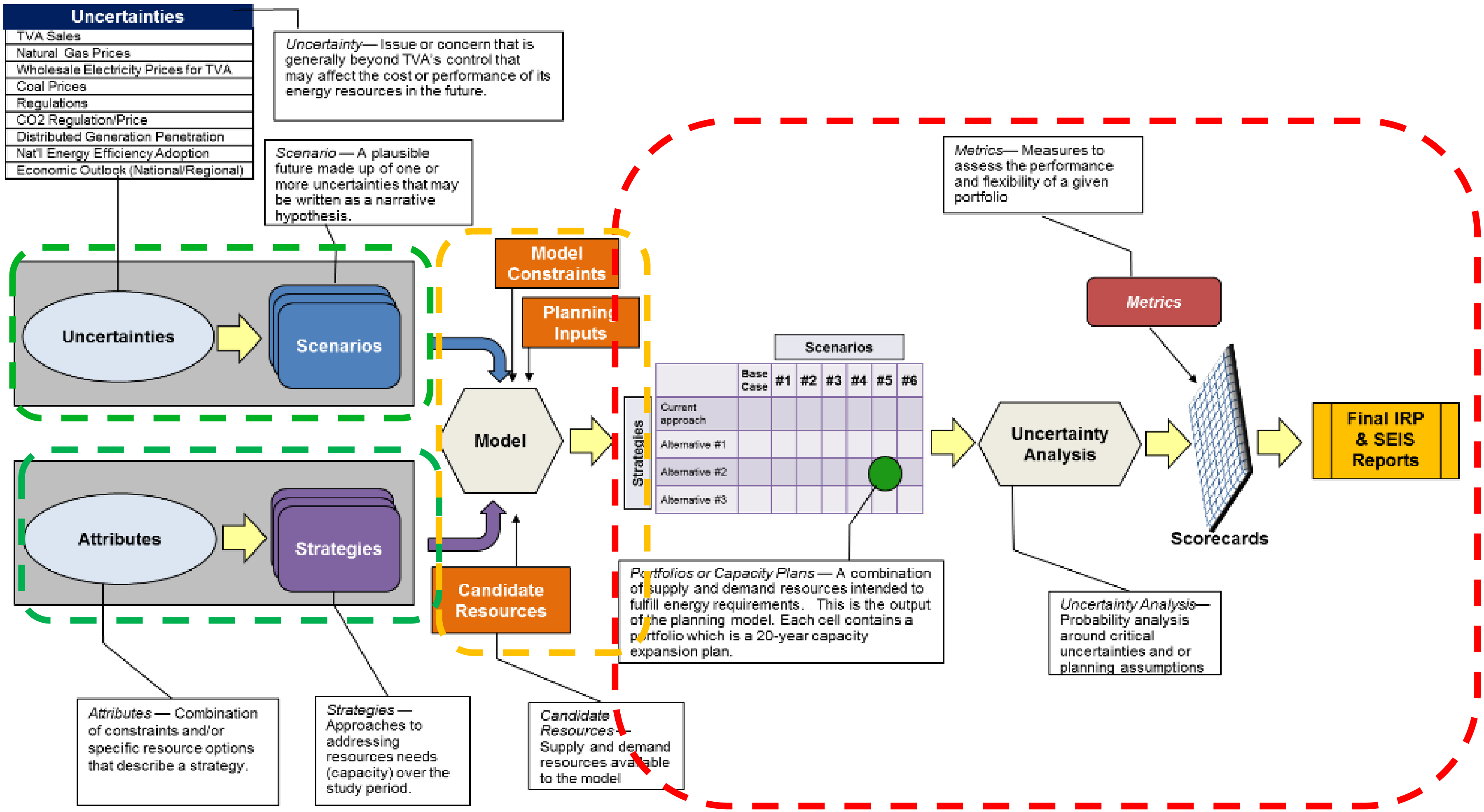
Overview of Assumptions on the Planning Strategies

Update on Strategy Design Parameters

STRATEGY	DESCRIPTION
A - “Traditional” Least Cost Planning	• No special modeling assumptions required in this strategy – all resources options in play
B- Meet an Emission Target	• Use 50% reduction in CO2 emission levels from 2005 actuals by 2033 and an emission rate target of 557 lbs/MWh. This level is projected to be well below emissions calculated based on the current power supply plan. • Model testing is still underway to confirm this constraint can be properly implemented
C - Lean on the Market	• This strategy increases the market depth already represented in the model
E - Doing More EEDR	• Implement this minimum EE target by computing the total amount of EE that represents 1% of sales, then deduct mandatory measures (i.e., EPA agreement); this net amount of EE can then be enforced/scheduled as a % of new capacity constraint • Model testing is still underway to confirm this technique • If necessary, defined EE portfolios will be used to achieve the required minimum levels (model will still be able to optimize additional EE if cost effective)
F – Embracing Renewables	• Enforce as a % of new generation or % of new capacity constraint (e.g., require that X% of capacity additions are renewable). • To better model this objective we would need to specify technology type (wind / solar). • Model testing is still underway to confirm this technique

Overview of Capacity Planning

Overview of Capacity Planning
2015 IRP Status



Completed
In process
Next steps

Operating a Multidirectional Electric System

Evolving Reality: Renewables, energy efficiency (EE), distributed generation, and demand response (DR) managed by multiple entities. Market may present strategic opportunities.

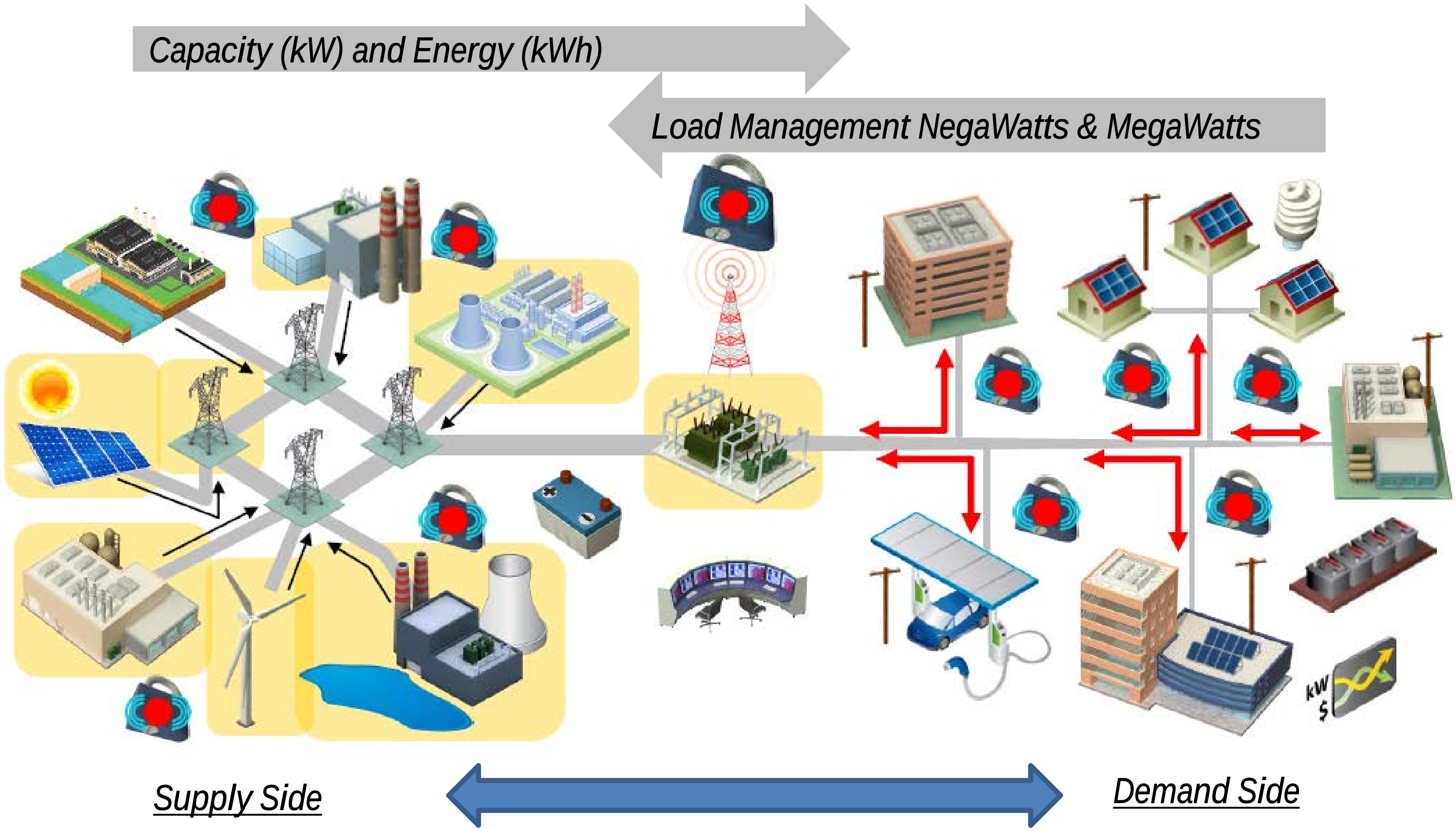


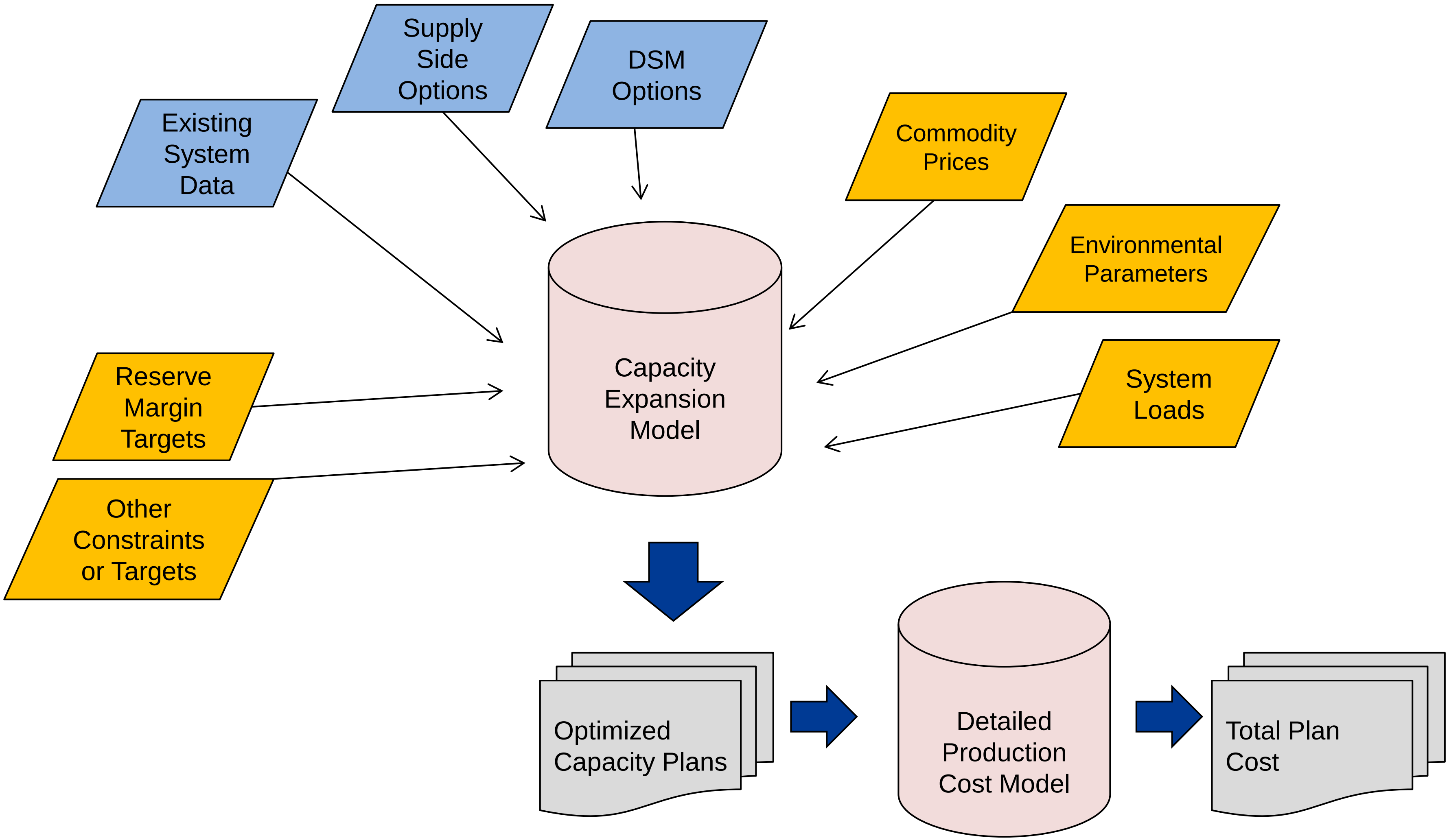
Image Source: EPRI

Capacity Expansion Model

- The capacity expansion model is used to determine the least-cost portfolio (as measured by PVRR) subject to a set of constraints; these constraints include:
  - Required system reliability (reserve margin)
  - Available supply options (type of unit, etc.) and/or conservation measures (customer-driven)
  - Constructability of assets (lead time and material availability)
  - Environmental compliance targets (existing and potential regulations)
  - Strategic targets, including fuel diversity and financial targets

1	2	3	4	5	6
Check Capacity Balance	Identify Resource Combinations	Compute Capital Investment	Compute Operating Expenses	Retain Lowest Cost Combination	Update System Capability
Confirm that system capacity is sufficient to meet projected peak demand plus reliability margin. If not, resources must be added	Find combinations of new resources that could provide the additional capacity needed	Annual capital for these new resource combinations based on amortized payment or annual carrying cost	Operating costs for the entire electric system including each of the proposed additional resource combinations	The annual system cost (capital plus operating) is used to identify the least cost option	The least cost combination of new resources is added to the existing system and become the basis for the capacity balance check in the following year

Capacity Expansion Model Inputs



Existing System Data

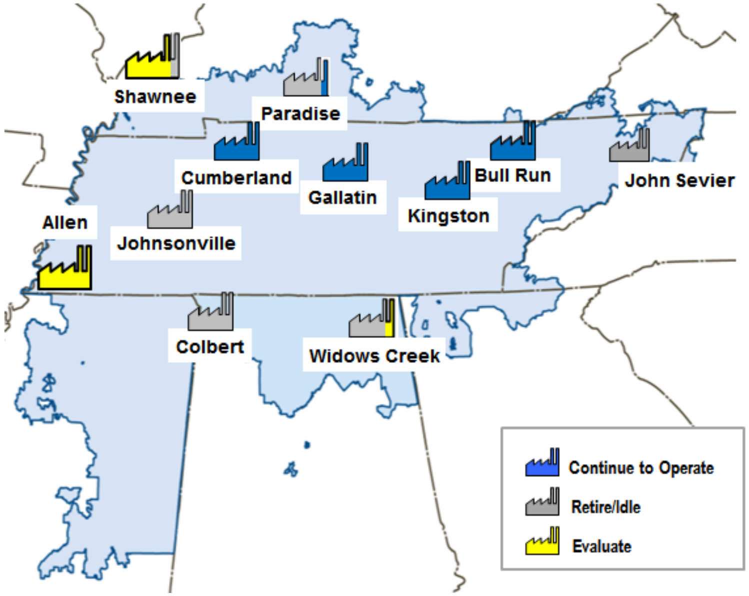
- **Nuclear:** About 6,600 MW at three different plants: Browns Ferry, Sequoyah, and Watts Bar. A second unit will be commercially available at Watts Bar by the end of 2015 increasing the total nuclear fleet capacity to more than 7,800 MW. For the 2015 IRP we do not assume any Nuclear retirements

- **Hydroelectric**: TVA maintains 29 conventional hydro dams throughout the Tennessee River system and one pumped-storage facility (Raccoon Mountain). For the 2015 IRP we do not assume any Hydro retirements

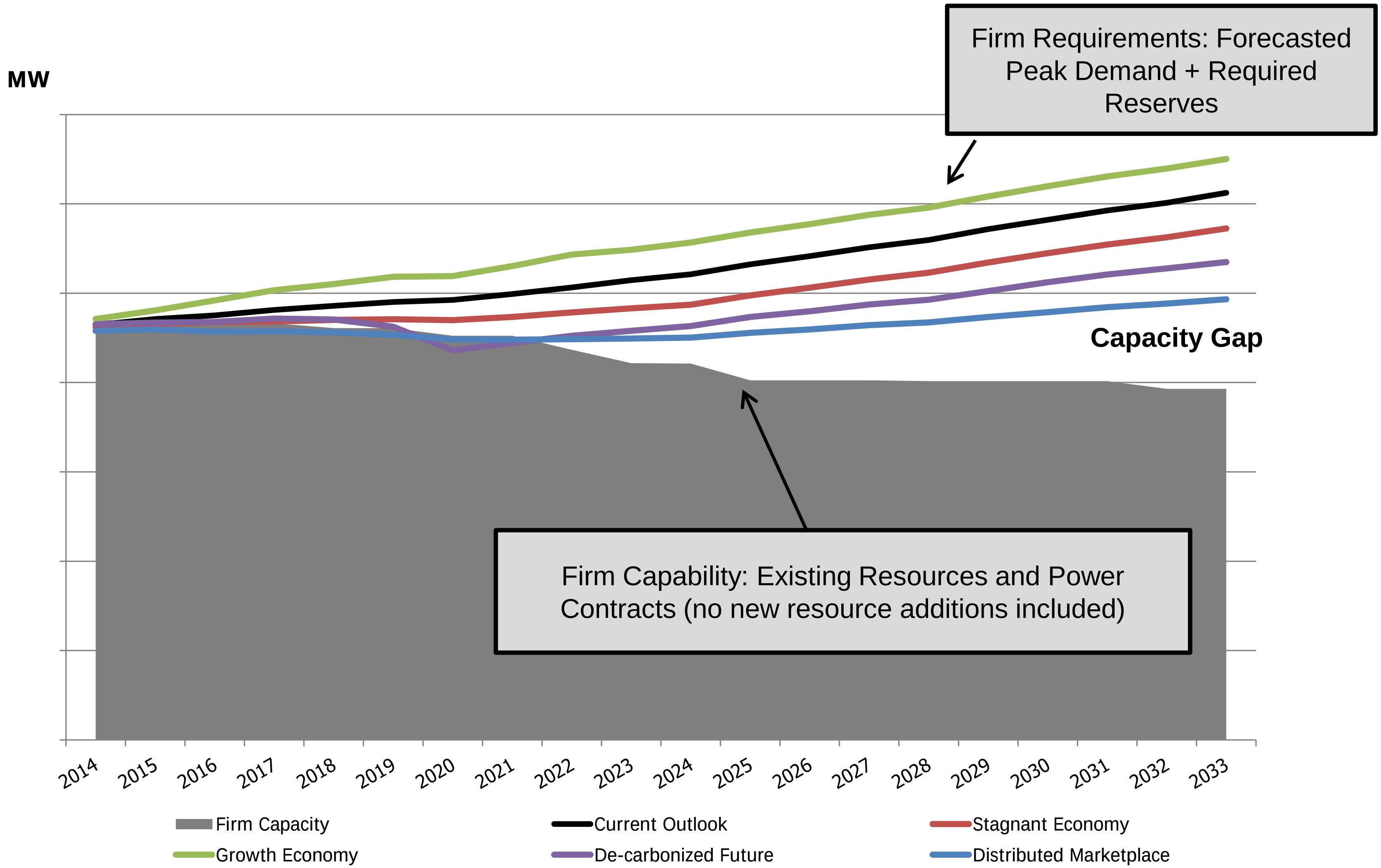
- **Gas:** About 3,000 MW of TVA-owned combined cycle assets and over 5,000 MW of combustion turbines

- **Coal:** Current operating coal fleet is over 11,000 MW. Coal fleet strategy includes announced retirements and the 2015 IRP will evaluate additional coal retirements

- **Power purchase agreements:** For the IRP, current contracts will adhere to existing contract terms



Capacity Balance



Generation Expansion Options

NATURAL GAS FIRED
- Simple cycle combustion turbine (CT3x)
- Simple cycle combustion turbine (CT4x)
- Combined cycle two on one (CC2x1)
- Combined cycle three on one (CC3x1)

COAL FIRED
- Integrated Gas Combined Cycle (IGCC)
- Pulverized Coal 1x8 (PC1x8)
- Pulverized Coal 2x8 (PC2x8)
- Integrated Gas Combined Cycle with Carbon Capture and Sequestration (IGCC CCS)
- Pulverized Coal 1x8 with Carbon Capture and Sequestration (PC1x8 CCS)
- Pulverized Coal 2x8 with Carbon Capture and Sequestration (PC2x8 CCS)

NUCLEAR
- Pressurized water reactor (PWR)
- Advanced pressurized water reactor (APWR)
- Small Modular Reactor (SMR)

HYDRO
- Power dam addition #1
- Power dam addition #2
- Run of river

UTILITY-SCALE STORAGE
- Pumped-hydro storage
- Compressed air energy storage (CAES)

BIOMASS
- New direct combustion
- Repowering

SOLAR
- Utility-scale one-axis tracking photovoltaic
- Utility-scale fixed-axis photovoltaic
- Commercial-scale large photovoltaic
- Commercial-scale small photovoltaic

WIND
- Midcontinent Independent System Operator (MISO)
- Southwest Power Pool (SPP)
- In valley
- High Voltage Direct Current (HVDC)

Generation Resources Characteristics & Costs
Screening of Peers' Generation Alternatives

Technology Evaluated for Planning Purposes	DEC 2013	GPC 2012	PCQ 2013	PEC 2012	DOM 2013	ETR 2012	APS 2012	TVA 2015
Coal Fired								
Circulating Fluidized Bed ("CFB")		X			X	✓		
Pulverized Coal	✓	✓	✓	✓	✓	✓	X	✓ 4
IGCC		✓	✓	X	✓		X	✓ 2
Gas Fired								
Gas Fired Combustion Turbine	✓	✓	✓	✓	✓	✓	✓	✓ 2
Gas-Fired Combined Cycle	✓	✓	✓	✓	✓	✓	✓	✓ 2
Internal Combustion Reciprocating		X	✓					
Small Scale Aeroderivatives						✓		
Nuclear								
Nuclear	✓	✓	✓	✓	✓	✓	X	✓ 2
Nuclear Fusion					X			
Small Modular Reactors ("SMR")	X				X			✓ 1
Renewables								
Biomass	✓	✓	✓	✓	✓	✓	✓	✓ 2
Concentrating Solar		✓	✓		X		X	
Fuel Cell	X	✓		X	✓			
Geothermal	X	X	✓		X		✓	
Hydro				X	X			✓ 3
Landfill Gas		✓		✓				
Offshore Wind	X	✓	✓	X	✓			
Onshore Wind	✓	✓	✓	✓	✓	✓	✓	✓ 4
Poultry and swine waste digesters	X							
Solar PV	✓	✓	✓	✓	✓	✓	✓	✓ 4
Tidal and Wave Power		✓			X			
Storage								
Battery	X	✓			X		✓	
Compressed Air	X	✓			X		✓	✓ 1
Flywheel		X	✓		X			
Pumped Storage		✓						✓ 1

✓ = Resource was evaluated and included in the planning process
X = Resource was evaluated and excluded from the planning process

- The number of potential expansion options available in the TVA IRP is comparable to other IRP exercises
- TVA has several options within each larger fuel category
- This list does not include the DSM options

Key Resource Specifications

	Description	Form
Unit Characteristics		
Capacity	Nameplate capacity	MW
Heat Rate	Summer full-load heat rate	Btu/kWh
Unit Availability	First year available	Year
Outage Rate	Forced and planned outage rate	Annual %
Cost Characteristics (2013$)		
Capital Costs	Total overnight capital cost	Millions of $
	Transmission costs	Millions of $
	Total overnight capital plus transmission costs per unit	$/kW
Variable Costs	Non-fuel variable O&M rate	$/MWh
Fixed Costs	Variable fixed O&M rate + fixed fuel transportation costs + transmission wheeling charges	$/kW-yr
Book life	Number of years a resource is expected to be in service	Yrs

Collaborative Assumption Gathering & Review Process

Tennessee Valley - Renewable Information Exchange (TV-RIX)

TV-RIX technology champions provided current data (~1 year review process)

↓

Renewable Energy Solutions Group Review

TVA subject matter experts reviewed TV-RIX inputs

↓

Capacity Planning Team Review

Ensured consistency of inputs through the resource type and across characteristics

↓

Independent External Review (Navigant Consulting Inc.)

Compared existing assumptions with proprietary and other industry sources

↓

IRP Working Group

Review final assumptions with group

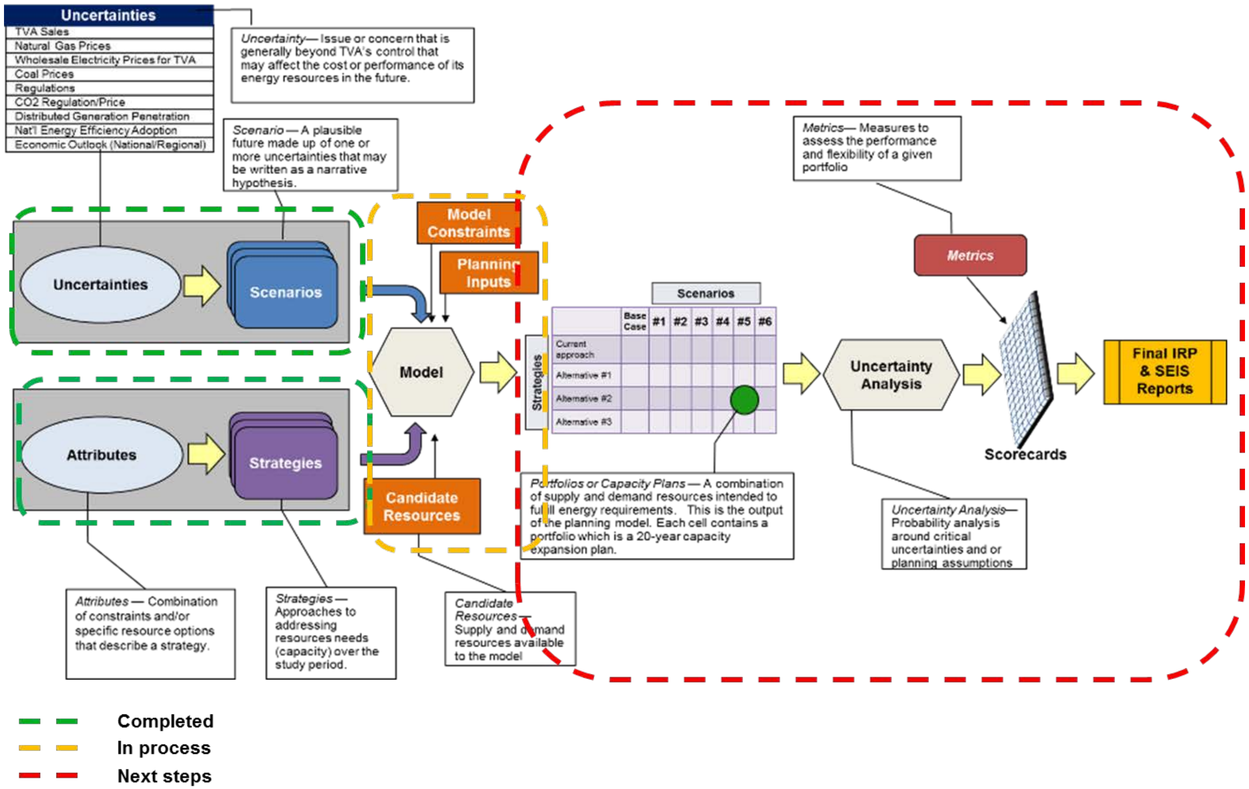
External Review

Internal Review

Detailed Planning Assumptions by Resource Type

Detailed assumptions around unit cost and operating characteristics are considered business sensitive information by TVA and have been excluded from this public version of the stakeholder briefing materials

Resource Planning: Key Takeaways



- TVA has several new expansion units for selection
- The TVRIX process, as well as the third party review, was an iterative process. Data exchanges were very helpful and informative
- TVA capacity expansion assumptions are more robust due to both of these collaborative efforts for all capacity planning exercises

Wind & Solar Resource Modeling

- Wind and Solar resources have unique operating characteristics that are different from other asset types:
  - Hourly energy profiles are fixed / "scheduled" in to the model and are not dispatchable
  - Heat Rates are not relevant, and a key variable for these resources is capacity factor (how much generation they produce relative to their capacity). This is a proxy for the shape and amount of generation produced
  - Because wind and solar are weather dependent, we must also establish a Net Dependable Capacity (NDC) - how much of each resource can we count on at our peak
  - Transmission costs may be quite significant (HVDC) or routine (in-Valley solar)

- For wind resources, we are modeling
  - in-Valley wind
  - out-of-valley wind
  - HVDC wind

- TVA benefits from our significant experience with wind power

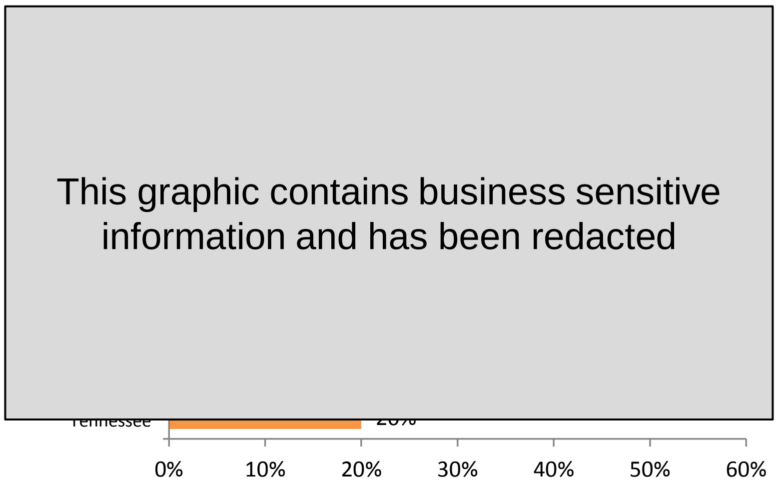
Wind & Solar Modeling – Collaboration with Stakeholders

- Similar to the units costs previously covered, TVA worked with TVRIX and other stakeholders to review and vet operating assumptions and incorporate the best currently available information
- TVRIX provided substantial, useful information to inform these resource characteristics
- TVRIX undertook extensive review of solar shapes and modeling with Clean Power Research, resulting in a robust data set used to analyze renewable options
- Strong collaboration on data / analytic methods; ongoing dialogue will inform future TVA analysis beyond the IRP

Wind - Capacity Factor

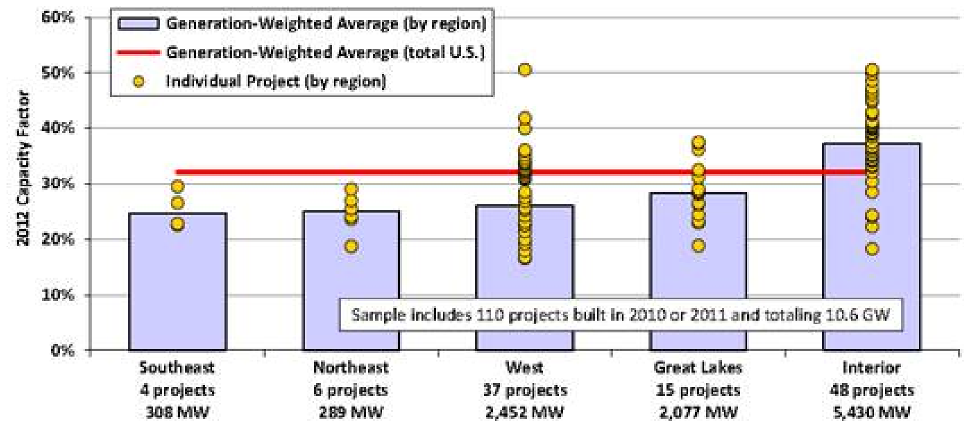
- Used actual results from TVA's wind contracts (1500 MW in Oklahoma, Illinois, Kansas, Iowa), simulated and actual data for the in-valley sites, and proposals for various projects

Wind Expected Capacity Factor



Source: TVA

2012 Wind Capacity Factor by Region



Source: Lawrence Berkeley National Lab

	In-Valley Wind	Out-of-Valley Wind	HVDC Wind
TVRIX Recommendation	30-40%	55%	55-61%*
IRP Input	30%	40%	55%

*TVRIX recommendation reflects oversubscription of HVDC line, which is not assumed for the IRP

Wind - Net Dependable Capacity

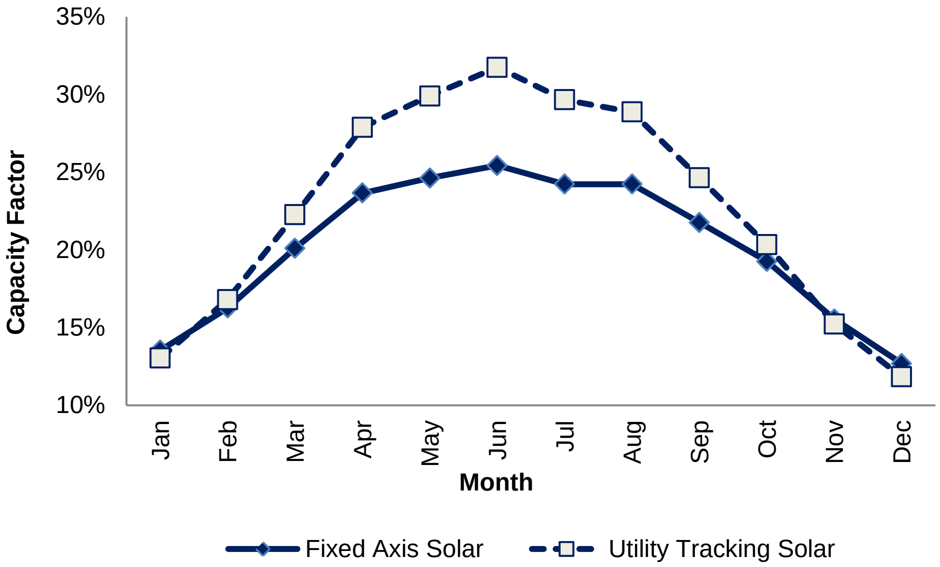
- Utilized up to 30 years of simulated wind generation for each of TVA's existing out-of-valley wind contracts, simulated in-Valley wind farms, and simulated HVDC wind sites
- For each wind resource, determined the capacity factor coincident with TVA's Top 20 summer peak hours each year
- Then, within each year, selected the 25th percentile of each of these capacity factors to ensure a 75% confidence factor that the wind generation at our system peak will meet or exceed this level
- Finally, average these resulting capacity factors across each year of data available to yield net dependable capacity

	In-Valley Wind	Out-of-Valley Wind	HVDC Wind
TVRIX Recommendation	8%	14%	40-47%*
IRP Input	14%	14%	14%

*TVRIX recommendation reflects oversubscription of HVDC line, which is not assumed for the IRP

Solar - Capacity Factor

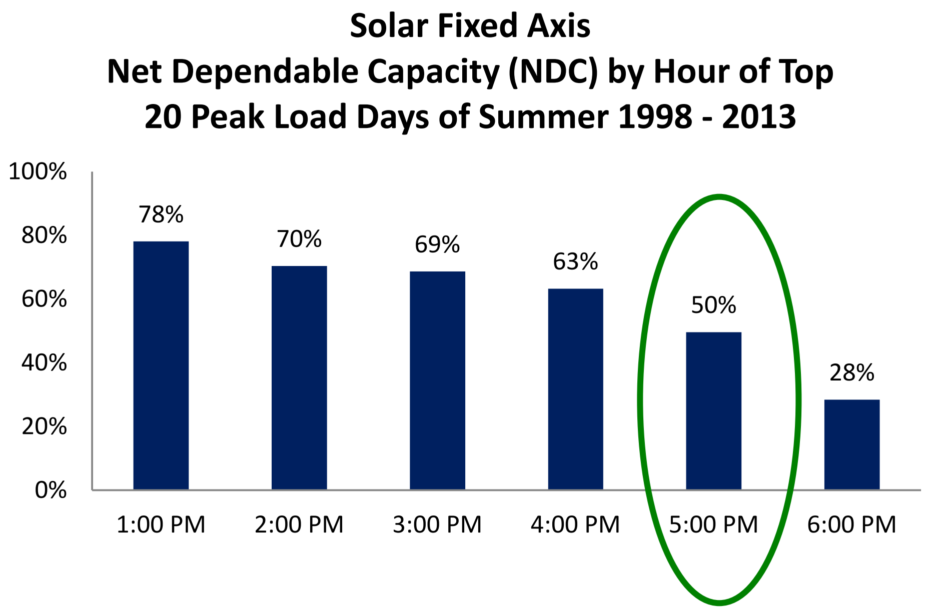
- Analyzed forecasted solar data provided by TVRIX to determine expected capacity factor
- TVA supports the TVRIX recommendations
- Chart shows monthly capacity factors; annual capacity factors are shown in table for comparison purposes



	Utility Tracking	Utility Fixed	Small Commercial	Large Commercial
TVRIX Recommendation	23%	20%	20%	20%
2015 IRP	23%	20%	20%	20%

Solar - Net Dependable Capacity

- Calculated with the same methodology as wind – ensuring a 75% confidence level that solar generation at our summer peak be at least as high as forecast
- TVA's summer peak typically occurs at 5:00 PM central time; solar NDC is sensitive to hour
- Based entirely on modeled data; TVA is data limited in this area and would update with actual experience over time
- Not site-specific units; assumed to represent multiple sites across the Valley



	Utility Tracking	Utility Fixed	Small Commercial	Large Commercial
TVRIX Recommendation	68%	50%	50%	50%
2015 IRP	68%	50%	50%	50%

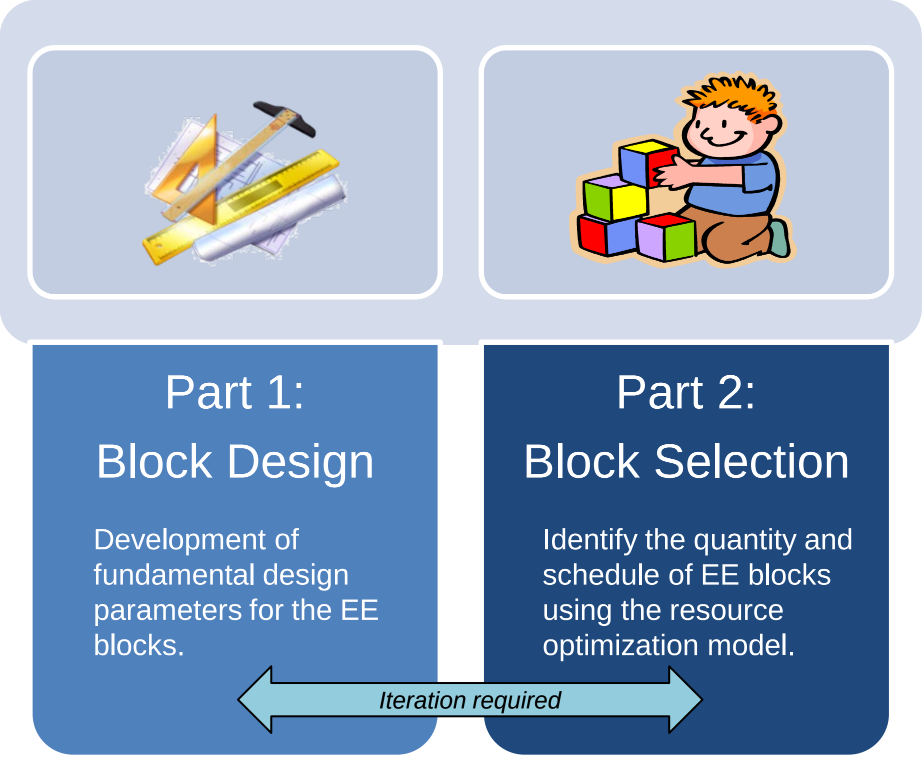
Wind / Solar Resource Characteristics & Modeling
Next Steps / Lessons Learned

- Renewable resource modeling is challenging and an exciting opportunity
- First-of-its-kind collaboration with renewable stakeholders was a major investment that resulted in increased learning
- Areas for future study:
  - Impact of increased solar penetration on the timing of our system peak
  - Impact on portfolio flexibility / operating constraints from increased levels of non-dispatchable resources

The Proposed EE Modeling Concept

- Enhanced approach to modeling and selection of EE as a resource in the IRP study

- Involves a 2-step process
  - Design of selectable "blocks" of EE that represent program bundles organized by customer sector (residential, commercial, industrial)
  - The optimization of the timing and quantity of EE in the resource plan by treating EE as a resource that competes with other options

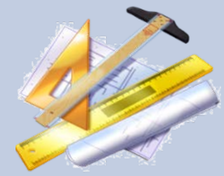


Responsibility of the EnergyRight Solutions team

Responsibility of the Enterprise Planning team

Block Design

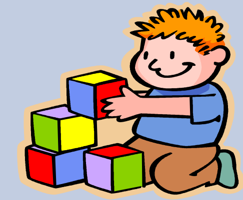
- Input from the Working Group and preliminary runs of the IRP model have led to review of some elements of the proposed EE block designs
- Elements currently under review:
  - Long-term acquisition cost profiles
  - Maximum number of blocks
  - Growth rate and schedule
  - Consistency of Tier break points
  - Foundational program costs



Part 1:

Block Design

Development of fundamental design parameters for the EE blocks.



Part 2:

Block Selection

Identify the quantity and schedule of EE blocks using the resource optimization model.

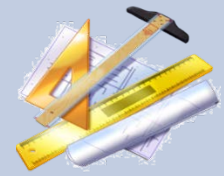
Iteration required

Responsibility of the EnergyRight Solutions team

Responsibility of the Enterprise Planning team

EE Modeling Update
Block Selection

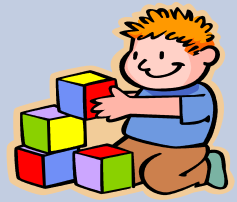
- Analyzed numerous test cases to validate modeling construct and inputs
  - Modeled cases at zero cost / high cost to test model selection
  - Modeled various approaches to program ramp rates (year-on-year acceleration) to test sensitivities
  - Modeled various cost structures to determine appropriate cost profiles vs. unit selection options
- Awaiting final cost curves and block inputs (as well as final loading of all unit operating characteristics) to analyze reference case
- Ongoing internal reviews of modeling approach and architecture



Part 1: Block Design

Development of fundamental design parameters for the EE blocks.

Responsibility of the EnergyRight Solutions team



Part 2: Block Selection

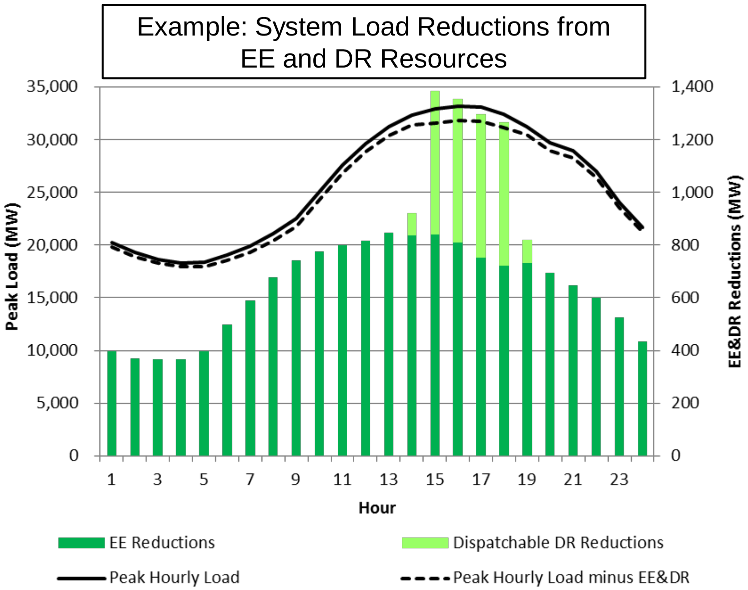
Identify the quantity and schedule of EE blocks using the resource optimization model.

Responsibility of the Enterprise Planning team

Iteration required

The Approach for Demand Response (DR) is Different

- The DR resource will be represented using a proxy unit method
  - This proxy unit will be part of the resource options available for selection by the model
- Proxy unit will be CT-like but have performance and cost characteristics that mimic typical DR contract terms
- TVA is still finalizing key DR unit assumptions including
  - Proper estimation of capacity value
  - Method for representing full availability of the resource
  - Appropriate representation of ancillary services value & reliability

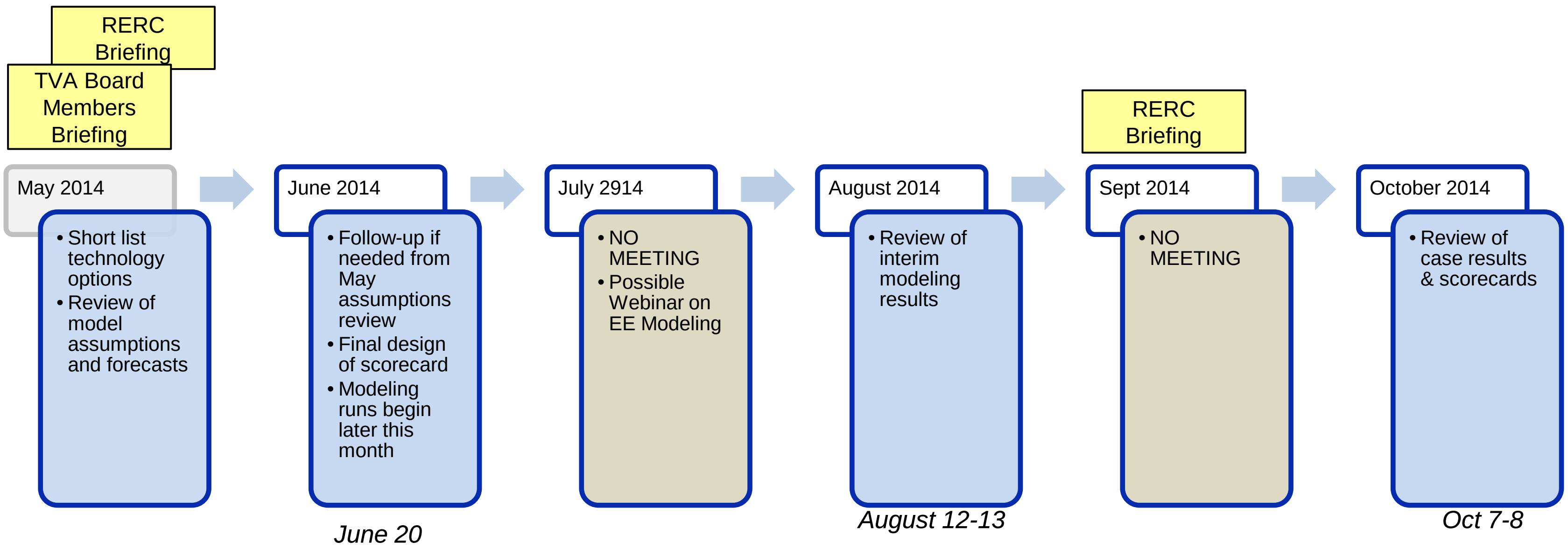


Group Feedback – Resources and Planning Assumptions

Feedback from the Working Group

- Any additional thoughts about the proposed resources?
- Other comments?

Meeting Objectives for IRPWG Through October 2014



- Next meeting will be on June 20 Knoxville
- Subsequent meeting dates (tentative):
  - August 12-13 TBD (potentially Huntsville)
  - October 7-8 in Chattanooga