2019 IRP Working Group

Meeting 13: May 13-14, 2019

Murfreesboro, TN


welcome

Safety Moment

Building Emergency Plan

Introductions

- Name
- Organization and Role

Agenda – May 13

11:30	**Lunch**	
12:30	**Welcome and Today's Meeting** **Recap Where we are in process**	**Jo Anne Lavender** **Brian Child**
1:00	**Public Comment Period Summary** **Key Topics and Responses**	**Amy Henry** **Matthew Higdon**
1:45	**Sensitivities**	**Jane Elliott/ Roger Pierce / Scott Jones**
2:00	**Break**	
2:15	**Sensitivities – cont'd**	**Jane Elliott/ Roger Pierce / Scott Jones**
3:45	**Group activity**	**Group**
5:00	**Wrap Up day 1**	**Jo Anne / Brian**
6:00	**Group Dinner *Five Senses***	

Agenda – May 14

7:30	***Breakfast – at hotel for guests*** ***Coffee / light refreshments in meeting room***	
8:30	**Welcome and Recap Day 1**	**Liz Upchurch/ Jane**
8:45	**Developing a Recommendation**	**Hunter Hydas**
9:15	**Group Break Out – on final recommendation development.**	**Liz and group**
10:30	**Thinking ahead:** **Considerations for Implementation of the 2019 IRP**	**Hunter**
10:45	**Group Discussion**	**Liz and group**
11:45	**Next Steps** **Adjourn**	**Liz/ Brian**
12:00	**Lunch**	
	Confidential Material	

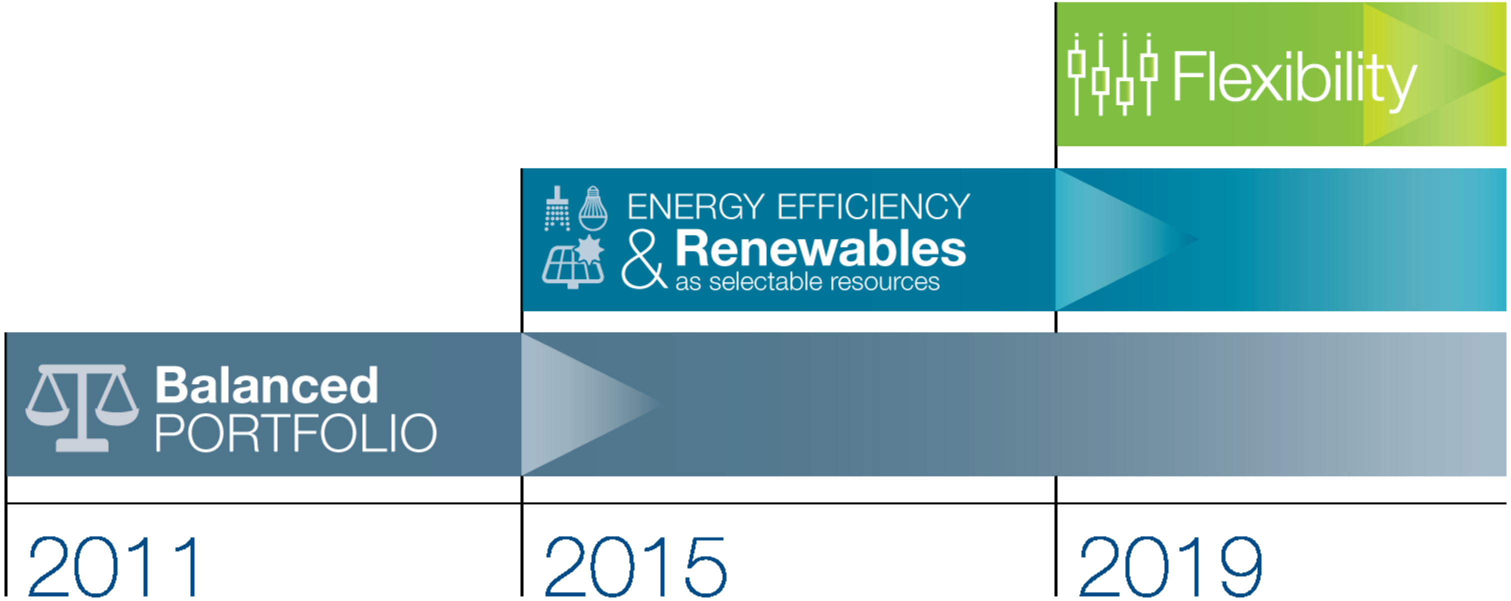
IRPWG Meeting 12 Recap

Brian Child

March Meeting Highlights

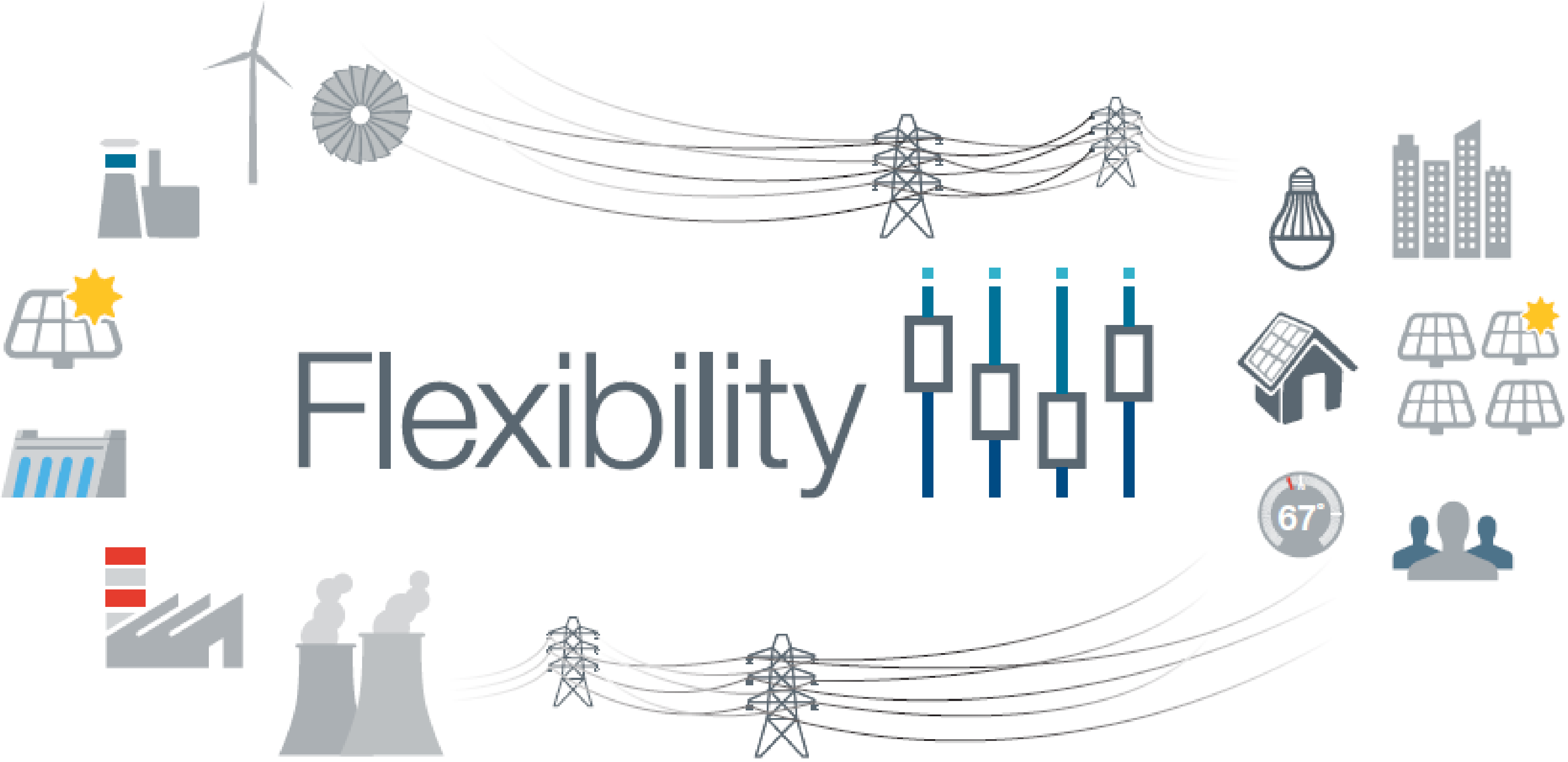
- Preliminary topics from public comments
- Second group of sensitivity results
- Considerations and input on developing a recommendation

INTEGRATED Resource Plan 2019



2019 IRP Focus Areas

- System Flexibility
- Distributed Energy Resources
- Portfolio Diversity


Flexibility
67°

2019 IRP Schedule: Schedule & Milestones

The 2019 IRP Study Approach is intended to ensure transparency & enable stakeholder involvement

Winter/Spring 2018	*Spring 2018*	*Summer/Fall 2018*	*Winter/Spring 2019*	*Spring/Summer 2019*	*Summer 2019*
Scoping **	Develop Inputs & Framework	Analyze & Evaluate	Present Initial Results **	Incorporate Input	Identify Preferred Plan/Direction

(** indicates timing of Valley-wide public meetings)

Key Tasks/Milestones in this study timeline include:

- Establish stakeholder group and hold first meeting (Feb 2018)
- System modeling (June - December 2018)
- Publish draft EIS and IRP (Feb 2019)
- Complete public meetings (March 2019)
- Board approval and final publication of EIS and IRP (expected Summer 2019)

IRP Working Group Meeting Objectives

February 28 – March 1	March 27 -28	May 13-14	June 25
• Updated Base Case • Sensitivities results so far • Discuss Sensitivities • Prioritize Sensitivities	• Sensitivity Results • Review public comment period • Early topics from public comments	• Final Sensitivities • Public Comments • Developing the Recommendation • Implementation Considerations	• TVA responses to public comments • Final Recommendation

Public Comment Period Summary
Key Topics & Responses

Amy Henry and Matthew Higdon

Draft IRP/EIS Comment Period Summary

- TVA released the Draft IRP and EIS on February 15, 2019, initiating a public review period that concluded on April 8th.
- TVA hosted eight public meetings around the Valley and held one public webinar.
- TVA's website included an *Interactive Report* for the public to learn about the IRP.
- During the comment period, TVA received over 300 comment submittals on the Draft IRP/EIS, as well as a petition signed by 979 individuals (Sierra Club).

2019 IRP Public Meetings

- February 19 – Murfreesboro (12 attendees)
- February 26 - Public Webinar (105 attendees)
- February 27 - Knoxville (39 attendees)
- March 18 - Memphis (56 attendees)
- March 19 - Huntsville (48 attendees)
- March 20 - Chattanooga (31 attendees)
- March 21 - Nashville (99 attendees)
- March 26 - Bowling Green (17 attendees)

Draft IRP/EIS Comment Period Summary

Organizations that provided comments on the Draft IRP/EIS include:

Tennessee Wildlife Federation
Tennessee Department of Environment and Conservation
Metro Government of Nashville
Tennessee Solar Energy Association
Center for Biological Diversity
City of Oak Ridge
City of Knoxville
The Climate Reality Project
Tennessee Citizens for Wilderness Planning
Tennessee Interfaith Power and Light
Tennessee Valley Industrial Committee
Tennessee Valley Public Power Association
Alabama Solar Association
Senator Rand Paul
U.S. Department of the Interior

U.S. Environmental Protection Agency
Kentucky State Clearinghouse
Mississippi Department of Archives and History
Tennessee Historical Commission
Virginia Department of Historic Resources
Southern Alliance for Clean Energy
Southern Environmental Law Center
Sierra Club (includes a petition)
Southern Renewable Energy Association Citizen's
Climate Lobby, Knoxville Chapter
Conservation Fisheries, Inc.
American Petroleum Institute
Sunrise Movement, Knoxville
Universal Fibers Systems
NAACP
Energy Alabama

Draft IRP and EIS Comment Topics

IRP Process
Cost of Implementing a Strategy
Data Inputs and Assumptions
Integrated Resource Planning
Planning Process
Purchased Power
Resource Plan Implementation
Scenarios
Sensitivity Testing
Strategies
Strategy Evaluation Metrics

Energy Resource Options
Biomass
Clean Energy
Coal
Distributed Energy Resources (DER)
Energy Efficiency
Facility Siting
Hydroelectric
Natural Gas
Nuclear Energy
Renewable Energy
Solar Energy
Storage
Wind Energy

Environmental Impacts
Air Quality
Endangered and Threatened Species
Greenhouse Gas Emissions and Climate Change
Historic Properties
Land Use
Life Cycle Impacts
Parks, Managed Areas and Ecologically Significant Sites
Socioeconomics
Solid and Hazardous Waste
Water Resources

Editorial Comments
Draft EIS
Draft IRP
General

Other
Comments Out Of Scope

Draft IRP and EIS Comment Topics

- Support for:
  - distributed generation
  - demand reduction
  - energy storage
- Concern over small amount of energy efficiency in portfolios
- Support for and concern about coal plant retirements
- Increased and earlier adoption of renewable energy
- Concerns about climate change and GHGs
- Support for and opposition to nuclear energy
- Concern about the accuracy of land use metric, particularly for solar generation
- Assumptions of costs for various resources
- Need for more transparency in IRP process and bench-marking
- Operations and role of the IRP Working Group
- Support for increased hydroelectric generation

Support and Challenges for Key Topics

- IRP Process and Transparency:
  - Support: *“appreciates TVA's openness and transparency during the process. TVA provided extensive background on the methodology, inputs, and results of the planning process*”
  - Challenge: *“For the 2019 IRP process TVA benchmarked its supply-side resource assumptions behind closed doors, and does not appear to have sought stakeholder input or industry expertise on demand-side resource assumptions.”*

Support and Challenges for Key Topics

- Renewables
  - Support: “*Please move toward more renewable and clean energy solutions as quickly as possible and phase out sources that have a negative impact on our climate.* ”
  - Challenge: “*Do not invest in renewable (green) power such as solar and wind power which are not economically attractive and only increase consumer's electricity costs.*”

Support and Challenges for Key Topics

- Metrics – Land Use
  - Positive: "*Given the large amount of land that is facing energy development and potential changes in land use, would like to discuss the details and implications of solar expansion on land use*"
  - Negative: "*the new metric disproportionately affected solar due to its flawed methodology, a reasonable observer can only conclude TVA ignored the IRPWG in order to disadvantage solar energy*"

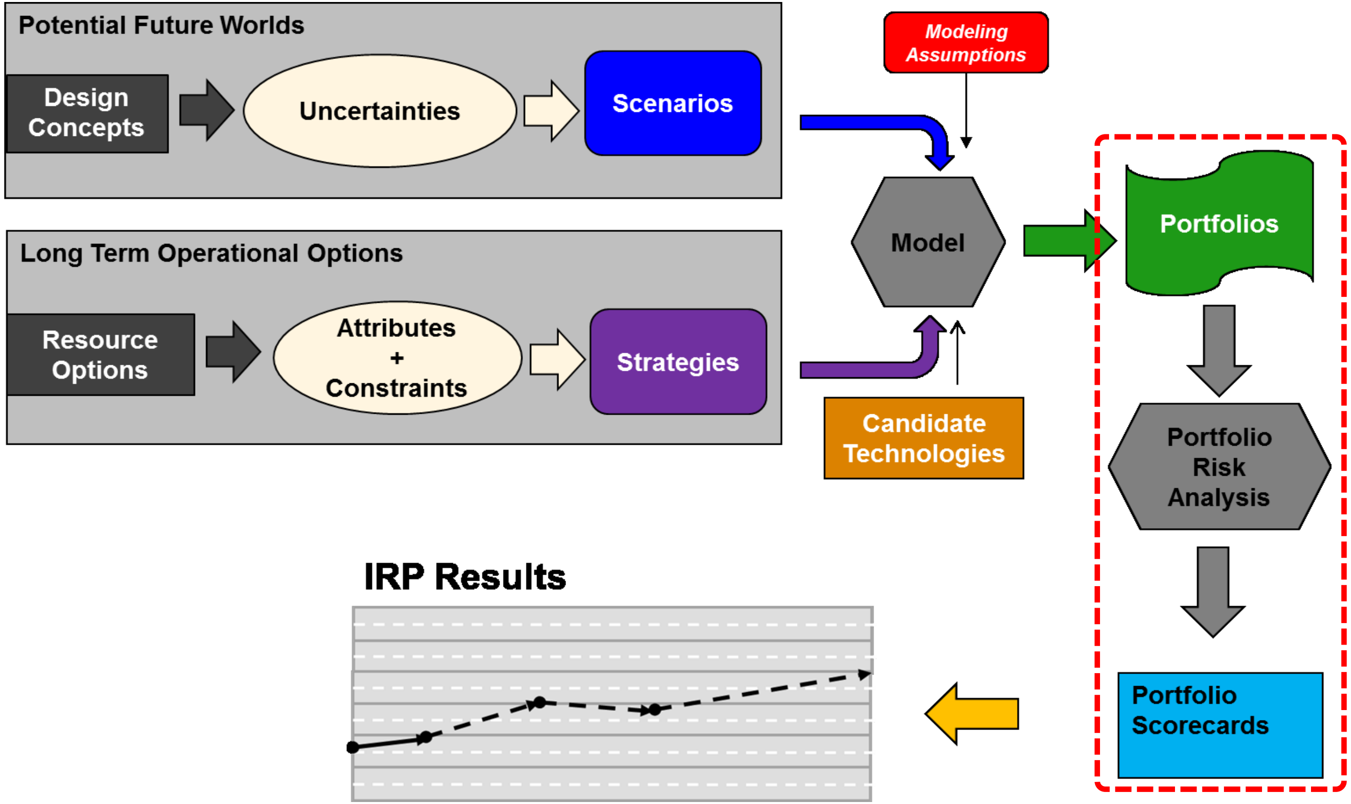
Responses to Public Comments

- Sensitivity analysis
- Forming a Recommendation (considered by TVA planning team, RERC & IRPWG)
- Some revisions to EIS to address substantive comments on environmental analysis
- Comments and Responses will be appended to the Final IRP / EIS

IRP Sensitivity Analysis

Jane Elliott, Roger Pierce, Scott Jones
Resource Strategy

Sensitivity Analysis Informs Recommendation



The result of a strategy evaluated in a scenario

How uncertainty impacts the portfolio results

Standard metrics to compare portfolios

Draft Results Prompt Additional Questions

Scenarios

1. *Current Outlook*
2. *Economic Downturn*
3. *Valley Load Growth*
4. *Decarbonization*
5. *Rapid DER Adoption*
6. *No Nuclear Extensions*

Strategies

A. *Base Case*
B. *Promote DER*
C. *Promote Resiliency*
D. *Promote Efficient Load Shape*
E. *Promote Renewables*

Sensitivities Complement Draft Results

- Sensitivity analyses are performed to help answer questions meriting further evaluation
- Sensitivity analyses are typically run as variations from Case 1A, the Base Case strategy applied in the Current Outlook scenario, to isolate the impact of a change in one key assumption
- All sensitivities will be run off the updated Base Case reflecting recent plant retirement decisions made by the TVA Board
- Sensitivities will be considered, along with the balance of portfolio results, when developing the 2019 IRP recommendation

2019 IRP Sensitivities

Prior Meetings

- ✓ Older Gas CT retirements
- ✓ Integration cost and flexibility benefit
- ✓ High and low gas prices (two standard deviations)
- ✓ Solar acceleration and caps
- ✓ Breakeven analysis for storage, wind, CHP and SMR capital costs

Today

- Double solar cap in growth case
- NREL ATB mid case wind trajectory
- Increased ongoing operating costs for coal plants
- More stringent carbon penalty (Double decarbonization scenario
- Increased EE and DR market depth
- Extreme weather case

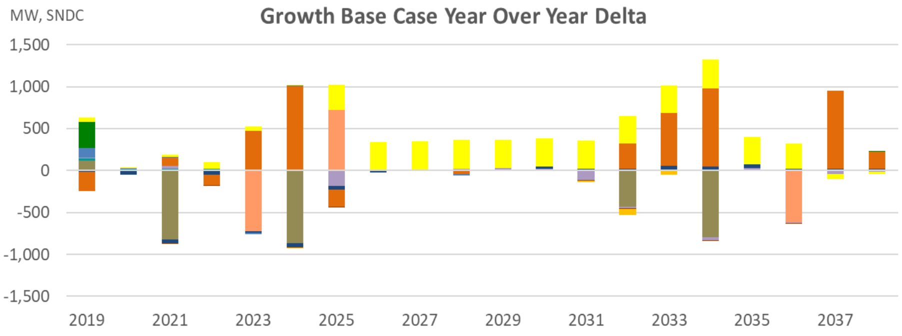
Double Solar Cap in Growth Case

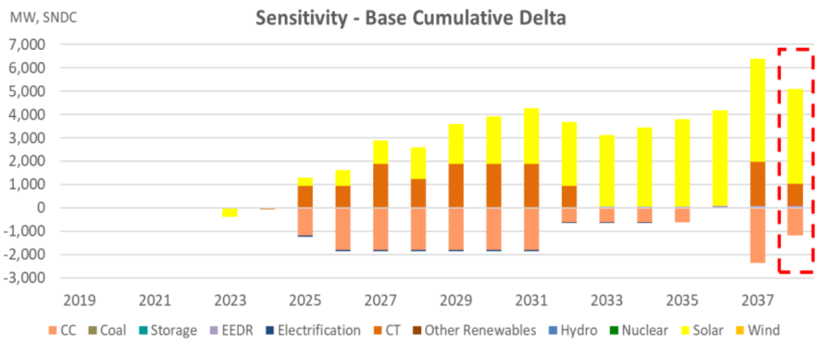
Double Solar Cap in Growth Case

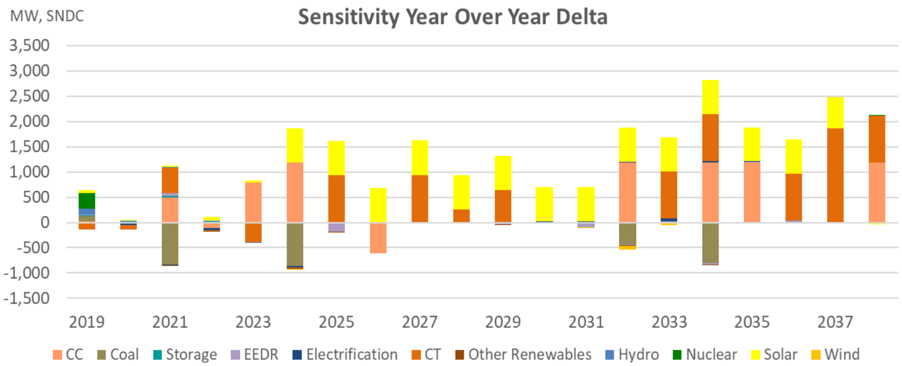
Objective:	Perform a sensitivity bounding case to evaluate the potential impact of increasing the annual cap on solar additions for the Valley Load Growth Base Case (3A).
Approach:	Double the annual solar cap to 1,000 MW and raise the cumulative cap on solar additions to 14,000 MW, then rerun models to derive impact on capacity expansion plan and metric results.

Note: There are limitations on the timing of other resource additions, such as how many new gas builds can be planned for a given year, to reflect the practicality of when we have knowledge of the need and other project management considerations.

Double Solar Cap in Growth Case



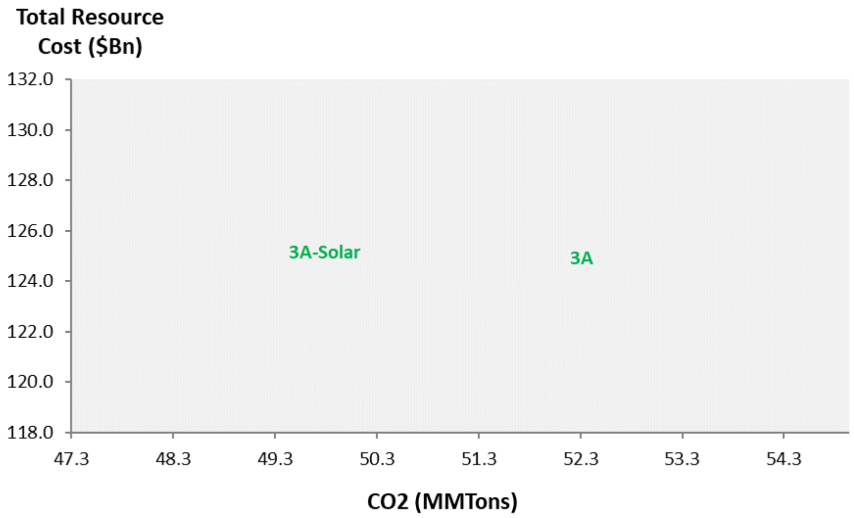


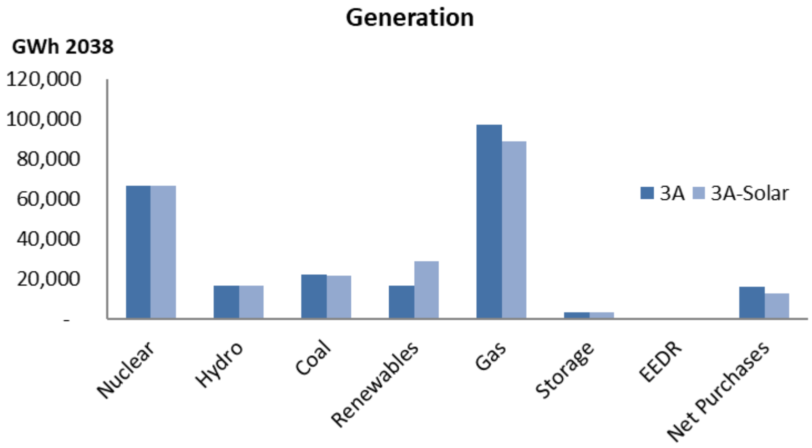


- Larger additions of solar occur every year, with 6,000 MW nameplate more solar added by 2038
- 14,000 MW nameplate total solar added by 2038
- CTs replace CCs to meet winter peak

Double Solar Cap in Growth Case

Increasing the annual solar cap results in similar costs and lower carbon emissions as renewable generation displaces gas generation.





Double Solar Cap in Growth Case

Sensitivity Metric Results

	PVRR ($Bn)	System Average Cost Years 1-20 ($/MWh)	Total Resource Cost ($Bn)	Risk/Benefit Ratio	Risk Exposure ($Bn)	CO2 (MMTons)	CO2 Intensity (lbs/MWh)	Water Consumption (MMGallons)	Waste (MMTons)	Land Use (Acres)	Flexible Resource Coverage Ratio	Flexibility Turn Down Factor (2038)	Percent Difference in Per Capita Income*	Percent Difference in Employment*
Double Solar Cap in Growth Case	124.9	70.2	125.2	1.06	137.0	49.8	524.5	57,849	2,249	103,427	1.64	41%	0.00%	0.00%
Growth Base Case	124.5	70.1	125.0	1.06	136.7	52.3	551.8	58,823	2,283	59,647	2.17	36%	0.00%	0.00%
Delta from Growth Base Case	0.34	0.10	0.21	0.00	0.30	-3	-27	-975	-35	43,780	-0.53	5%	0.00%	0.00%

**Economic analysis was not run for sensitivities*

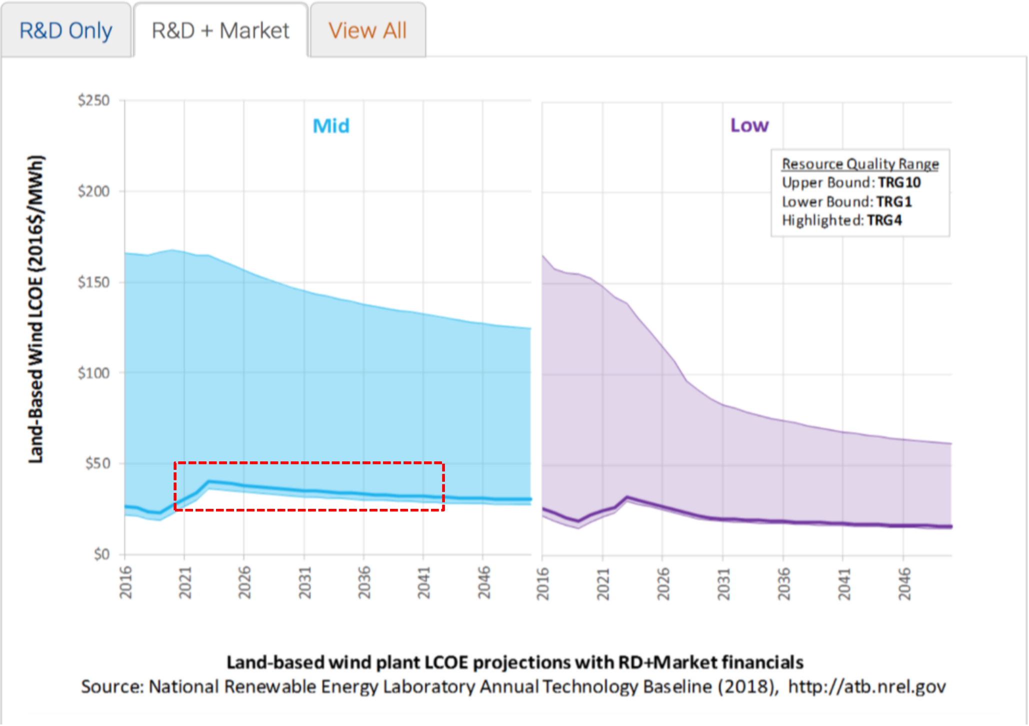
NREL ATB Mid Case Wind Trajectory

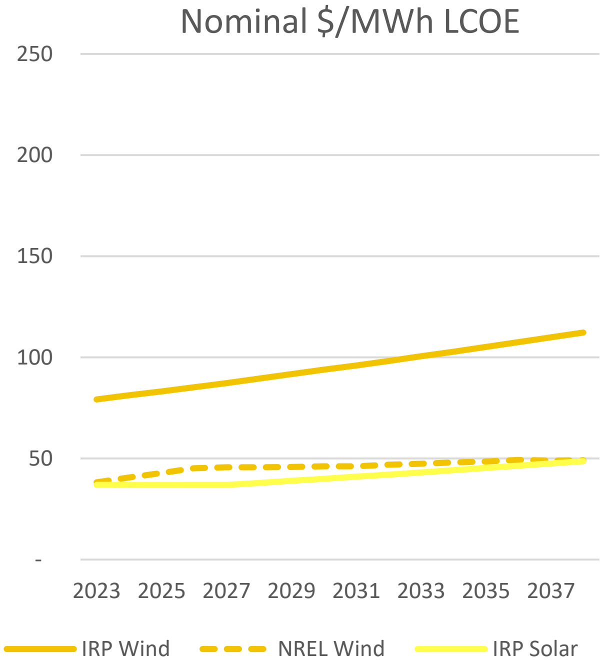
NREL ATB Mid Case Wind Trajectory

Objective: Perform a sensitivity bounding case to evaluate the potential impact of lower levelized cost for wind that may manifest itself through technology improvements or reduced wheeling costs.

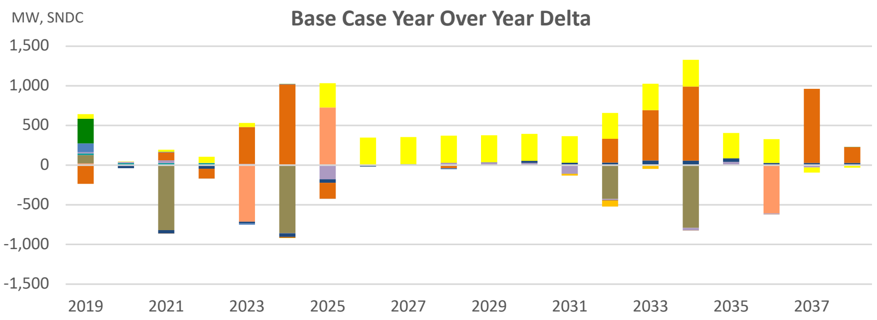
Approach: Use NREL ATB mid case trajectory wind prices to inform PPA assumptions in this sensitivity, then rerun models to derive impact on capacity expansion plan and metric results.

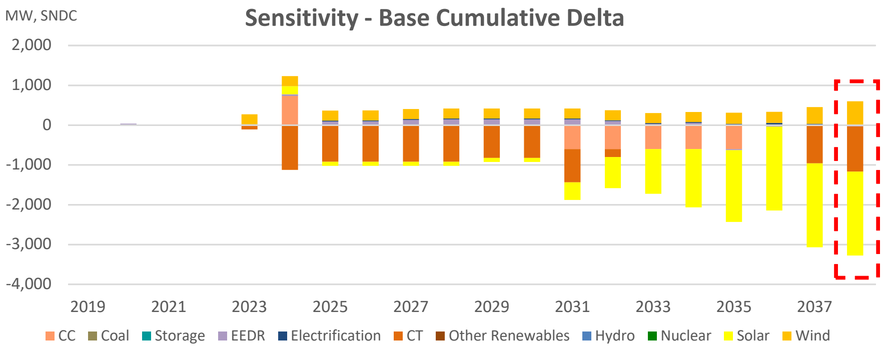
NREL ATB Mid Case Wind Trajectory

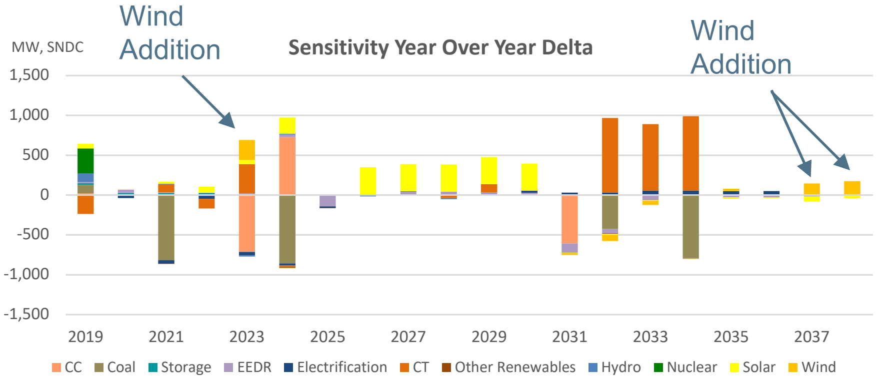




NREL ATB Mid Case Wind Trajectory



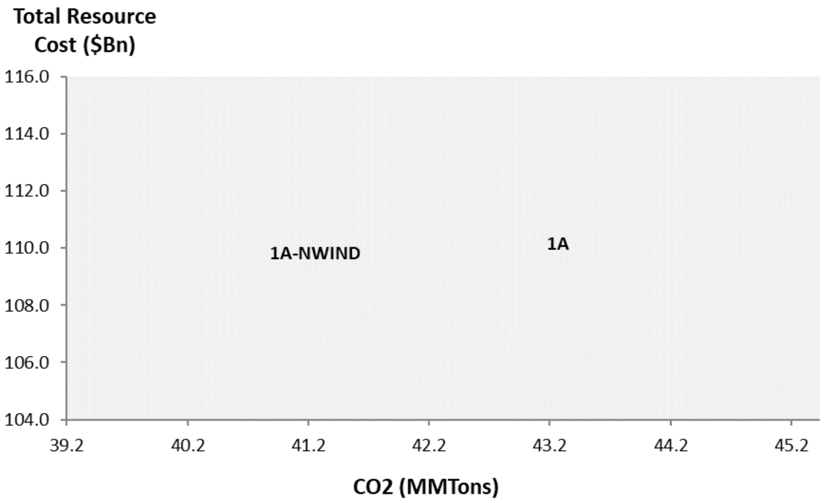


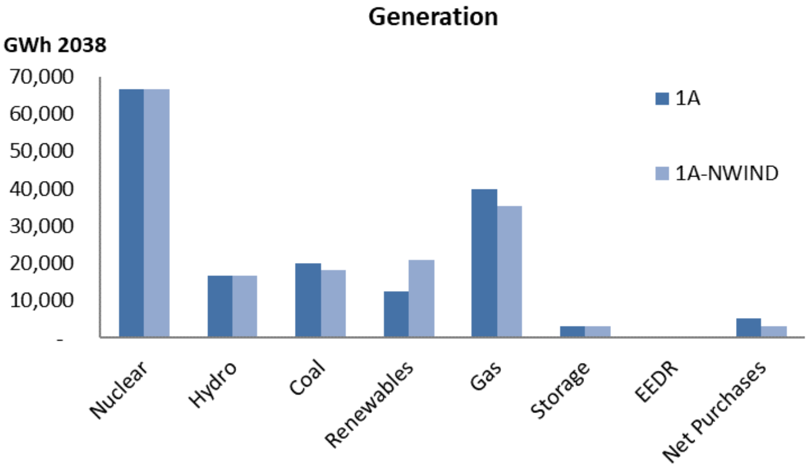


- 4,200 MW nameplate of wind added by 2038
- Wind displaces early gas additions needed for winter peak and eventually competes with solar in the long term (3,100 MW nameplate less solar)

NREL ATB Mid Case Wind Trajectory

Using a higher wind trajectory results in similar costs but lower carbon emissions as wind displaces early gas additions.





NREL ATB Mid Case Wind Trajectory

Sensitivity Metric Results

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NREL Wind	109.4	69.9	109.9	1.1	117.9	41.2	515.8	53,267	2,184	21,703	1.60	55%	0.00%	0.00%
Base Case	109.7	70.1	110.2	1.1	118.7	43.2	540.7	54,053	2,269	43,365	1.98	50%	0.00%	0.00%
Delta from Base Case	-0.33	-0.16	-0.32	-0.01	-0.80	-2	-25	-786	-84	-21,662	-0.38	5%	0.00%	0.00%

**Economic analysis was not run for sensitivities*

Increased Coal Operating Costs

Increased Coal Operating Costs

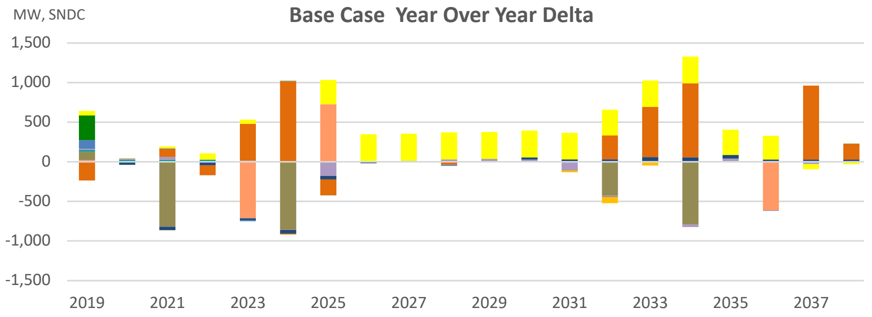
Objective: Perform a sensitivity bounding case to evaluate the potential impact of increased operating costs for coal plants. Aging coal units operated outside their design have a risk of substantially increased operating costs.

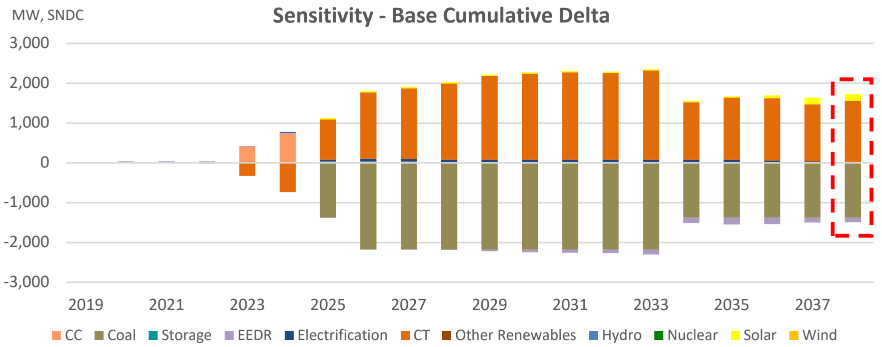
Approach: Simulate a high trajectory for O&M, capital project, and environmental spend for the remaining coal units, then rerun models to derive impact on capacity expansion plan and metric results.

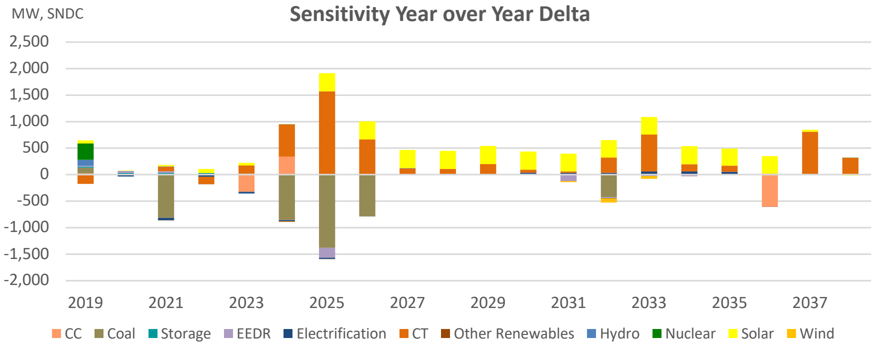
Increased Coal Operating Costs

Coal Plant Spend $2017 NPV (Millions)	Base Case	Sensitivity	Variance %
Cumberland 1 & 2	1,372	2,145	56%
Gallatin 1-4	580	873	51%
Kingston 1-9	905	1,566	73%
Shawnee 1 & 4	187	424	127%
Shawnee 2-3, 5-9 (uncontrolled)	653	1055	62%
Total	3,697	6,063	64%

Increased Coal Operating Costs



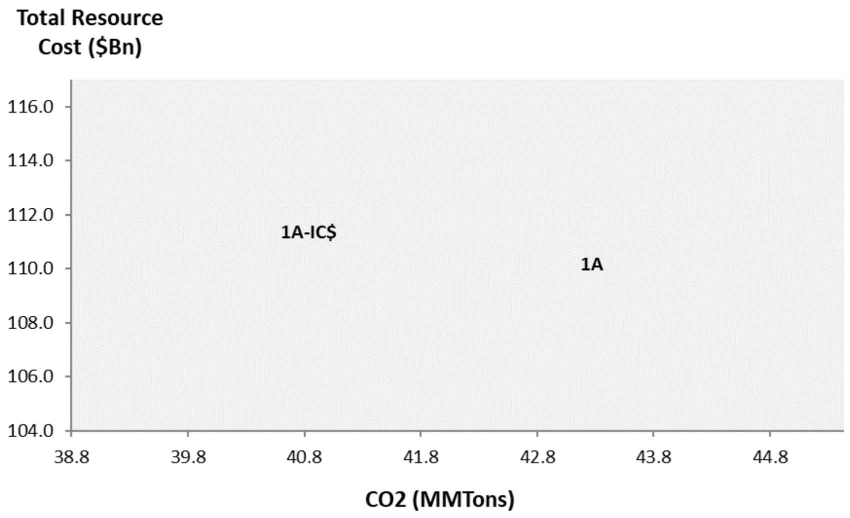


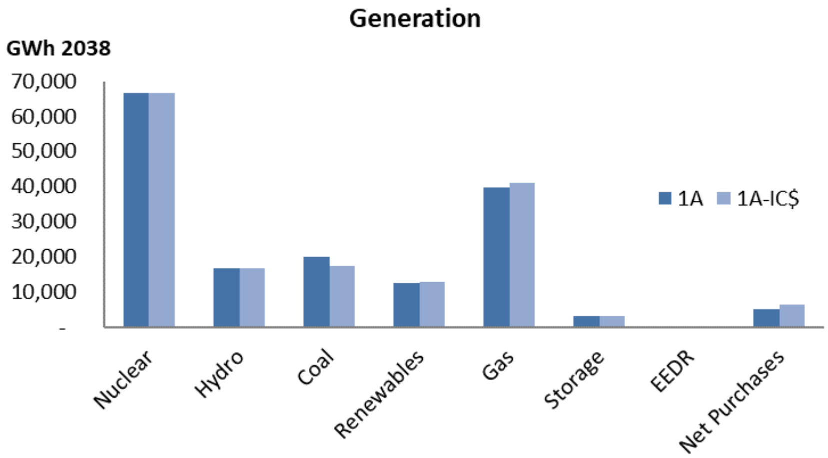


- Kingston is retired in 2025, first year available
- Shawnee 2,3,5-9 retirement accelerated from 2034 to 2026
- Coal replaced mainly by CTs due to low capacity factors

Increased Coal Operating Costs

Increasing coal operating costs results in somewhat higher cost and lower carbon emissions as coal generation is displaced largely by gas generation.





Increased Coal Operating Costs

Sensitivity Metric Results

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Increased Coal Operating Costs	110.9	70.8	111.4	1.07	120.2	40.8	509.9	53,306	2,205	45,307	2.23	50%	0.00%	0.00%
Base Case	109.7	70.1	110.2	1.06	118.7	43.2	540.7	54,053	2,269	43,365	1.98	50%	0.00%	0.00%
Delta from Base Case	1.21	0.72	1.21	0.01	1.50	-2	-31	-747	-64	1,942	0.25	0%	0.00%	0.00%

**Economic analysis was not run for sensitivities*

Double Decarbonization

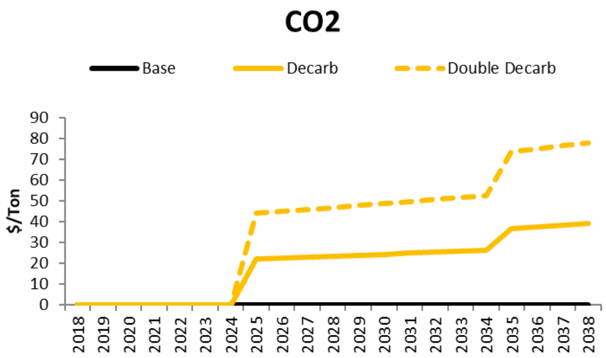
Double Decarbonization

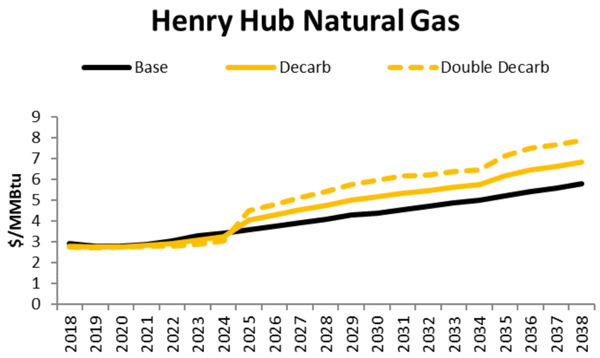
Objective: Perform a sensitivity bounding case to evaluate the potential impact of a higher than expected carbon penalty in the decarbonization scenario.

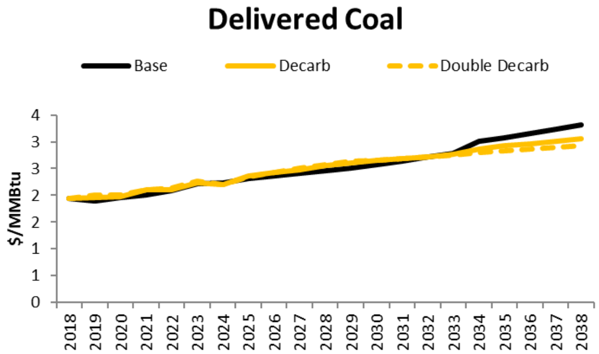
Approach: Double carbon costs in case 4A to reflect the potential for a higher than expected carbon penalty, along with increasing gas prices to reflect higher natural gas demand.

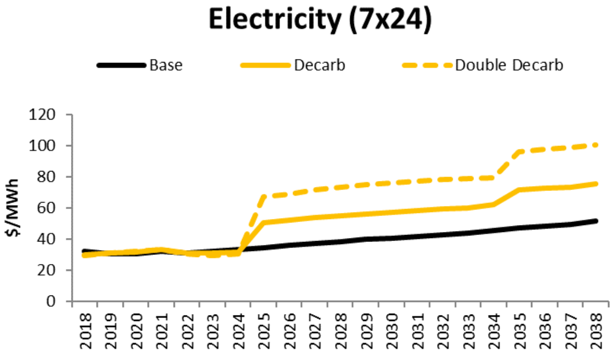
Double Decarbonization

In addition to carbon prices, the Double decarbonization case reflects higher gas prices and power prices and lower coal prices relative to the base case and decarbonization case.

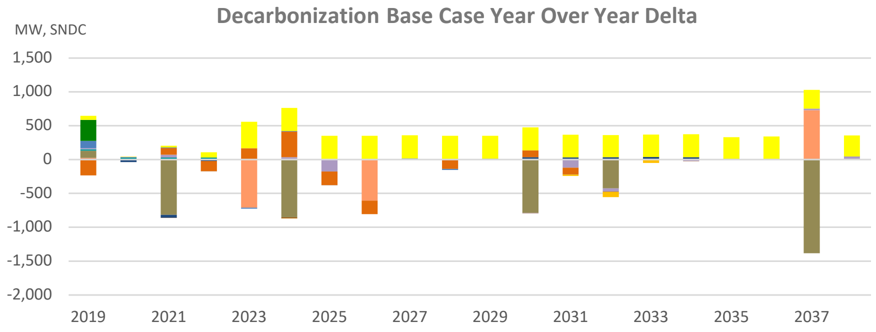


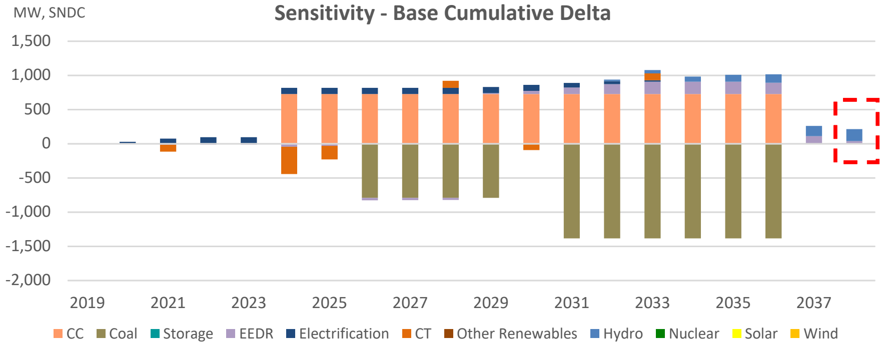


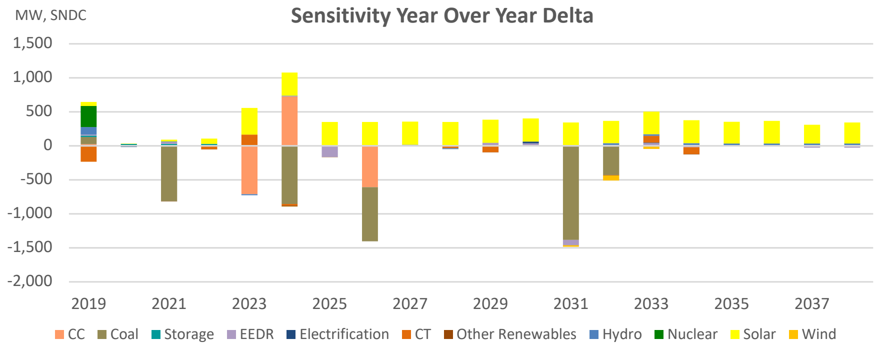




Double Decarbonization



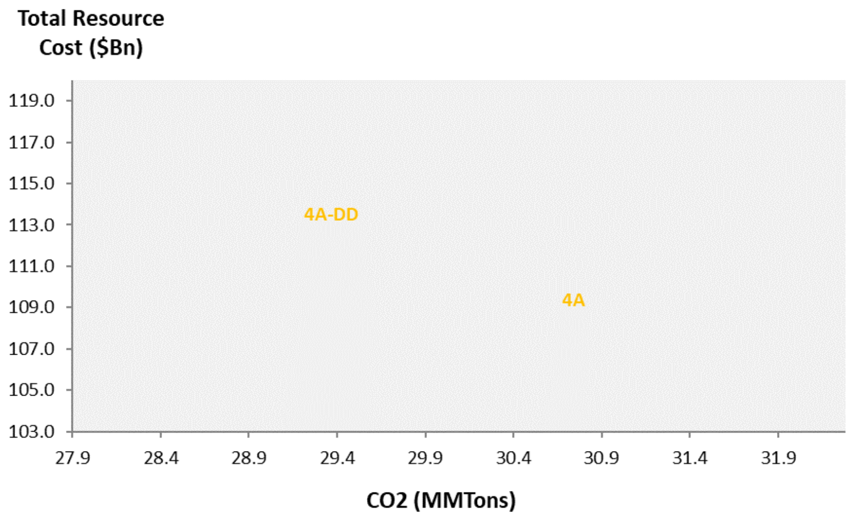


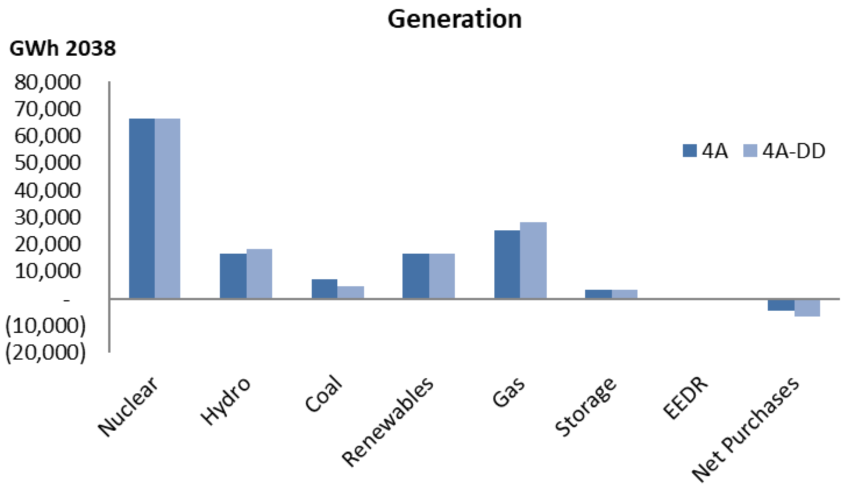


- Double carbon prices further accelerate the retirements of Shawnee 2,3,5-9 and Kingston
- CC expansion accelerated from 2037 to 2024, displacing coal generation
- 175 MW of hydro added late in the plan

Double Decarbonization

Increasing the carbon price results in higher costs and lower carbon emissions as accelerated coal retirements are replaced with combined cycle and hydro generation.





Double Decarbonization

Sensitivity Metric Results

	PVRR ($Bn)	System Average Cost Years 1-20 ($/MWh)	Total Resource Cost ($Bn)	Risk/Benefit Ratio	Risk Exposure ($Bn)	CO2 (MMTons)	CO2 Intensity (lbs/MWh)	Water Consumption (MMGallons)	Waste (MMTons)	Land Use (Acres)	Flexible Resource Coverage Ratio	Flexibility Turn Down Factor (2038)	Percent Difference in Per Capita Income*	Percent Difference in Employment*
Double Decarb	113.1	77.6	113.5	1.1	124.6	29.4	408.2	50,240	1,076	58,488	0.97	66%	0.00%	0.00%
Base Case	108.9	74.7	109.4	1.0	118.0	30.8	426.9	50,276	1,272	58,400	0.98	66%	0.00%	0.00%
Delta from Base Case	4.15	2.84	4.12	0.09	6.66	-1	-19	-36	-195	88	-0.01	0%	0.00%	0.00%

**Economic analysis was not run for sensitivities*

Increased EE and DR Market Depth

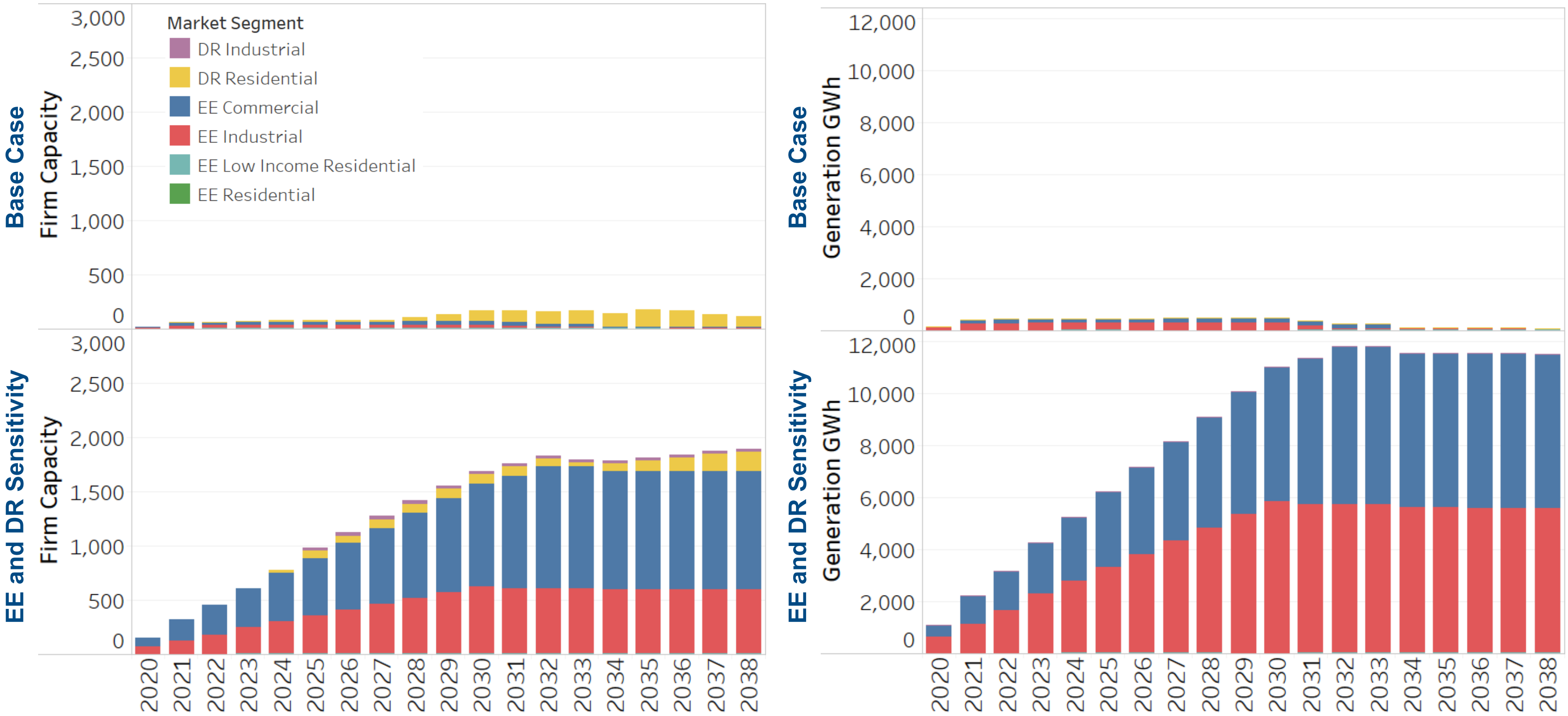
Increased EE and DR Market Depth

Objective: Perform a sensitivity bounding case to evaluate the potential impact of greater energy efficiency (EE) and demand response (DR) market depth than expected.

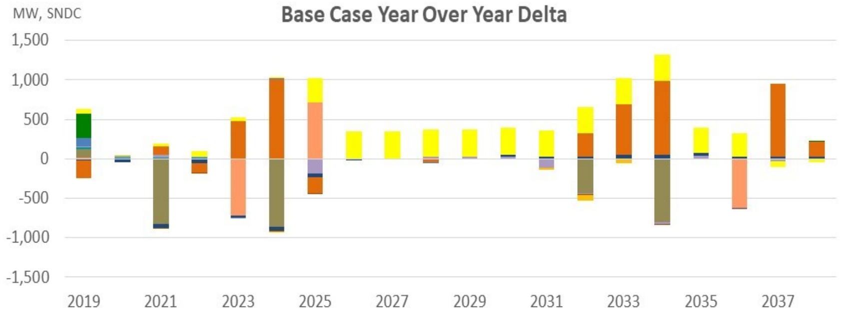
Approach: An additional two tiers of EE for all market segments were offered as selectable in the model. Each had the same volume of energy as the base level tiers but at 50% higher cost over the previous tier and no cumulative limit.

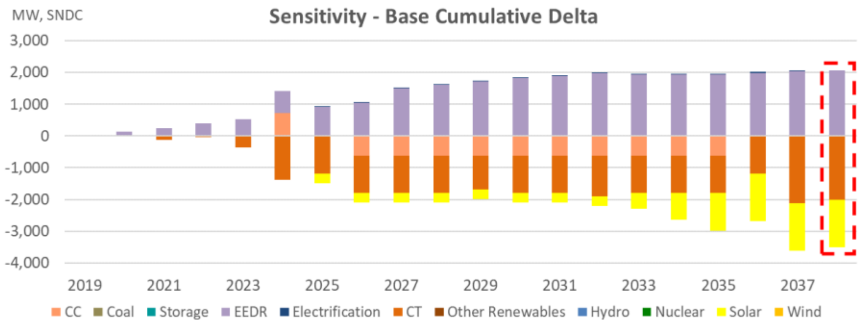
Additional commercial and industrial (C&I) DR options were added as additional tiers at incrementally increasing cost.

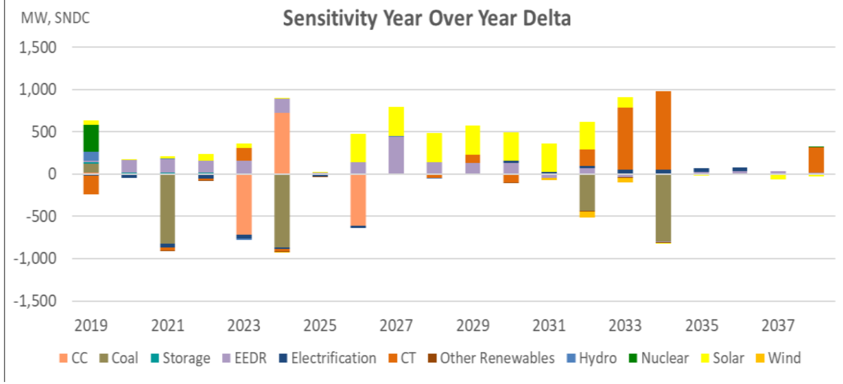
EE and DR by Market Segment



Increased EE and DR Market Depth



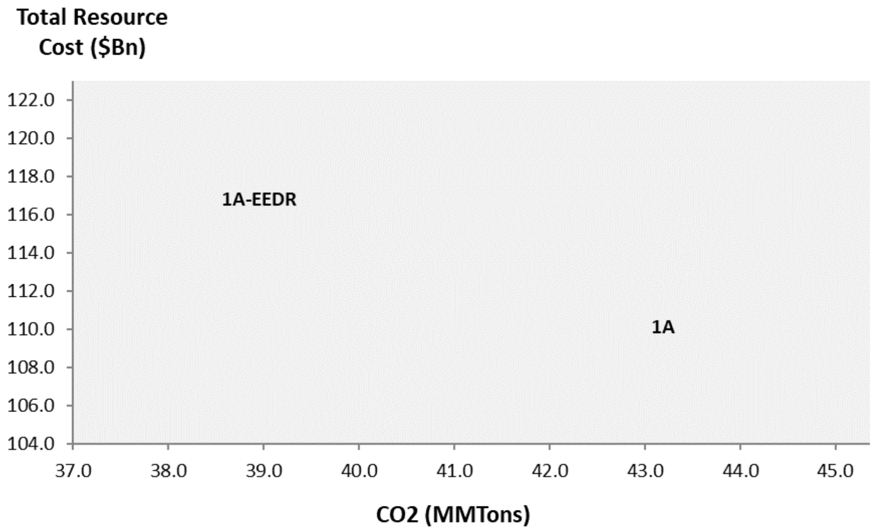


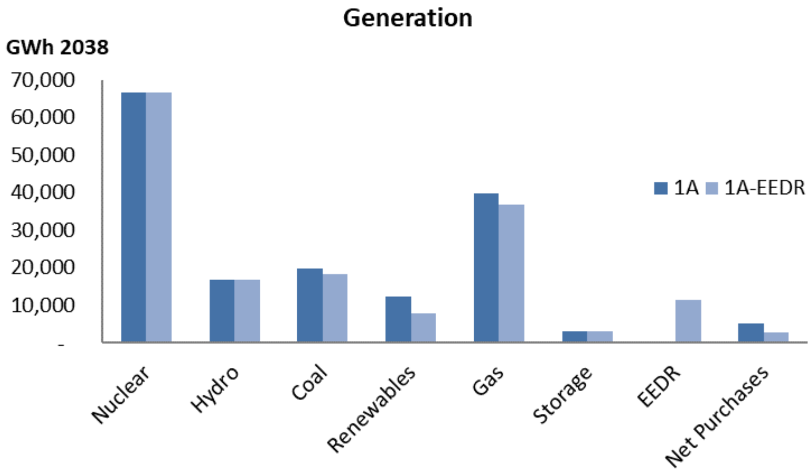


- 1,900 MW of increased C&I EEDR displaces CT builds due to coincidence with winter peak
- 2,200 MW of nameplate solar is displaced as solar prices begin to increase at inflation and compete with EE energy value
- Additional two tiers of C&I DR selected

Increased EE and DR Market Depth

Increasing EE and DR market depth results in a similar PVRR, higher Total Resource Cost, and lower carbon emissions as EEDR generation displaces gas and solar generation.





Increased EE and DR Market Depth

Sensitivity Metric Results

	PVRR ($Bn)	System Average Cost Years 1-20 ($/MWh)	Total Resource Cost ($Bn)	Risk/Benefit Ratio	Risk Exposure ($Bn)	CO2 (MMTons)	CO2 Intensity (lbs/MWh)	Water Consumption (MMGallons)	Waste (MMTons)	Land Use (Acres)	Flexible Resource Coverage Ratio	Flexibility Turn Down Factor (2038)	Percent Difference in Per Capita Income*	Percent Difference in Employment*
Increased EEDR	109.7	72.9	116.9	1.02	118.3	39.0	512.5	52,513	2,123	27,158	2.00	58%	0.00%	0.00%
Base Case	109.7	70.1	110.2	1.06	118.7	43.2	540.7	54,053	2,269	43,365	1.98	50%	0.00%	0.00%
Delta from Base Case	-0.05	2.75	6.68	-0.04	-0.41	-4.25	-28.15	-1,540	-146	-16,208	-0.02	9%	0.00%	0.00%

**Economic analysis was not run for sensitivities*

Extreme Weather

Extreme Weather

Objective: Perform a sensitivity bounding case to evaluate the potential impact of extreme weather patterns.

Approach: Use stochastic analysis to determine the potential impacts of persistent extreme weather patterns, then rerun models to derive impact on capacity expansion plan and metric results.

Considering Uncertainty in Resource Planning

While scenarios explore step changes in possible futures, stochastic analysis evaluates risk of uncertainty around key planning assumptions for each portfolio.

Variability occurs within each scenario and strategy combination driven by:

- Weather
  - **Demand peak & energy**
  - **Rainfall**
  - Solar
  - Wind
- Unit performance
  - Unplanned outages
  - **Reduced operation (derates)**
- Operating costs
- Capital costs
- Market conditions
  - Gas price
  - Coal price
  - Oil price
  - Power price
  - Interest rates

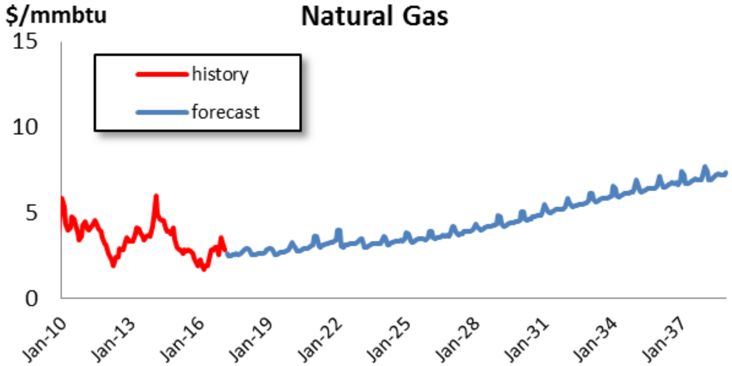
A stochastic model estimates probability distributions of potential outcomes by allowing for simultaneous random-walking variation of many correlated inputs over time.

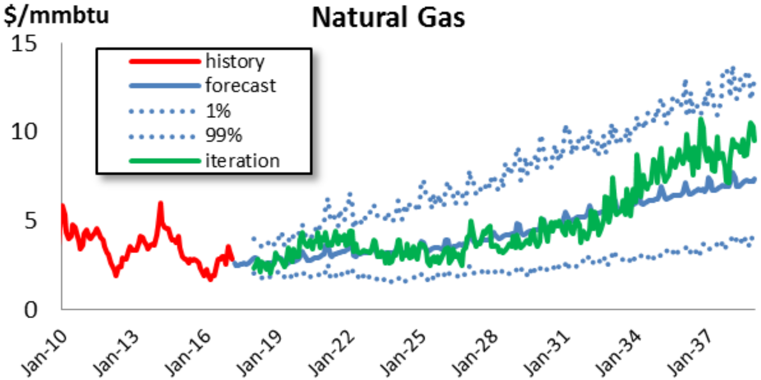
Monte Carlo distributions are created using Latin Hypercube sampling of the variables that have the most impact on production cost and financial results.

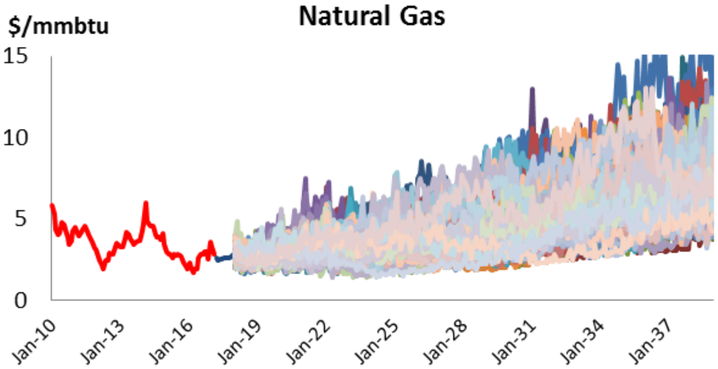
History Can Provide Clues to Future Dynamics

The future is not likely to evolve as our planning forecasts predict.

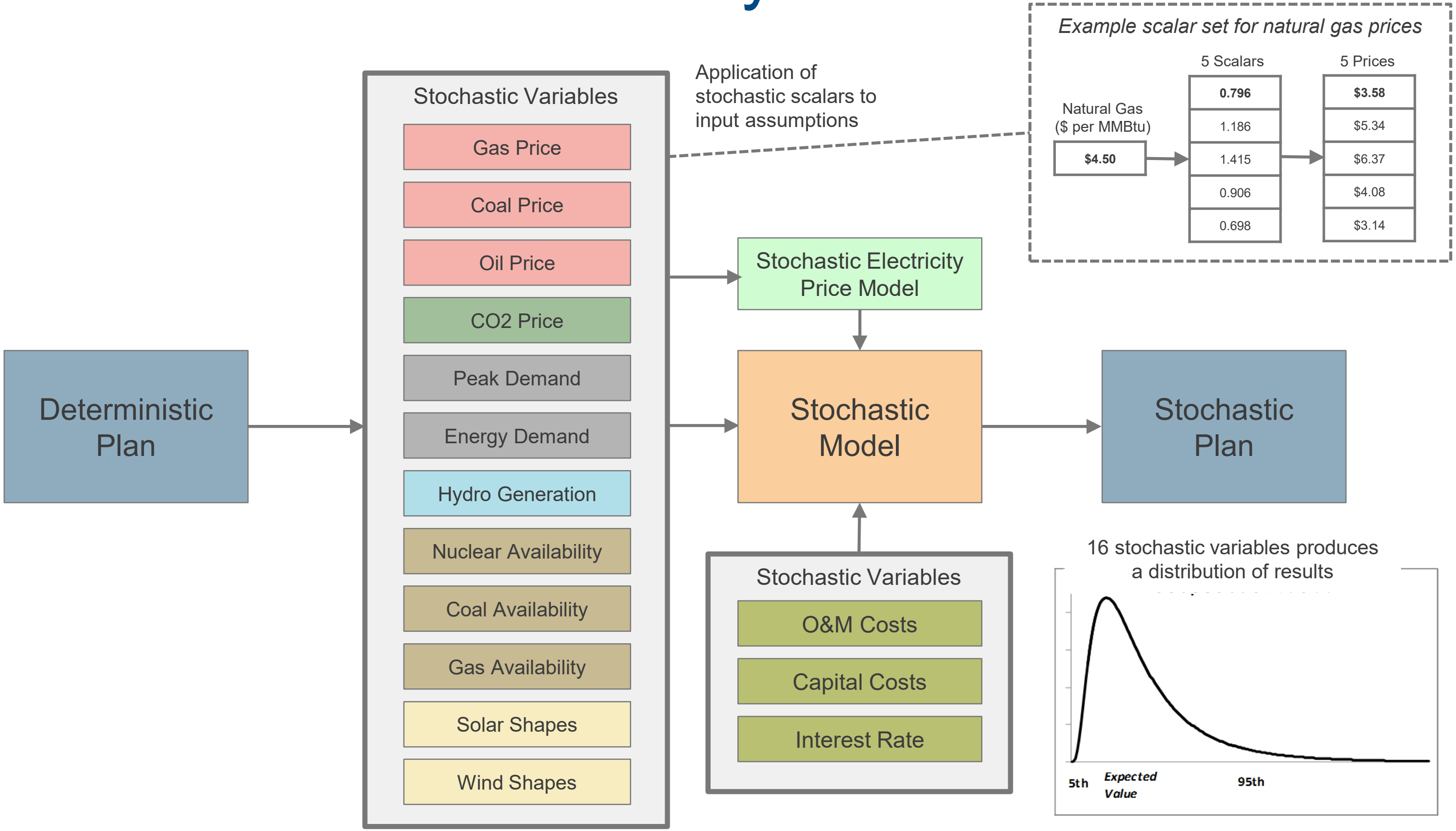
Stochastic parameters allow for understanding of realistic "alternative" futures and their likelihoods. The full set of Monte-Carlo draws of future price paths represents the forecast's probability distribution.



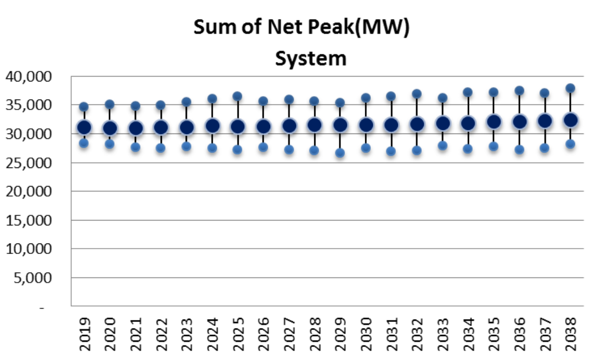


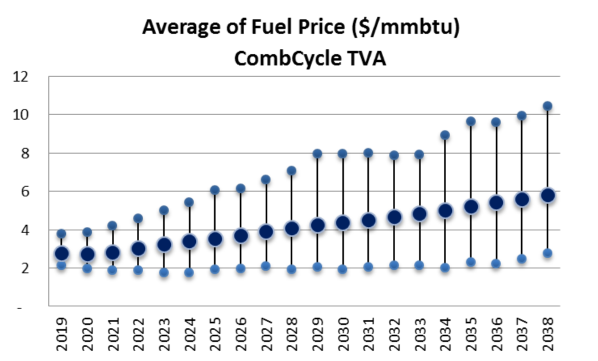


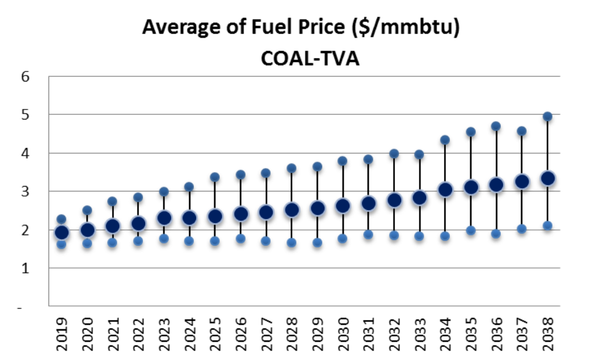
Portfolio Stochastic Analysis

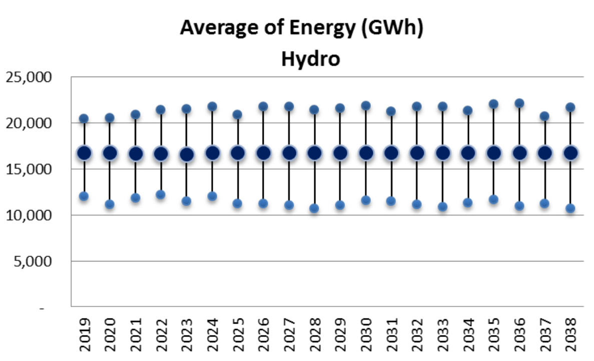


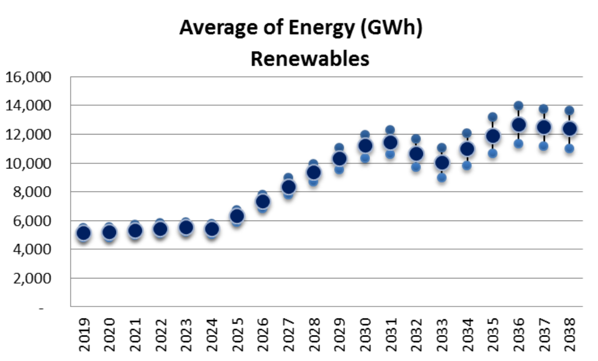
Base Case Stochastic Input: P5 - P95 Ranges

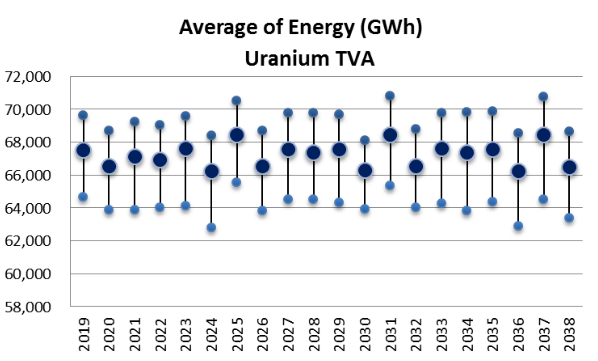




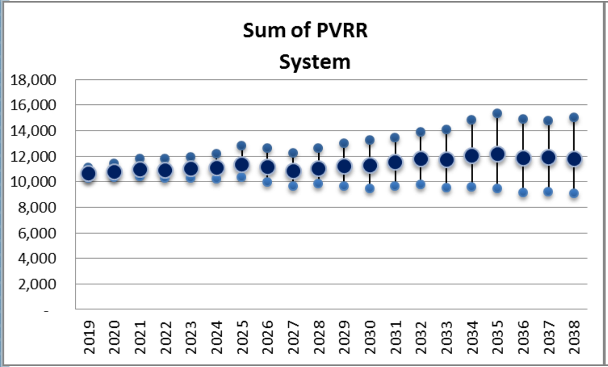


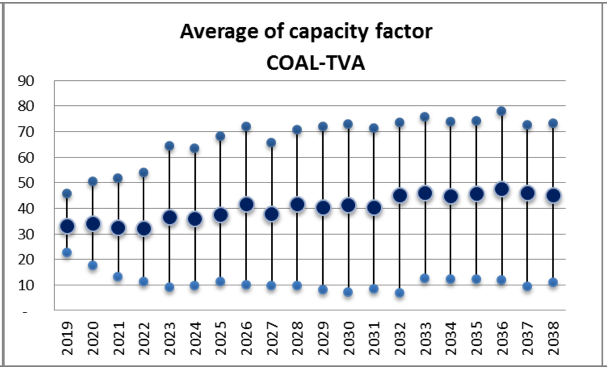


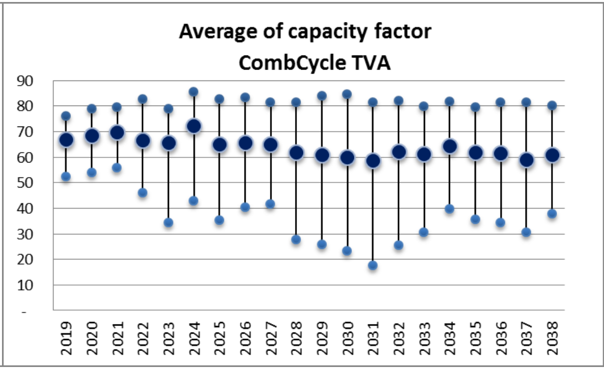


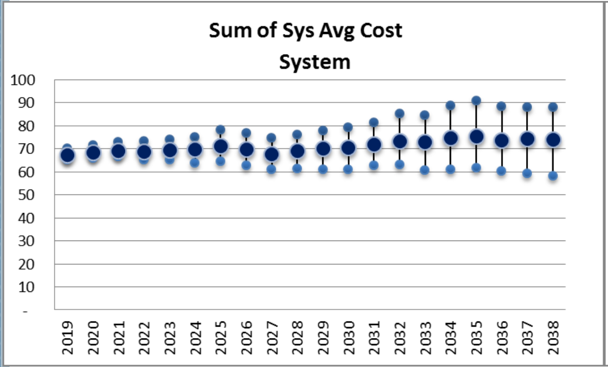


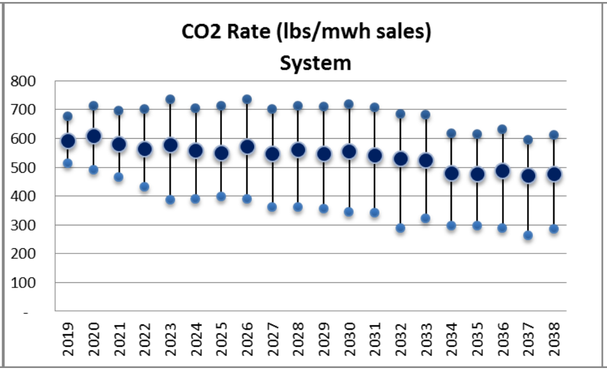
Base Case Stochastic Output: P5 - P95 Ranges

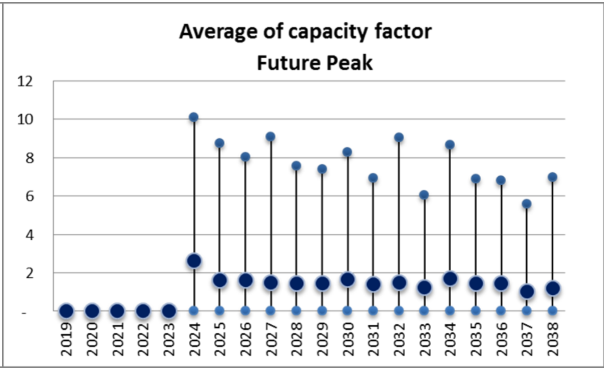




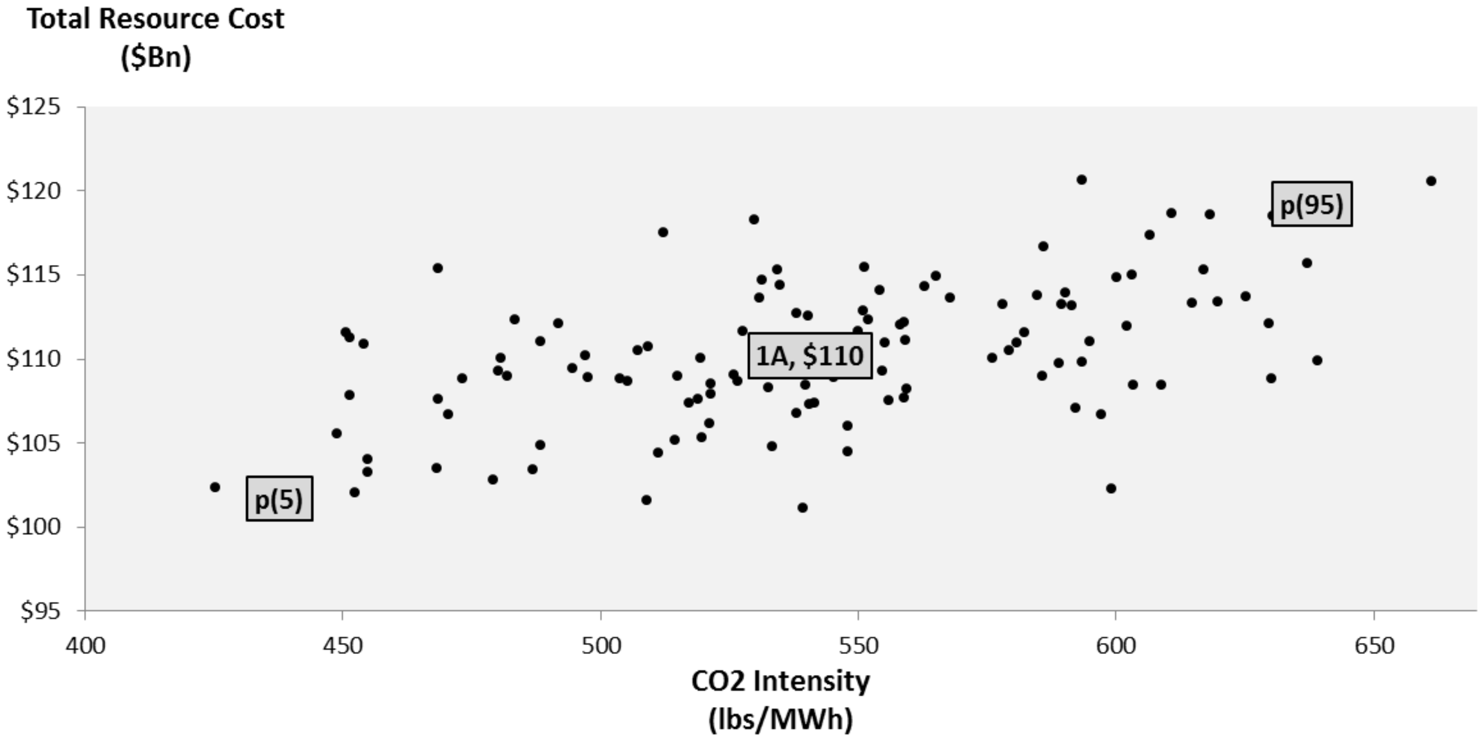








All Iterations of the Base Case



Weather Sensitivity

Impacts

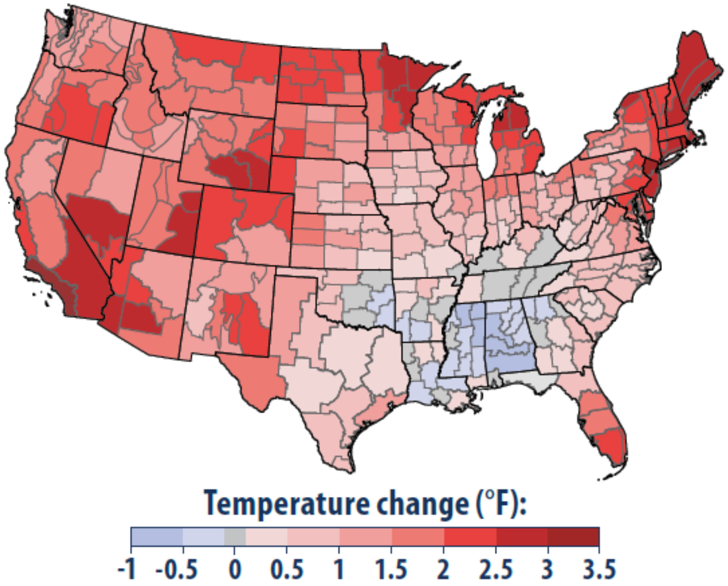
Temperature

Although the average temperature did not change much during the 20th century, temperatures in the state have warmed in the last 20 years.

Rainfall

Floods may be more frequent, and **droughts** may be longer, which would increase the difficulty of meeting the competing demands for water in the Tennessee and Cumberland Rivers.

Nuclear and coal capacity is derated in the summer due to drought.



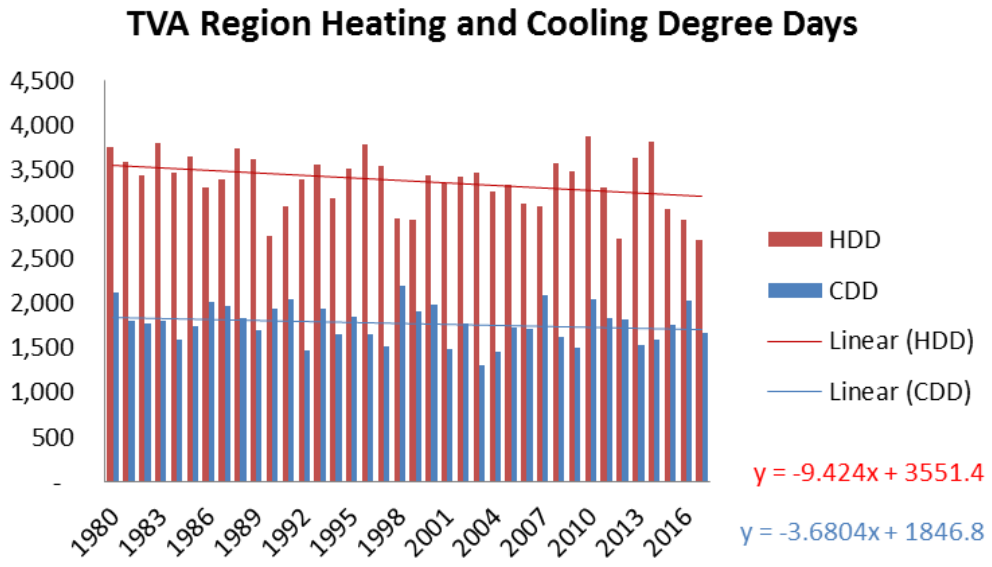
Rising temperatures in the last century. Tennessee has warmed less than most of the United States. Source: EPA, Climate Change Indicators in the United States.

What Climate Change Means for Tennessee
August 2016, EPA 430-F-16-044
https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-tn.pdf

Heating and Cooling Degree Days

Heating degree days (HDD) is a measurement designed to quantify the demand for energy needed to heat a building. **Cooling degree days (CDD)** quantifies the demand for air conditioning.

A "degree day" indicates that the daily average outdoor temperature was one degree higher or lower than 65°F. The heating requirements for a given building at a specific location are considered to be directly proportional to the number of HDD, while the cooling requirements are proportional to the number of CDD at that location.

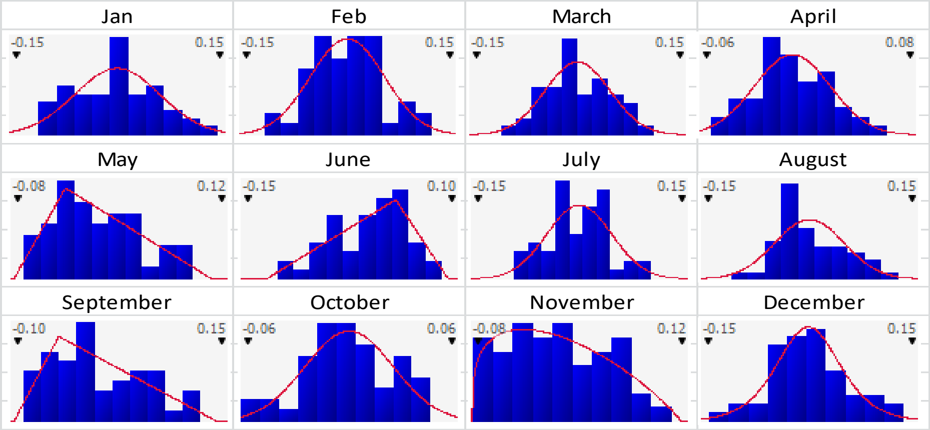


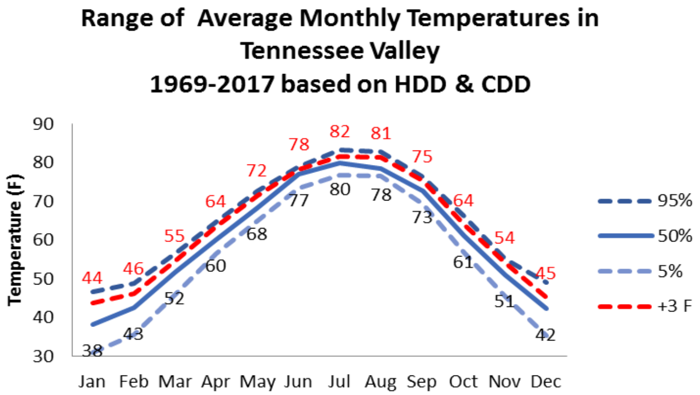
Monthly Energy Distributions

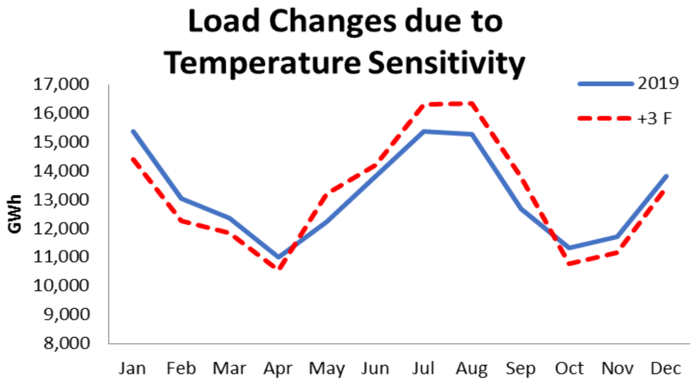
Although the average temperature did not change much during the 20th century, temperatures in the state have warmed in the last 20 years.

Assume 3°F increase in annual temperature aligned to the extreme case as shown in the national map. Translate into CDD & HDD, then into energy.

July & August: 500 CDD at 82°F average similar to 2007
January: 670 HDD at 44 F average similar to 1993





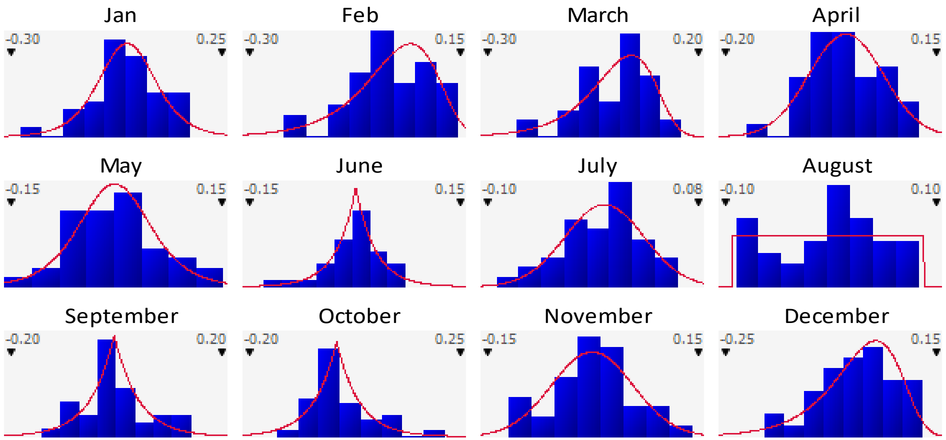


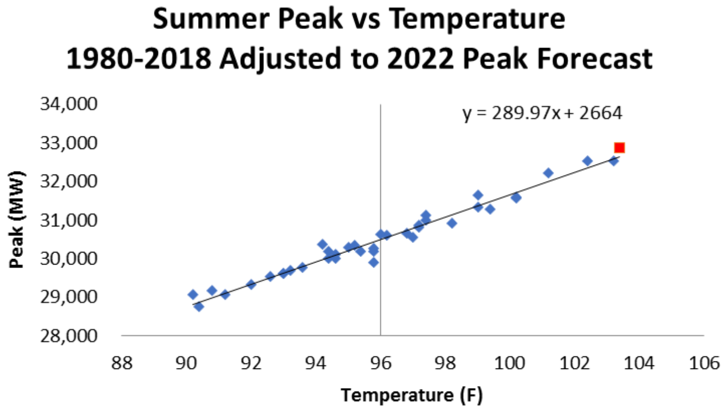
Monthly Peak Distributions

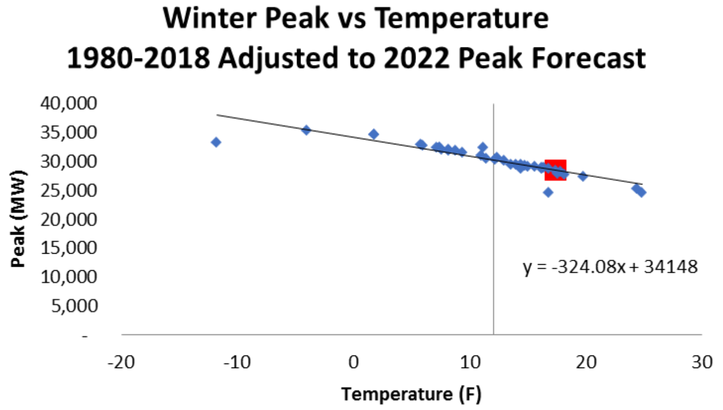
Although the average temperature did not change much during the 20th century, temperatures in the state have warmed in the last 20 years.

Selected the same year for summer and winter peaks which corresponded to the energy changes.

Summer: 2007 (same as hydro), 103 F, normal is 96 F
Winter: 1993, 17 F, normal is 12 F



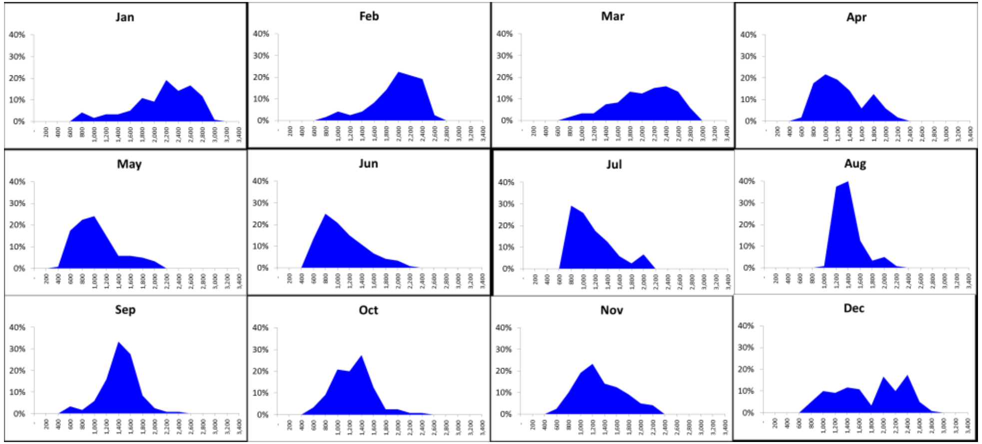


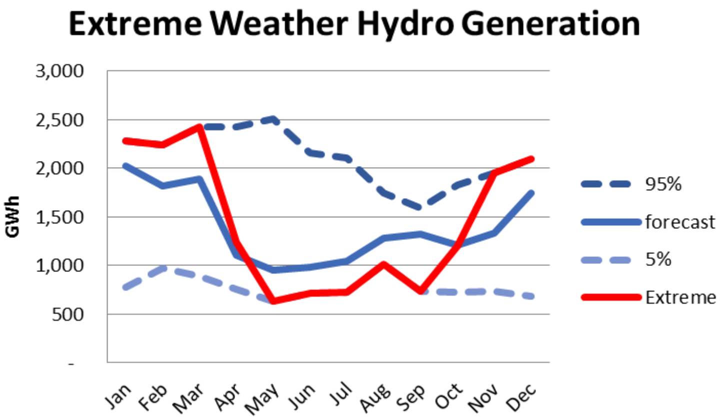


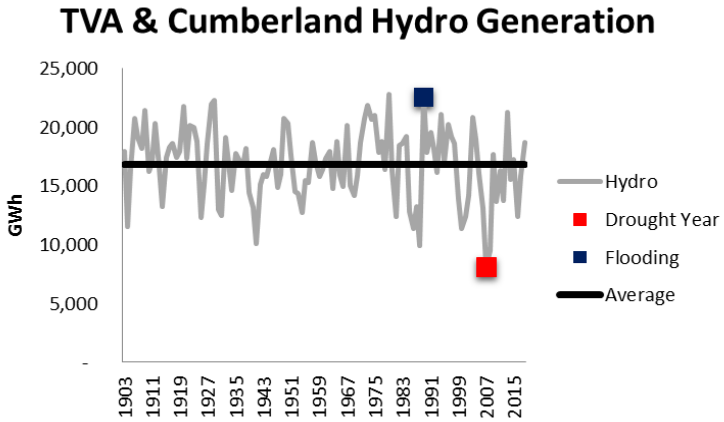
Impact of Extreme Weather on Hydro Generation

***Floods** may be more frequent, and **droughts** may be longer, which would increase the difficulty of meeting the competing demands for water in the Tennessee and Cumberland Rivers.*

Historical distributions and forecasts include more rainfall in winter and less in summer.







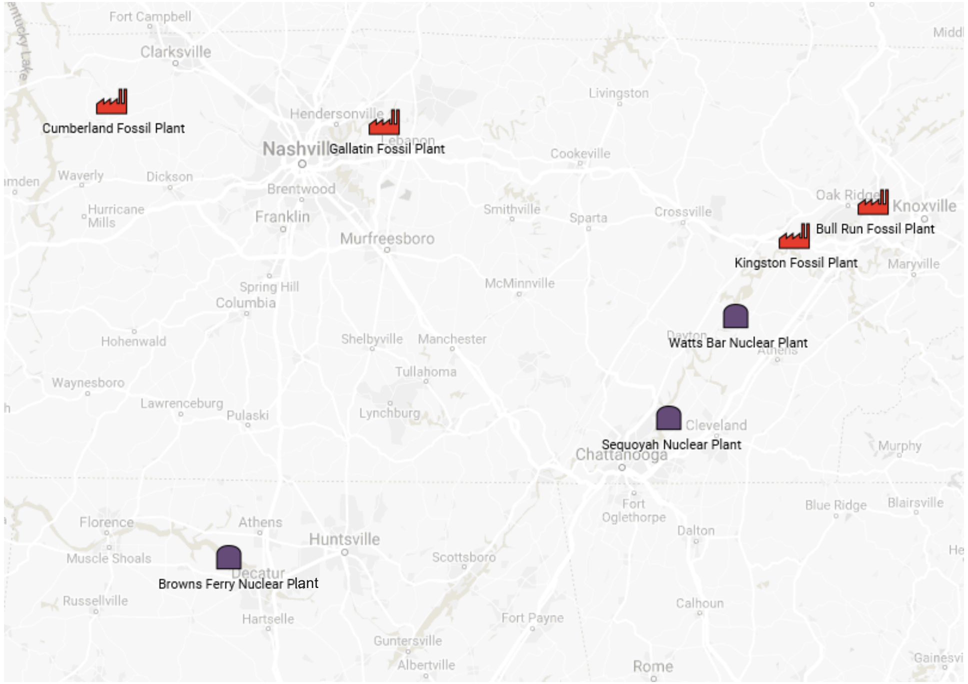
Impact of Drought on Plant Operations

Floods may be more frequent, and droughts may be longer, which would increase the difficulty of meeting the competing demands for water in the Tennessee and Cumberland rivers

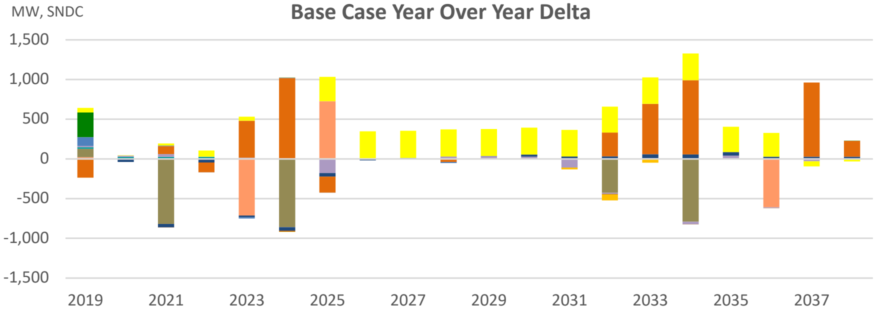
Assumed derated capacity based on 2007 drought impact on plants located on the Cumberland and Tennessee Rivers:

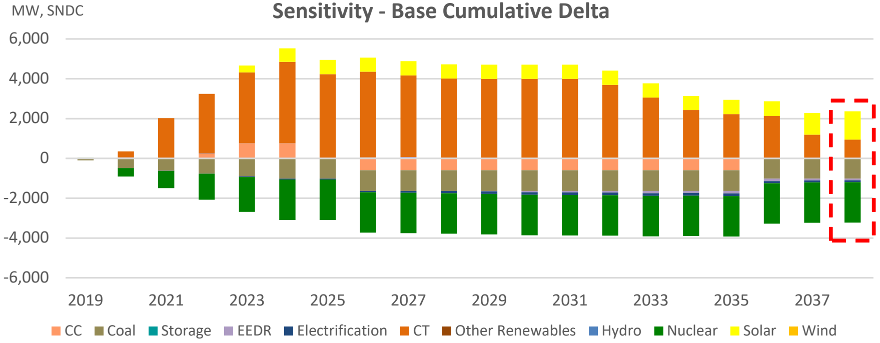
July	939 MW total
August	3,254 MW total

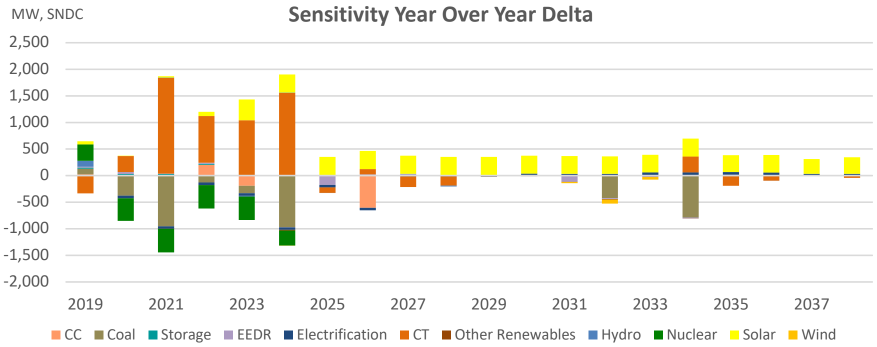
Nuclear				
	BFN1	derate 300MW of 1253MW	late Jul-early Aug	4 weeks
	BFN2	derate 300MW of 1253MW	late Jul-early Aug	4 weeks
	BFN3	full shutdown	late Jul-early Aug	4 weeks
	SQN1	risk of UHS limit (assume 10%)	late Jul-early Aug	4 weeks
	SQN2	risk of UHS limit (assume 10%)	late Jul-early Aug	4 weeks
	WBN1	risk of UHS limit (assume 10%)	late Jul-early Aug	4 weeks
	WBN2	risk of UHS limit (assume 10%)	late Jul-early Aug	4 weeks
Coal				
	CUF1	derate 250MW of 1205MW	late Jul - early Sep	8 weeks
	CUF2	derate 250MW of 1205MW	late Jul - early Sep	8 weeks
	GAF1	-40 to 50% (100MW of 221MW)	late Jul - early Sep	8 weeks
	GAF2	-40 to 50% (100MW of 221MW)	late Jul - early Sep	8 weeks
	GAF3	-40 to 50% (121MW of 269MW)	late Jul - early Sep	8 weeks
	GAF4	-40 to 50% (119MW of 264MW)	late Jul - early Sep	8 weeks



Extreme Weather



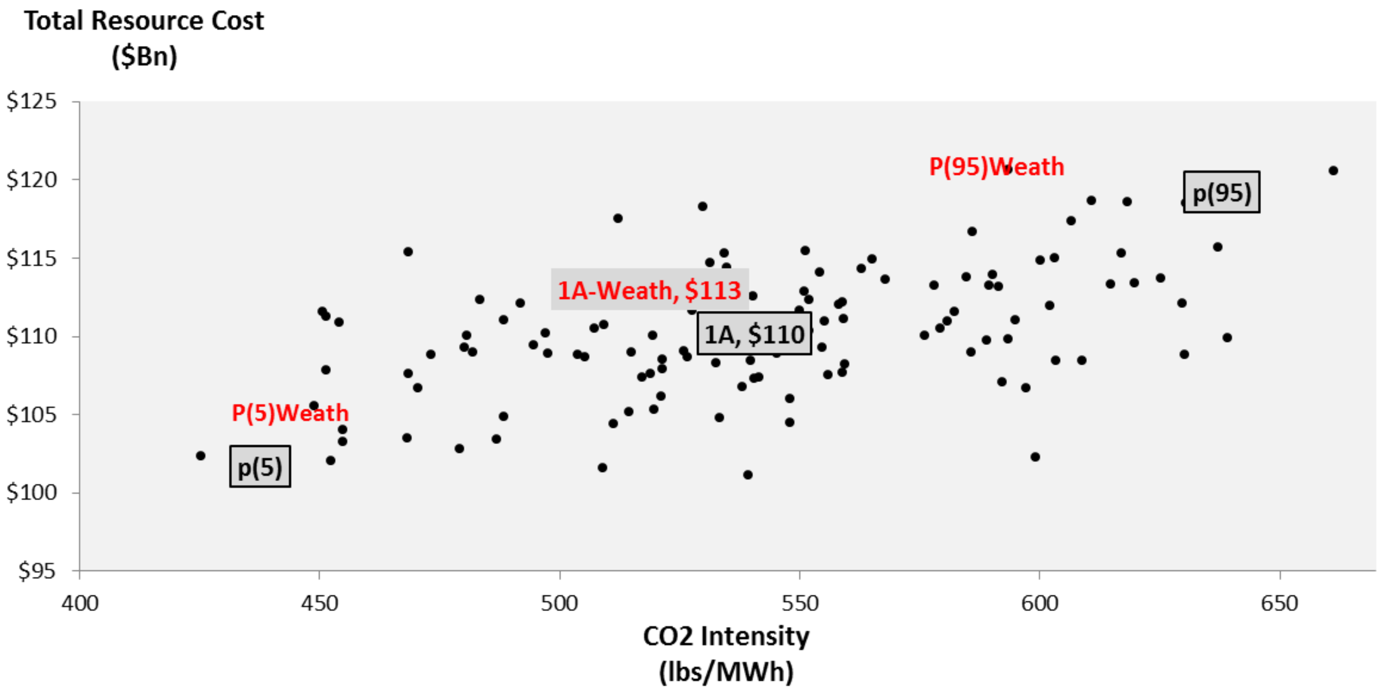




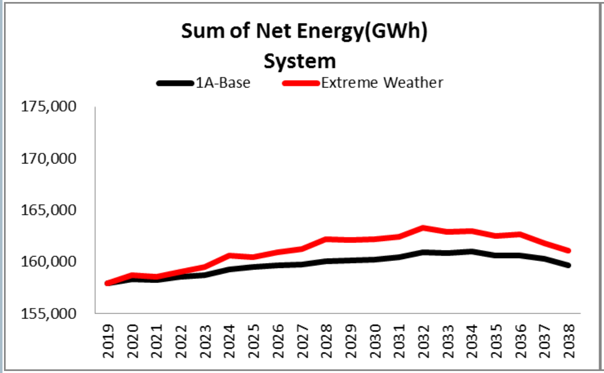
- System becomes summer peaking and summers are drier, causing thermal derates
- Derated nuclear and coal capacity is initially replaced with CTs until 2,100 MW nameplate of solar is added by 2038
- Hydro generation is higher from warm and wet winters, but capacity remains the same

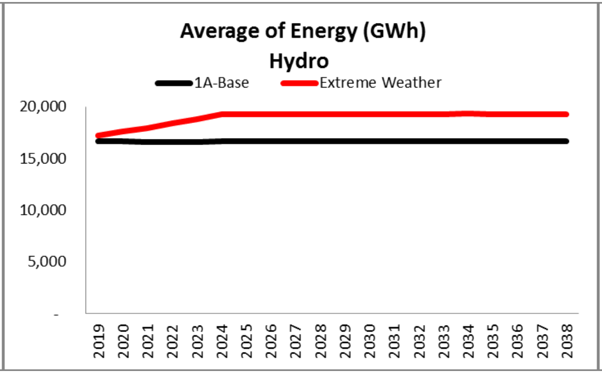
Results of Weather Sensitivity

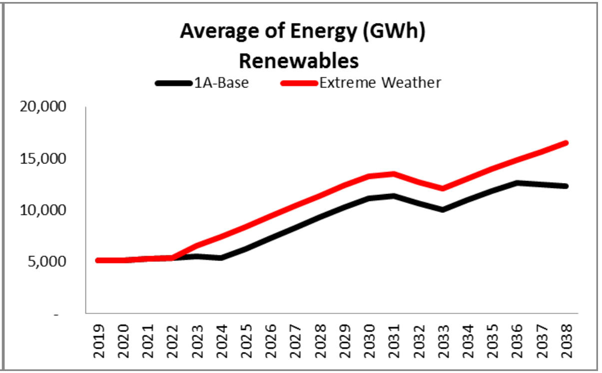
More extreme weather results in higher cost and lower carbon emissions as hydro and solar generation displaces thermal generation.

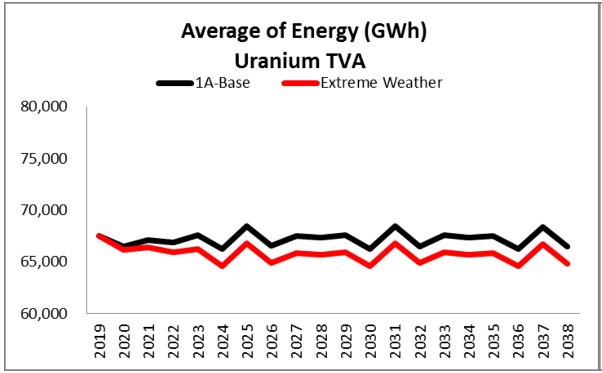


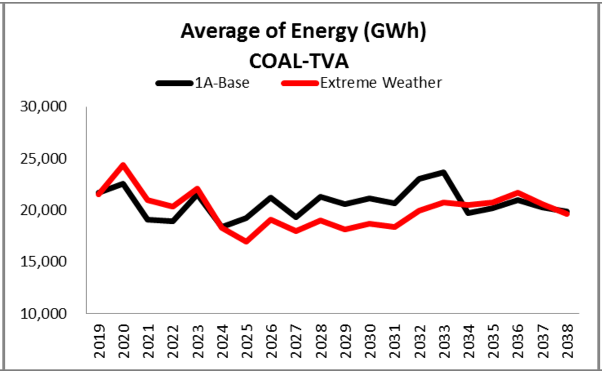
Base Case vs. Extreme Weather Case (Expected Value)

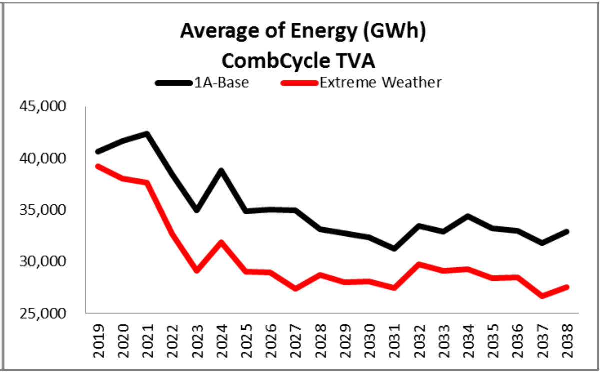




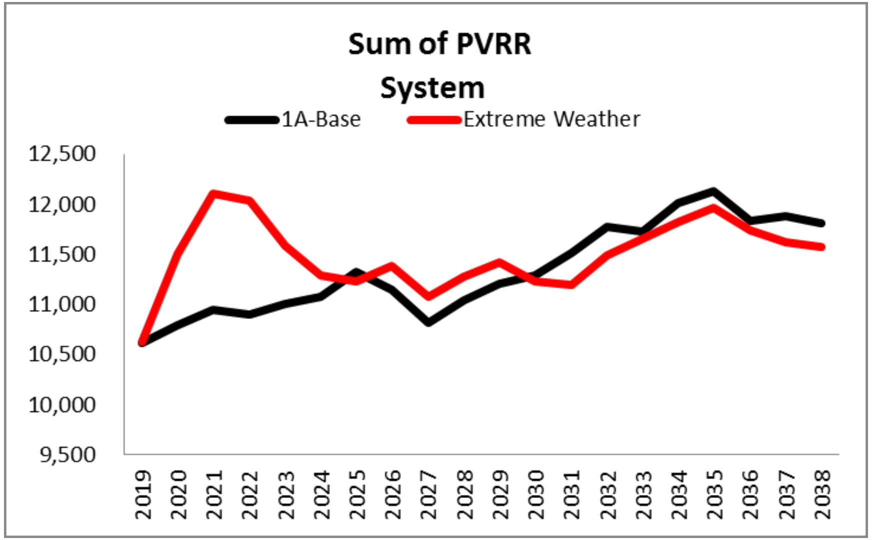


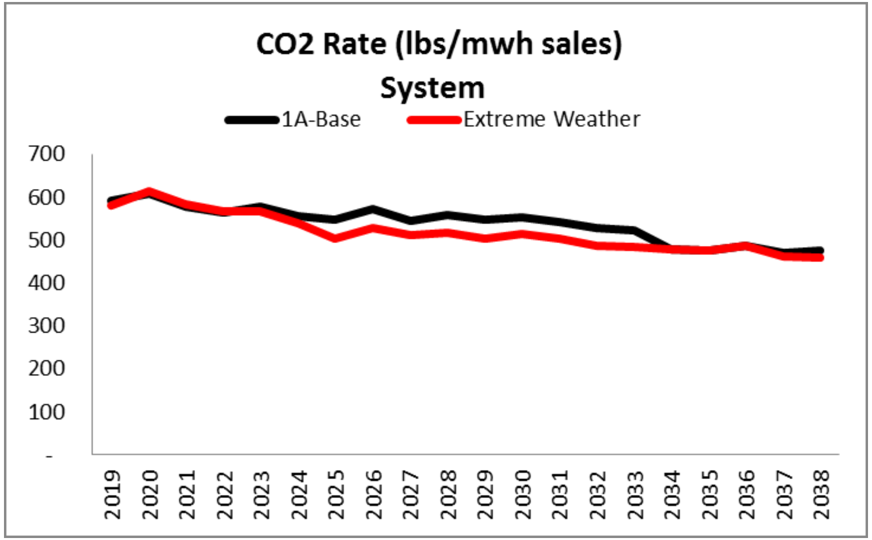






Base Case Stochastic Output: P5 - P95 Ranges





Extreme Weather

Sensitivity Metric Results

	PVRR ($Bn)	System Average Cost Years 1-20 ($/MWh)	Total Resource Cost ($Bn)	Risk/Benefit Ratio	Risk Exposure ($Bn)	CO2 (MMTons)	CO2 Intensity (lbs/MWh)	Water Consumption (MMGallons)	Waste (MMTons)	Land Use (Acres)	Flexible Resource Coverage Ratio	Flexibility Turn Down Factor (2038)	Percent Difference in Per Capita Income*	Percent Difference in Employment*
Extreme Weather	112.5	71.4	113.0	1.0	120.4	41.8	518.9	52,783	2,350	58,842	1.66	50%	0.00%	0.00%
Base Case	109.7	70.1	110.2	1.1	118.7	43.2	541	54,053	2,269	43,365	1.98	50%	0.00%	0.00%
Delta from Base Case	2.81	1.28	2.83	-0.06	1.65	-1	-22	-1,270	81	15,477	-0.31	0%	0.00%	0.00%

**Economic analysis was not run for sensitivities*

Summary of 2019 IRP Sensitivities

Sensitivity Case	Summary of Expansion Changes
Older Gas CT Retirements	CT retirements are replaced in kind with peaking capacity beginning in the mid-2020s.
Integration Cost & Flexibility Benefit	Negligible impact to capacity expansion.
High and Low Gas Prices	Under high gas prices, additional ~2,050 MW nameplate of solar and 55 MW of hydro are added. Under low gas prices, CC capacity replaces ~5,900 MW nameplate of solar and ~2,000 MW of CT capacity; customer demand would drive solar additions in this case.
Solar Acceleration and Caps	In the Current Outlook, accelerating solar and doubling the annual cap brings forward solar additions and results in an additional ~1,100 nameplate MW of solar by 2038. In the Growth Case, doubling the annual cap results in 6,000 MW nameplate additional solar by 2038.
Breakeven Analysis	The LCOE of wind, battery storage, SMR, and CHP are at least double the breakeven value. Under the NREL ATB mid case wind trajectory, 4,200 MW nameplate of wind is added by 2038, displacing early gas additions and competing with solar in the long term.
Increased Coal Operating Costs	Kingston and Shawnee 2,3,5-9 are retired in the mid-2020s, replaced by peaking capacity.
Double Decarbonization	Kingston and Shawnee 2,3,5-9 retirements are further accelerated and replaced with CC and hydro capacity.
Increased EE and DR Market Depth	1,900 MW of C&I EEDR displaces CT and solar capacity.
Extreme Weather	Derated capacity is initially replaced with CTs until 2,100 MW nameplate of solar is added by 2038.

Group Breakout

Breakout Questions

- <u>Public Comments:</u>
  What are your observations from the public comments as they relate to considerations for the IRP?
- <u>Sensitivities:</u>
  What are your thoughts on the impact of the sensitivities covered today as they relate to the IRP recommendation?

Wrap Up Day 1

2019 IRP Working Group

Meeting 13: May 13-14, 2019

Day 2


welcome

Agenda – May 14

7:30	***Breakfast – at hotel for guests*** ***Coffee / light refreshments in meeting room***	
8:30	**Welcome and Recap Day 1**	**Liz Upchurch / Jane**
8:45	**Developing a Recommendation**	**Hunter Hydas**
9:15	**Group Break Out – on final recommendation development.**	**Liz and group**
10:30	**Thinking ahead:** **Considerations for Implementation of the 2019 IRP**	**Hunter**
10:45	**Group Discussion**	**Liz and group**
11:45	**Next Steps** **Adjourn**	**Liz**
12:00	**Lunch**	
	Confidential Material	

Recap: Sensitivities

Jane Elliott, Roger Pierce, Scott Jones
Resource Strategy

Developing the Recommendation

Hunter Hydas

Strategy Performance

	COST	RISK	ENVIRONMENTAL STEWARDSHIP		OPERATIONAL FLEXIBILITY	VALLEY ECONOMICS
			CO_2, Water, Waste	Land Use		
STRATEGY A: BASE CASE						All strategies have similar impacts on the Valley economy as measured by per capita income and employment
STRATEGY B: PROMOTE DER						
STRATEGY C: PROMOTE RESILIENCY						
STRATEGY D: PROMOTE EFFICIENT LOAD SHAPE						
STRATEGY E: PROMOTE RENEWABLES						

Good — Better — Best

Confidential Slides

Individual Feedback
Final Recommendation

Liz Upchurch

Developing the Recommendation

What are you thoughts on these aspects of the recommendation

- format of the chart
- the narrative
- whether it tells the story we have observed in the portfolio/ sensitivity results

Thinking ahead: Considerations for Implementation of the 2019 IRP

Hunter Hydas

Considerations for Implementation

Changing Market Conditions

More Stringent Regulations

Technology Advancements

Group Discussion

Group Discussion Questions

- What do we need to be thinking about regarding implementation of the 2019 IRP?

- What signposts of change do we need to watch?

Next Steps

Next Steps

- Complete responses to public comments
- Send responses to RERC and IRPWG – Early June
- RERC Webinar June 10, 2019, 1:30 – 3:30 pm
- Develop the recommendation
- IRPWG Meeting June 25 – Present recommendation
- RERC Meeting June 26-27 – Includes panel presentation with the TVA Board

Tentative Meeting Dates / Locations

Future Sessions:

- ✔ **#11: Feb 28 – March 1, 2019 Knoxville, TN**
- ✔ **#12: March 27-28, 2019 Bowling Green, KY**
- ✔ **#13: May 13 - 14, 2019 Murfreesboro, TN**
- **#14: June 25, 2019 Chattanooga, TN**

IRPWG Appreciation Dinner
June 24, 2019 6:00 pm
Chattanooga, TN

Completed Sessions:

- ✔ **#4 June 6 and 7, 2018**
  Nashville, TN Music City Sheraton
- ✔ **#5 July 23-24, 2018**
  Middle Tennessee
- ✔ **#6 August 29 – 30, 2018**
  Memphis, TN / Memphis Chamber of Commerce
- ✔ **#7 September 26-27, 2018**
  Franklin, TN, Marriott
- ✔ **#8 October 25, 2018**
  Huntsville, Alabama
- ✔ **#9 December 19-20, 2018**
  Knoxville, Tennessee
- ✔ **#10 Jan 30-31, 2018**
  Oxford, Mississippi

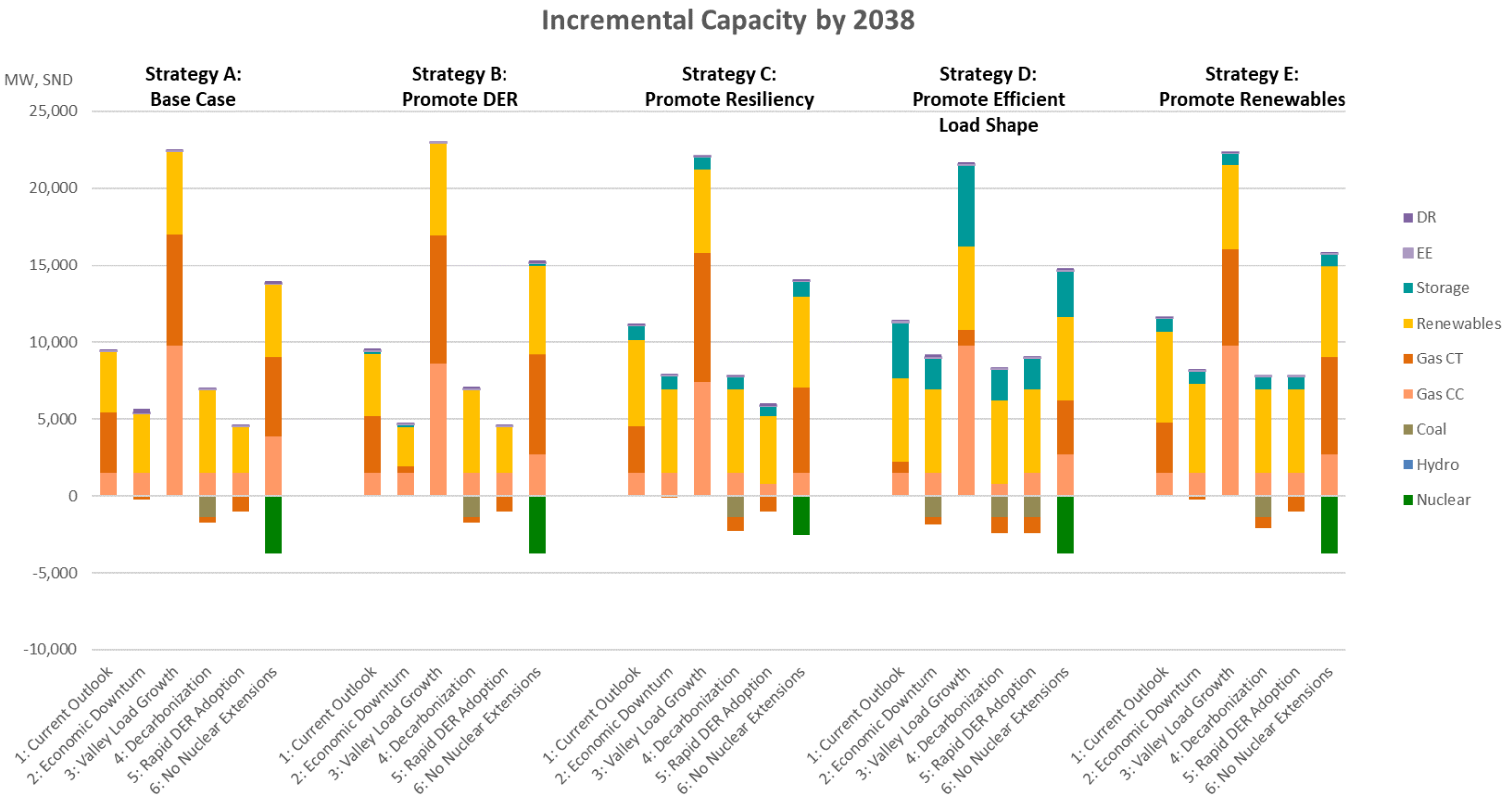
TVA

Thank you and Safe Travels!!

Please leave your name badge.

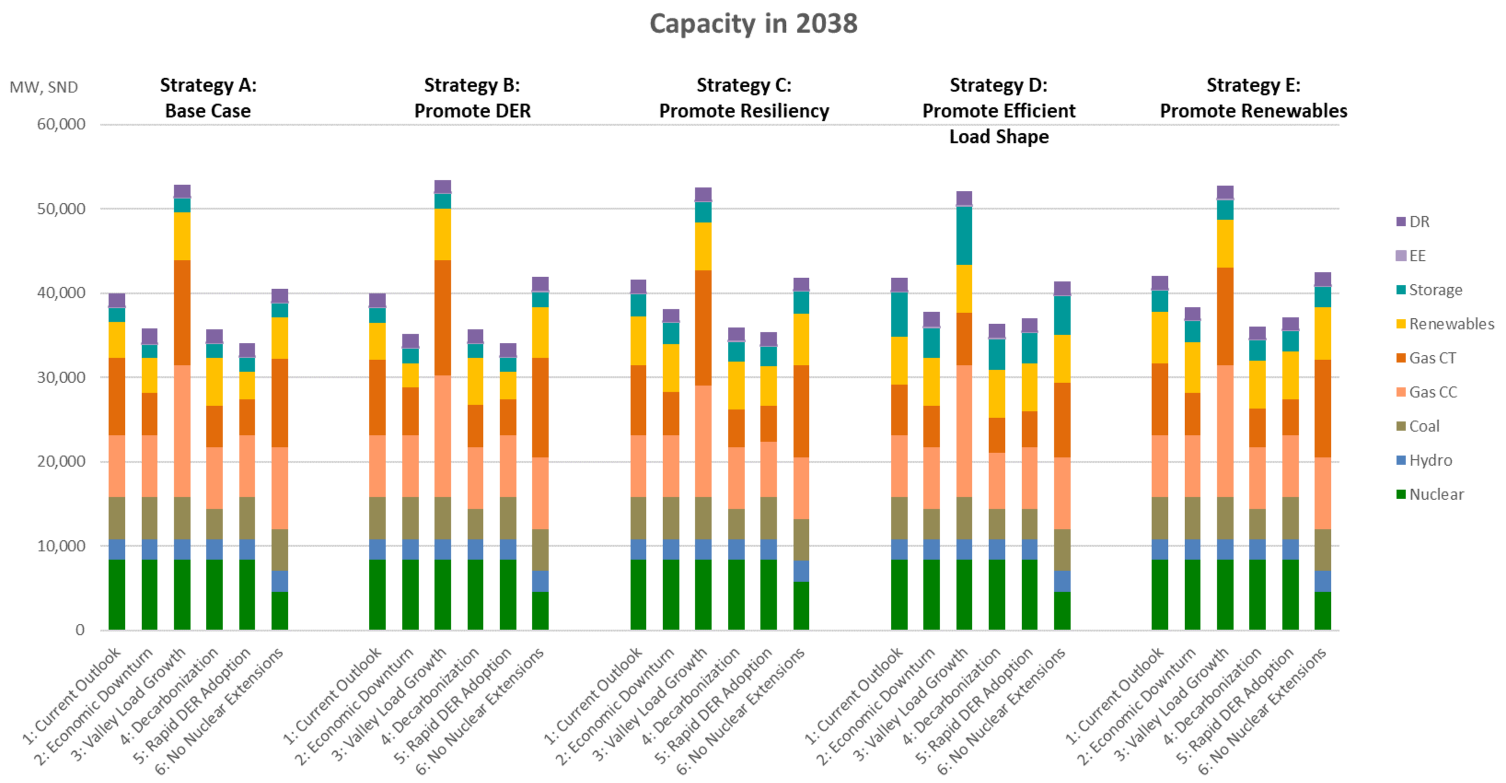
Appendix:
Base Case Portfolio Results

Incremental Capacity by 2038



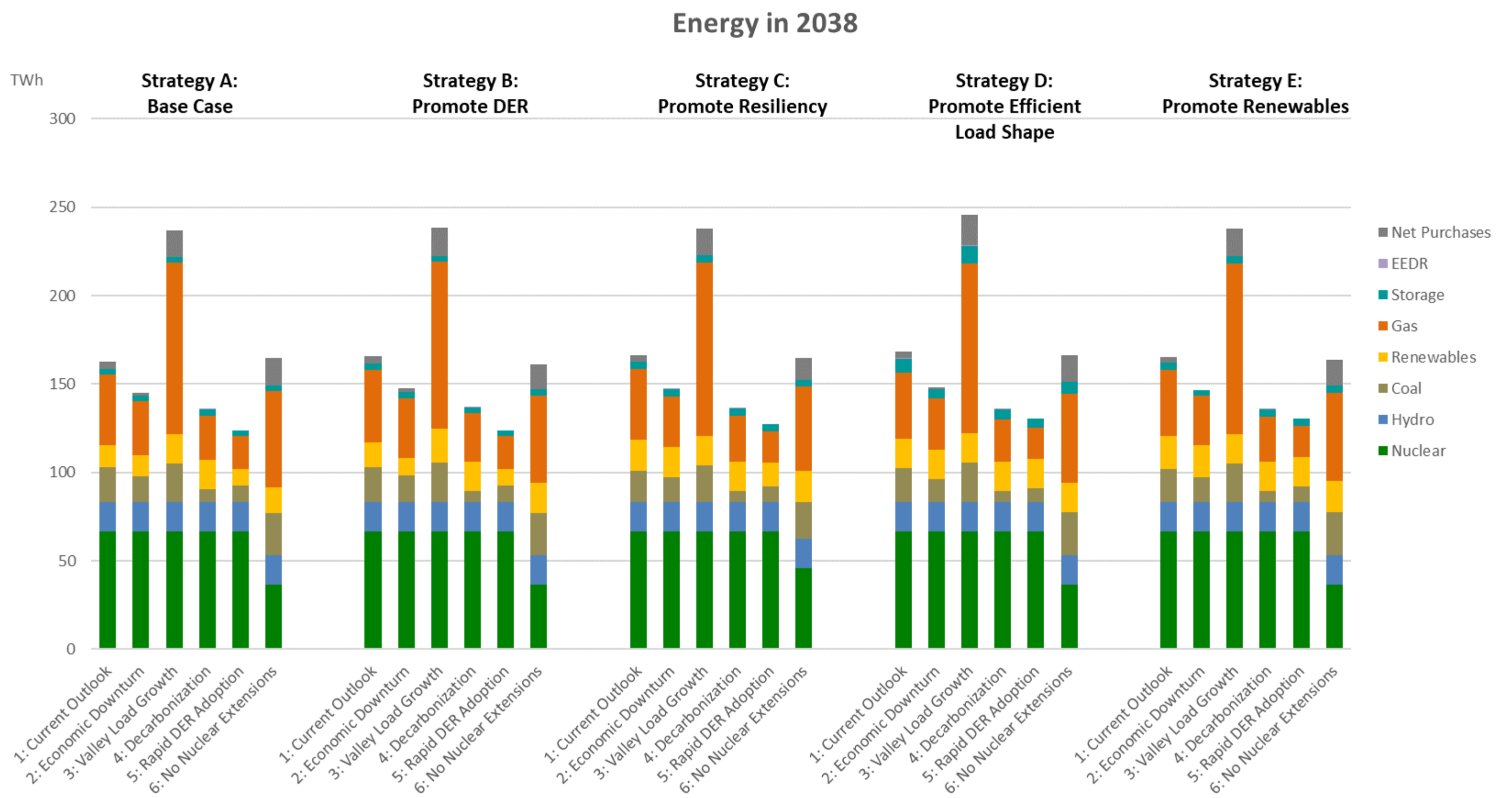
Results updated based on 2/14/2019 TVA Board decision to retire Bull Run and Paradise 3 fossil plants.

Capacity in 2038



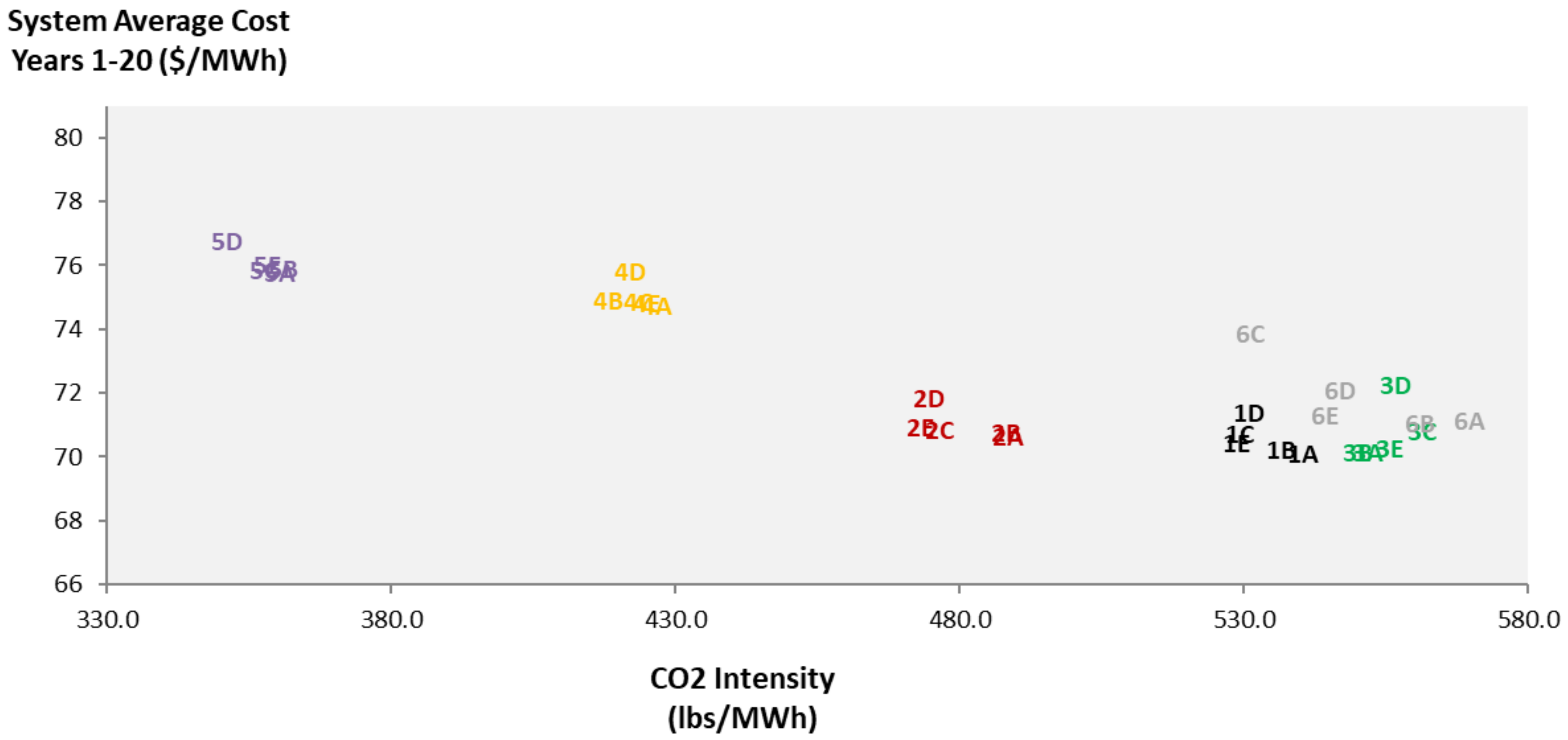
Results updated based on 2/14/2019 TVA Board decision to retire Bull Run and Paradise 3 fossil plants.

Energy in 2038



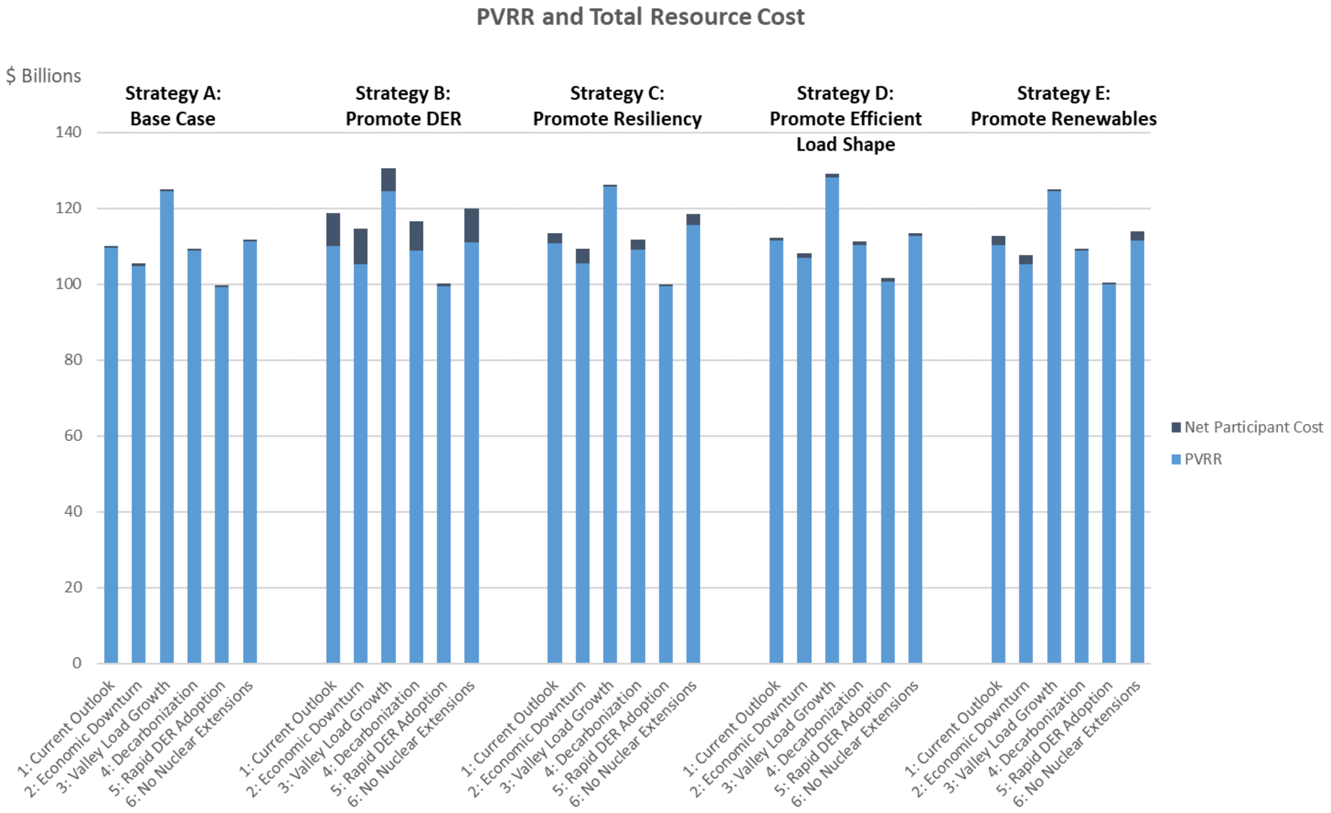
Results updated based on 2/14/2019 TVA Board decision to retire Bull Run and Paradise 3 fossil plants.

Portfolio Cost and CO2 Tradeoff



Results updated based on 2/14/2019 TVA Board decision to retire Bull Run and Paradise 3 fossil plants.

PVRR and Total Resource Cost in 2038



Results updated based on 2/14/2019 TVA Board decision to retire Bull Run and Paradise 3 fossil plants.

Cost Metrics Summary

Scorecard Metric	Current Outlook	Economic Downturn	Valley Load Growth	De-Carbonization	Rapid DER Adoption	No Nuclear Extensions	Average Result	Average Rank
PVRR ($Bn)								
Base Case	$ 109.7	$ 104.9	$ 124.5	$ 108.9	$ 99.3	$ 111.2	$ 109.8	1.7
Promote DER	$ 110.0	$ 105.2	$ 124.5	$ 109.0	$ 99.5	$ 111.1	$ 109.9	1.8
Promote Resiliency	$ 110.7	$ 105.4	$ 125.7	$ 109.1	$ 99.5	$ 115.6	$ 111.0	4.0
Promote Efficient Load Shape	$ 111.5	$ 107.0	$ 128.2	$ 110.3	$ 100.7	$ 112.7	$ 111.7	4.8
Promote Renewables	$ 110.4	$ 105.4	$ 124.5	$ 108.9	$ 99.9	$ 111.6	$ 110.1	2.7
System Average Cost Years 1-20 ($/MWh)								
Base Case	$ 70.1	$ 70.6	$ 70.1	$ 74.7	$ 75.8	$ 71.2	$ 72.1	1.2
Promote DER	$ 70.2	$ 70.8	$ 70.1	$ 74.9	$ 75.9	$ 71.1	$ 72.2	2.3
Promote Resiliency	$ 70.7	$ 70.9	$ 70.8	$ 74.9	$ 75.9	$ 73.9	$ 72.8	3.5
Promote Efficient Load Shape	$ 71.4	$ 71.9	$ 72.3	$ 75.8	$ 76.8	$ 72.1	$ 73.4	4.8
Promote Renewables	$ 70.5	$ 71.0	$ 70.3	$ 74.8	$ 76.0	$ 71.3	$ 72.3	3.2
Total Resource Cost ($Bn)								
Base Case	$ 110.2	$ 105.6	$ 125.0	$ 109.4	$ 99.7	$ 111.7	$ 110.3	1.3
Promote DER	$ 118.9	$ 114.8	$ 130.6	$ 116.5	$ 100.1	$ 120.0	$ 116.8	4.7
Promote Resiliency	$ 113.5	$ 109.3	$ 126.2	$ 111.7	$ 100.0	$ 118.5	$ 113.2	3.5
Promote Efficient Load Shape	$ 112.3	$ 108.1	$ 129.0	$ 111.2	$ 101.5	$ 113.6	$ 112.6	3.2
Promote Renewables	$ 112.8	$ 107.7	$ 124.9	$ 109.4	$ 100.4	$ 114.0	$ 111.5	2.3

Results updated based on 2/14/2019 TVA Board decision to retire Bull Run and Paradise 3 fossil plants.

Risk Metrics Summary

Scorecard Metric	Current Outlook	Economic Downturn	Valley Load Growth	De-Carbonization	Rapid DER Adoption	No Nuclear Extensions	Average Result	Average Rank
Risk/Benefit Ratio								
Base Case	1.06	1.00	1.06	1.04	0.94	1.08	1.03	4.33
Promote DER	1.05	1.00	1.06	1.03	0.94	1.07	1.03	3.33
Promote Resiliency	1.05	0.98	1.06	1.04	0.94	1.07	1.02	3.50
Promote Efficient Load Shape	1.02	0.97	1.04	1.02	0.93	1.07	1.01	1.00
Promote Renewables	1.04	0.98	1.06	1.04	0.93	1.07	1.02	2.83
Risk Exposure ($Bn)								
Base Case	$ 118.7	$ 112.6	$ 136.7	$ 118.0	$ 105.5	$ 120.8	$ 118.7	1.7
Promote DER	$ 119.0	$ 113.0	$ 136.7	$ 118.0	$ 105.8	$ 120.6	$ 118.8	1.7
Promote Resiliency	$ 119.7	$ 113.2	$ 138.0	$ 118.2	$ 105.8	$ 125.0	$ 120.0	4.0
Promote Efficient Load Shape	$ 120.6	$ 115.0	$ 141.1	$ 119.6	$ 107.2	$ 122.5	$ 121.0	4.8
Promote Renewables	$ 119.4	$ 113.1	$ 136.7	$ 118.0	$ 106.3	$ 121.2	$ 119.1	2.8

Results updated based on 2/14/2019 TVA Board decision to retire Bull Run and Paradise 3 fossil plants.

Environmental Metrics Summary

Scorecard Metric	Current Outlook	Economic Downturn	Valley Load Growth	De-Carbonization	Rapid DER Adoption	No Nuclear Extensions	Average Result	Average Rank
CO2 (MMTons)								
Base Case	43.2	36.5	52.3	30.8	23.3	45.5	38.6	4.2
Promote DER	42.9	36.5	52.2	30.1	23.4	44.9	38.3	3.3
Promote Resiliency	42.3	35.7	53.3	30.5	23.2	42.5	37.9	2.7
Promote Efficient Load Shape	42.4	35.6	52.8	30.4	22.8	43.7	37.9	2.5
Promote Renewables	42.3	35.3	52.6	30.6	23.3	43.6	37.9	2.3
Water Consumption (MMGallons)								
Base Case	54,053	51,136	58,823	50,276	45,678	51,895	51,977	4.5
Promote DER	53,958	51,133	58,675	48,706	45,697	51,637	51,634	3.3
Promote Resiliency	53,343	50,708	57,456	48,878	45,582	51,878	51,307	2.3
Promote Efficient Load Shape	53,746	50,658	58,999	48,627	45,402	51,363	51,466	2.3
Promote Renewables	53,720	50,569	58,843	49,087	45,640	51,304	51,527	2.5
CO2 Intensity (lbs/MWh)								
Base Case	541	489	552	427	361	570	490	4.3
Promote DER	537	488	550	418	361	561	486	3.2
Promote Resiliency	529	477	561	424	358	531	480	2.7
Promote Efficient Load Shape	531	475	557	422	351	547	481	2.5
Promote Renewables	529	473	556	425	358	544	481	2.3
Waste (MMTons)								
Base Case	2,269	1,865	2,283	1,272	1,177	2,371	1,873	4.3
Promote DER	2,256	1,861	2,318	1,271	1,176	2,354	1,873	3.5
Promote Resiliency	2,196	1,843	2,363	1,266	1,162	2,300	1,855	2.2
Promote Efficient Load Shape	2,229	1,849	2,386	1,235	1,137	2,367	1,867	2.8
Promote Renewables	2,227	1,831	2,350	1,260	1,167	2,347	1,864	2.2
Land Use (Acres)								
Base Case	43,365	41,245	59,647	58,400	32,850	51,730	47,873	1.8
Promote DER	33,145	18,980	59,627	58,400	32,850	51,710	42,452	1.0
Promote Resiliency	56,570	54,810	59,679	58,464	47,502	59,711	56,123	3.5
Promote Efficient Load Shape	59,034	58,560	60,091	58,560	58,560	59,189	58,999	4.8
Promote Renewables	58,759	58,464	59,637	58,464	58,464	59,074	58,810	3.3

Results updated based on 2/14/2019 TVA Board decision to retire Bull Run and Paradise 3 fossil plants.

Operational Flexibility Metrics Summary

Scorecard Metric	Current Outlook	Economic Downturn	Valley Load Growth	De-Carbonization	Rapid DER Adoption	No Nuclear Extensions	Average Result	Average Rank
Flexible Resource Coverage Ratio								
Base Case	1.98	1.37	2.17	0.98	1.14	2.22	1.64	2.0
Promote DER	1.97	1.71	2.11	0.98	1.14	2.03	1.66	2.3
Promote Resiliency	1.65	1.29	2.09	1.04	1.02	1.75	1.47	4.0
Promote Efficient Load Shape	1.60	1.39	1.79	1.15	1.13	1.83	1.48	3.3
Promote Renewables	1.65	1.26	2.15	1.04	1.02	1.98	1.52	3.2
Flexibility Turn Down Factor (2038)								
Base Case	0.50	0.56	0.36	0.66	0.63	0.32	0.51	1.5
Promote DER	0.50	0.53	0.36	0.66	0.63	0.34	0.50	2.7
Promote Resiliency	0.53	0.59	0.36	0.66	0.66	0.40	0.53	3.3
Promote Efficient Load Shape	0.53	0.59	0.36	0.66	0.69	0.34	0.53	3.8
Promote Renewables	0.53	0.60	0.36	0.66	0.67	0.34	0.53	3.7

Results updated based on 2/14/2019 TVA Board decision to retire Bull Run and Paradise 3 fossil plants.

Valley Economics Metrics Summary

Scorecard Metric	Current Outlook	Economic Downturn	Valley Load Growth	De-Carbonization	Rapid DER Adoption	No Nuclear Extensions	Average Result	Average Rank
Percent Difference in Per Capita Income								
Base Case	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	1.5
Promote DER	0.002%	-0.002%	-0.001%	0.002%	-0.001%	0.003%	0.001%	1.5
Promote Resiliency	-0.006%	-0.004%	-0.017%	-0.002%	-0.003%	-0.027%	-0.010%	4.0
Promote Efficient Load Shape	-0.014%	-0.020%	-0.086%	-0.016%	-0.019%	-0.011%	-0.028%	4.8
Promote Renewables	-0.003%	-0.002%	-0.006%	-0.002%	-0.010%	-0.002%	-0.004%	3.2
Percent Difference in Employment								
Base Case	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	4.2
Promote DER	0.009%	0.002%	0.003%	0.011%	0.100%	-0.004%	0.020%	3.3
Promote Resiliency	0.011%	0.008%	-0.005%	0.007%	0.101%	0.014%	0.023%	2.5
Promote Efficient Load Shape	0.020%	0.015%	-0.063%	0.013%	0.107%	0.000%	0.015%	2.0
Promote Renewables	0.012%	0.007%	0.005%	0.002%	0.100%	-0.005%	0.020%	3.0

Economic results are rounded to the thousandths decimal place.
Results updated based on 2/14/19 TVA Board decision to retire Bull Run and Paradise 3 fossil plants.

Appendix
Sensitivities Covered in Prior Meetings

Older Gas CT Retirements

Gas CT Retirement

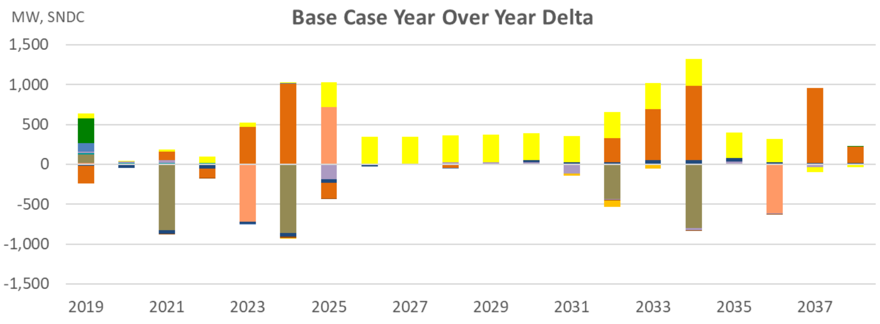
Objective: Perform a sensitivity bounding case to evaluate the potential impact of retiring older Gas CTs on IRP results.

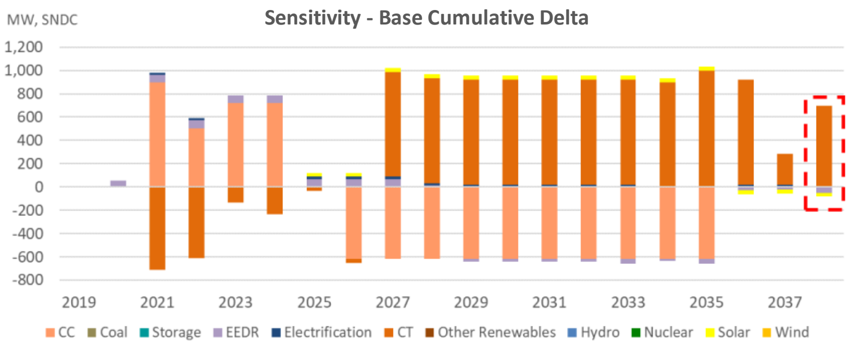
Approach: Assume all Gas CTs older than 40 years are retired at the earliest possible date (2020), then rerun models to derive impact on capacity expansion plan and metric results.

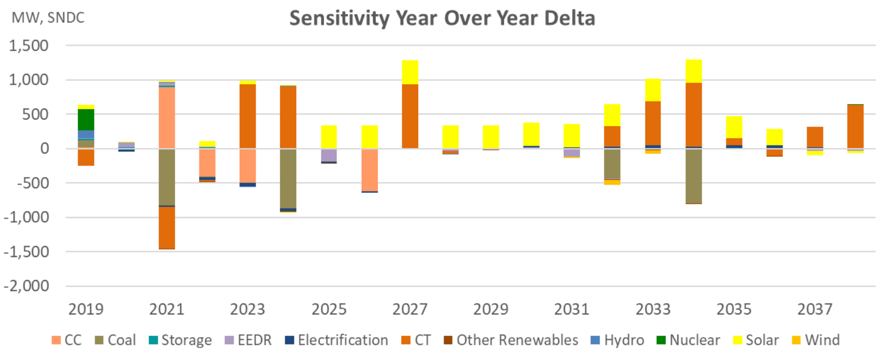
Gas CTs older than 40 years include:

- Allen CT Plant
- Colbert CT Plant
- Gallatin CT Units 1-4
- Johnsonville CT Units 1-16

Gas CT Retirement Case



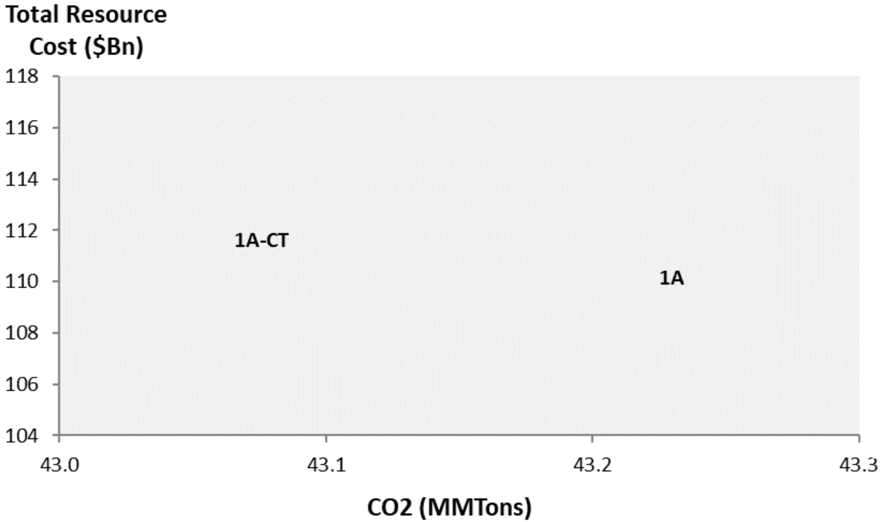


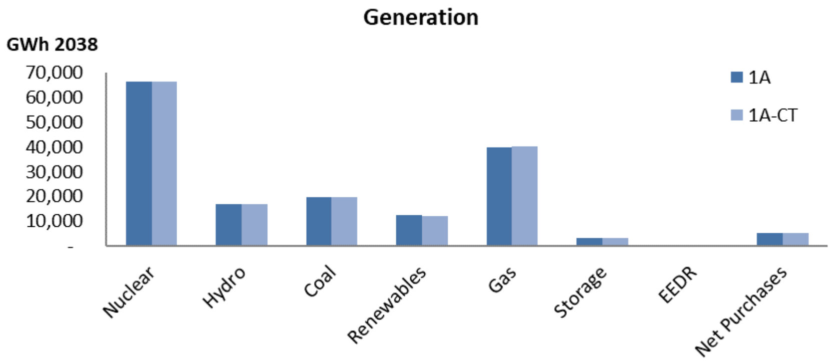


- The timing of CT capacity additions shift, and over the course of 20 years there is an increase of ~700 MW of CT capacity
- CT capacity replaces CC capacity starting in 2027 to meet peaking needs

Gas CT Retirement

Retiring older Gas CTs results in similar costs and carbon emissions, as older, higher maintenance CTs are replaced with newer, lower maintenance CTs. Generation largely remains the same.





Gas CT Retirement

Sensitivity Metric Results

	PVRR ($Bn)	System Average Cost Years 1-20 ($/MWh)	Total Resource Cost ($Bn)	Risk/Benefit Ratio	Risk Exposure ($Bn)	CO2 (MMTons)	CO2 Intensity (lbs/MWh)	Water Consumption (MMGallons)	Waste (MMTons)	Land Use (Acres)	Flexible Resource Coverage Ratio	Flexibility Turn Down Factor (2038)	Percent Difference in Per Capita Income*	Percent Difference in Employment*
Gas CT Retirement Case	111	71	112	1.06	120	43	539	54,001	2,259	43,221	2.07	50%	0.00%	0.00%
Base Case	110	70	110	1.06	119	43	541	54,053	2,269	43,365	1.98	50%	0.00%	0.00%
Delta from Base Case	1.44	0.98	1.45	0.00	1.43	0	-1	-0,052	-10	-144	0.09	0%	0.00%	0.00%

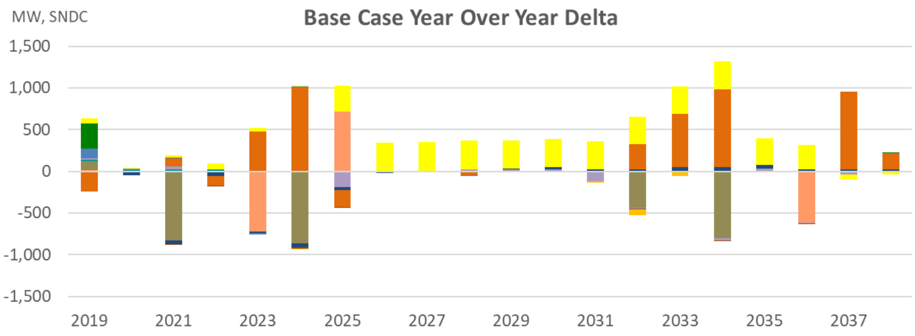
**Economic analysis was not run for sensitivities*

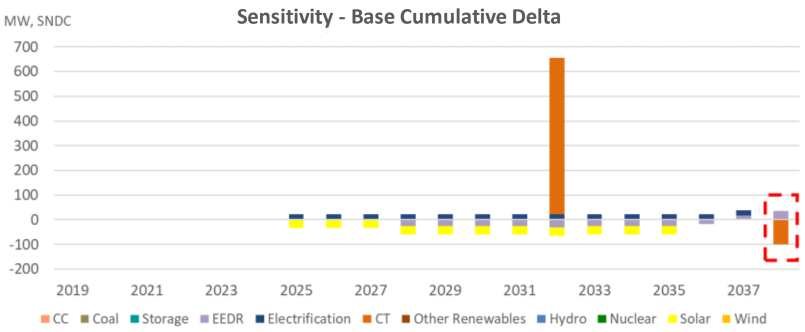
Integration Cost & Flexibility Benefit Case

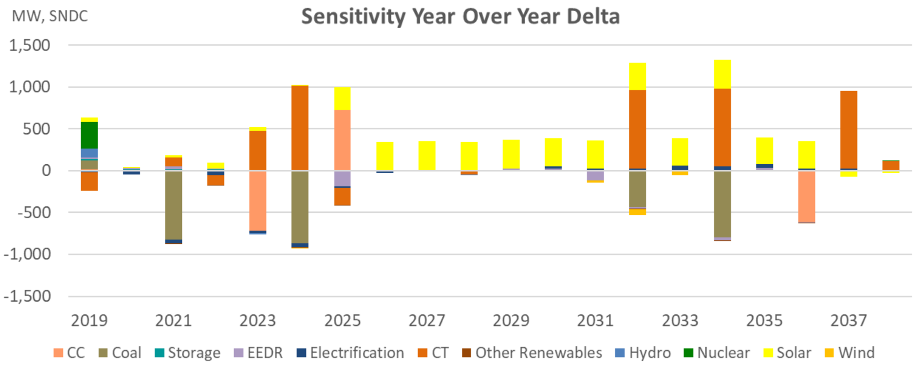
Integration Cost & Flexibility Benefit Case

Objective:	Perform a sensitivity case to evaluate the impact of removing integration costs and flexibility benefits on IRP results.
Approach:	Remove solar & wind integration costs and aeroderivative CT & battery flexibility benefits, then rerun models to derive impact on capacity expansion plan and metric results.

Integration Cost & Flexibility Benefit Case



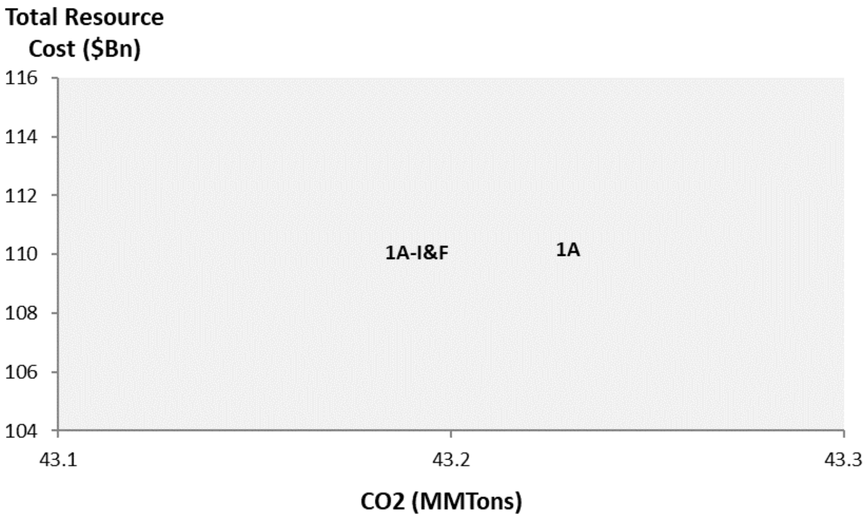


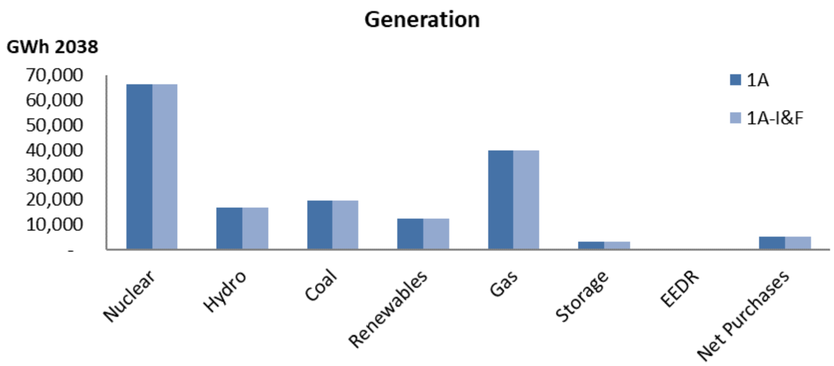


- Minimal impact on the capacity plan overall
- Removing integration costs and flexibility benefits drives timing differences in CT capacity additions but a very similar end result

Integration Cost & Flexibility Benefit Case

As removing integration costs and flexibility benefits has minor impact on capacity expansion plans, impacts on metric results overall from hourly models are also minor. However, it is important to understand integration costs and flexibility benefits in specific asset evaluations.





Integration Cost & Flexibility Benefit Case

Sensitivity Metric Results

	PVRR ($Bn)	System Average Cost Years 1-20 ($/MWh)	Total Resource Cost ($Bn)	Risk/Benefit Ratio	Risk Exposure ($Bn)	CO2 (MMTons)	CO2 Intensity (lbs/MWh)	Water Consumption (MMGallons)	Waste (MMTons)	Land Use (Acres)	Flexible Resource Coverage Ratio	Flexibility Turn Down Factor (2038)	Percent Difference in Per Capita Income*	Percent Difference in Employment*
Integration Cost & Flexibility Benefit Case	110	70	110	1.06	119	43	541	54,037	2,267	43,365	1.97	50%	0.00%	0.00%
Base Case	110	70	110	1.06	119	43	541	54,053	2,269	43,365	1.98	50%	0.00%	0.00%
Delta from Base Case	-0.10	-0.02	-0.10	0.00	-0.11	0	0	-0,016	-2	0	-0.01	0%	0.00%	0.00%

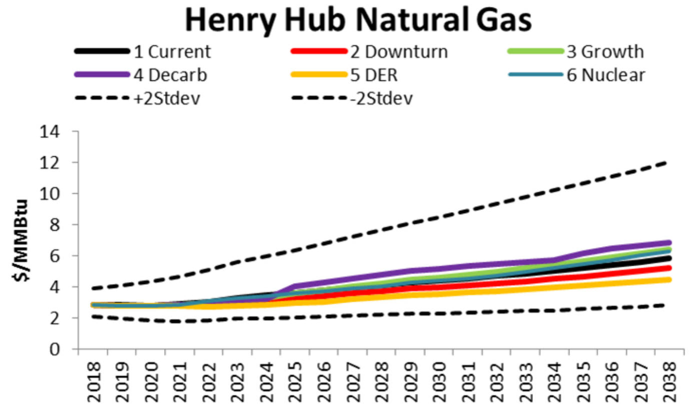
**Economic analysis was not run for sensitivities*

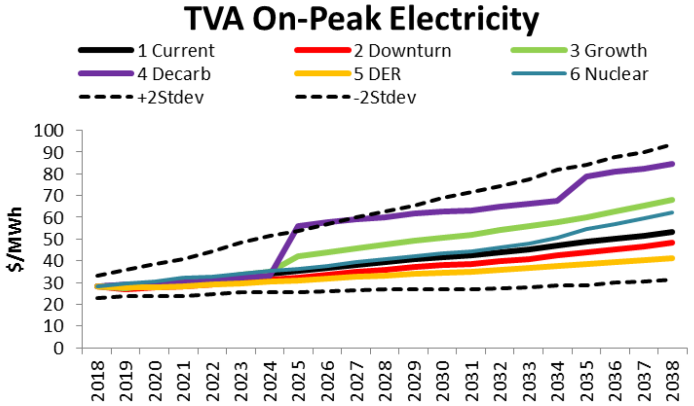
High and Low Gas Prices

High & Low Gas Prices

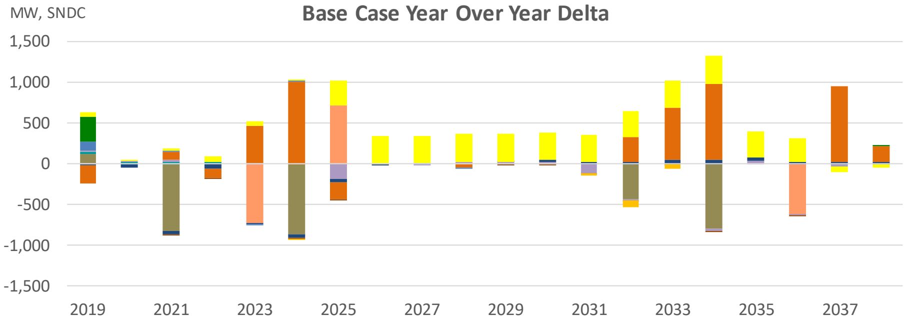
Objective: Perform a sensitivity bounding case to evaluate the potential impact of high and low gas prices.

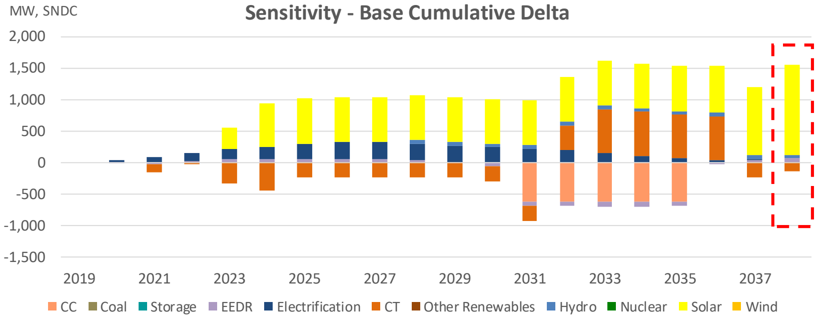
Approach: Assume additional sensitivities in which gas prices are two standard deviations below and two standard deviations above the fundamental forecast, then rerun models to derive impact on capacity expansion plan and metric results.

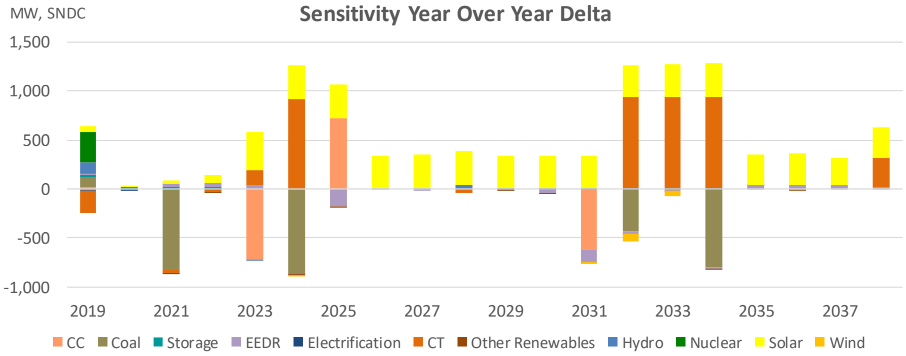




High Gas Prices



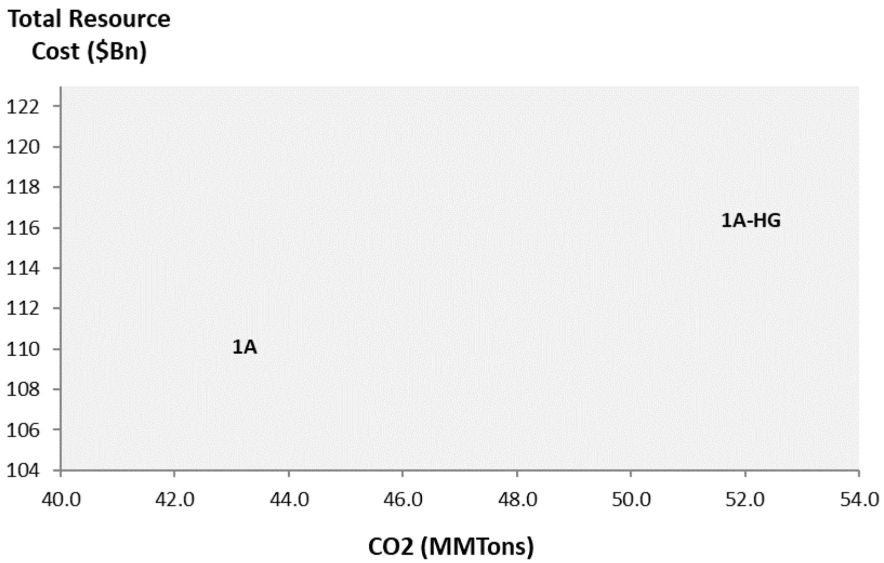


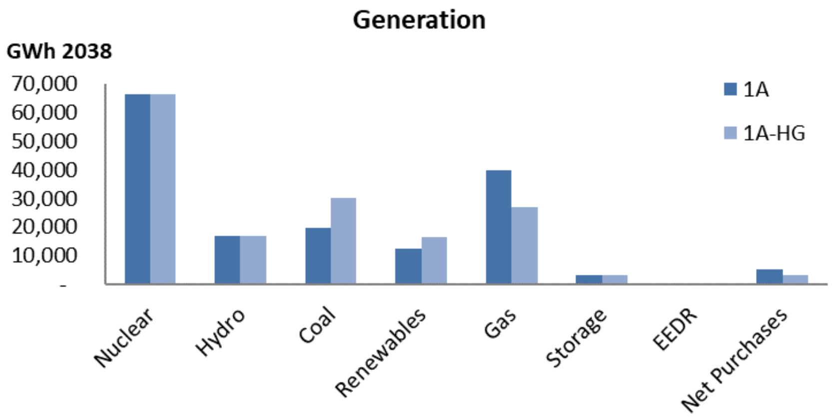


- By 2038, an additional ~2,050 MW nameplate of solar and ~55 MW of new hydro replace a small amount of CT capacity
- Electrification is reduced and CC capacity is swapped for CT capacity earlier in the plan
- Gas is a significant portion of total generation, so the avoided energy cost for alternate resources is higher in this sensitivity

High Gas Prices

High gas prices drive increased renewables capacity and coal generation along with lower gas capacity factors, resulting in higher carbon emissions overall.



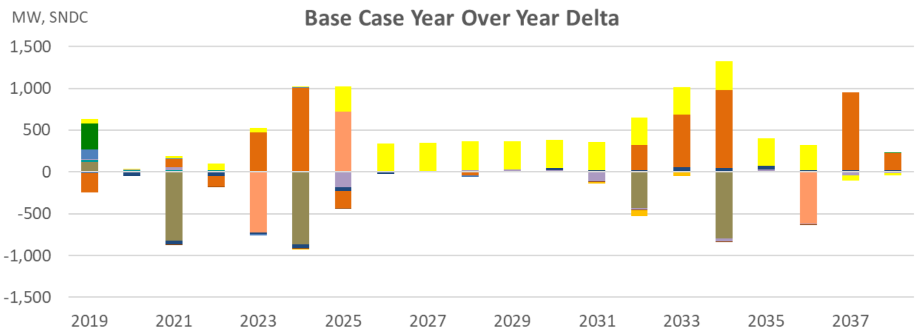


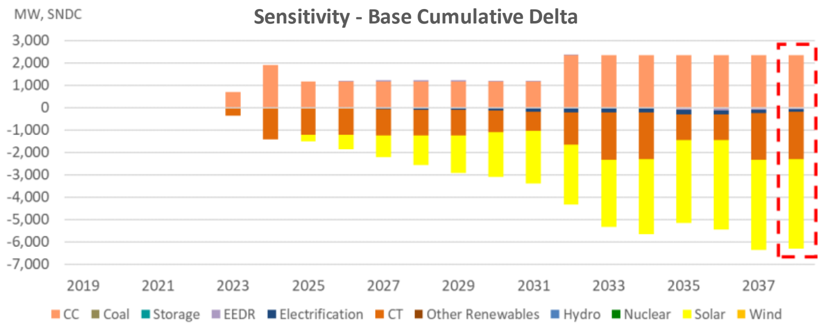
High Gas Prices

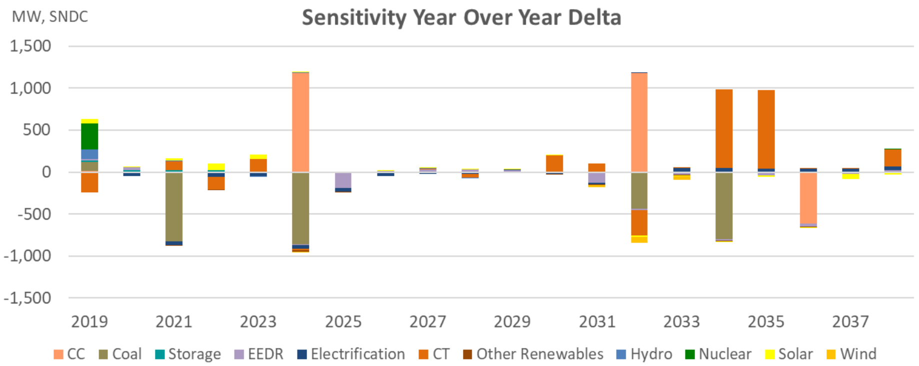
Sensitivity Metric Results

	PVRR ($Bn)	System Average Cost Years 1-20 ($/MWh)	Total Resource Cost ($Bn)	Risk/Benefit Ratio	Risk Exposure ($Bn)	CO2 (MMTons)	CO2 Intensity (lbs/MWh)	Water Consumption (MMGallons)	Waste (MMTons)	Land Use (Acres)	Flexible Resource Coverage Ratio	Flexibility Turn Down Factor (2038)	Percent Difference in Per Capita Income*	Percent Difference in Employment*
High Gas Prices	116	75	116	1.10	128	52	658	56,902	3,296	58,695	1.70	53%	0.00%	0.00%
Base Case	110	70	110	1.06	119	43	541	54,053	2,269	43,365	1.98	50%	0.00%	0.00%
Delta from Base Case	6.27	4.66	6.25	0.03	8.88	9	117	2,849	1,028	15,330	-0.28	3%	0.00%	0.00%

Low Gas Prices



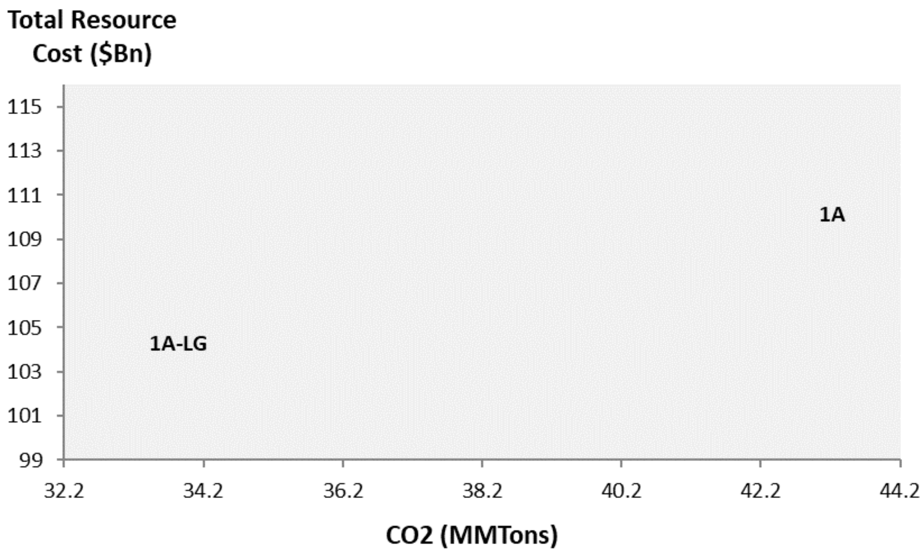


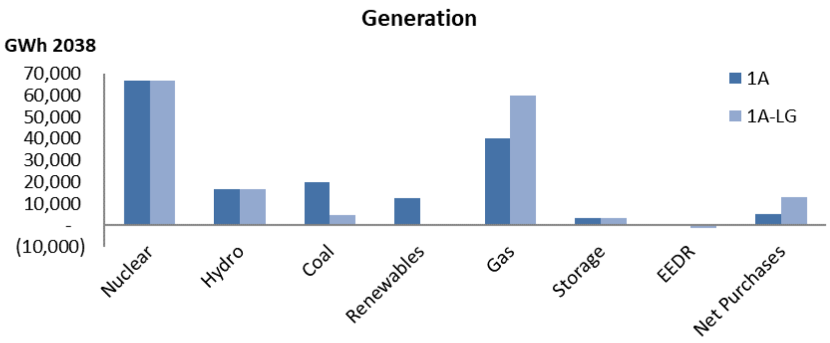


- By 2038, ~5,900 MW nameplate of solar and ~2,000 MW of CT capacity is replaced with CC capacity
- However, this sensitivity does not take into account customer demand for renewables that would likely create a floor for renewable additions

Low Gas Prices

Low gas prices drive lower renewable capacity along with increased gas generation and lower coal capacity factors, resulting in lower carbon emissions overall.





Low Gas Prices

Sensitivity Metric Results

	PVRR ($Bn)	System Average Cost Years 1-20 ($/MWh)	Total Resource Cost ($Bn)	Risk/Benefit Ratio	Risk Exposure ($Bn)	CO2 (MMTons)	CO2 Intensity (lbs/MWh)	Water Consumption (MMGallons)	Waste (MMTons)	Land Use (Acres)	Flexible Resource Coverage Ratio	Flexibility Turn Down Factor (2038)	Percent Difference in Per Capita Income*	Percent Difference in Employment*
Low Gas Prices	104	66	104	1.02	111	34	421	50,314	952	335	2.06	41%	0.00%	0.00%
Base Case	110	70	110	1.06	119	43	541	54,053	2,269	43,365	1.98	50%	0.00%	0.00%
Delta from Base Case	-5.87	-4.00	-5.85	-0.04	-7.72	-9	-120	-3,739	-1,316	-43,030	0.08	-9%	0.00%	0.00%

**Economic analysis was not run for sensitivities*

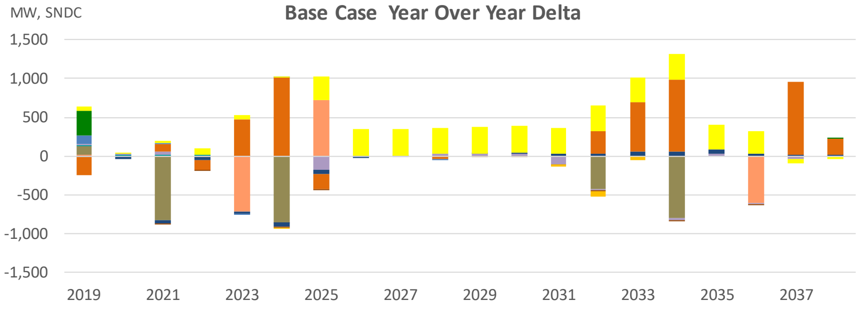
Solar Acceleration and Annual Caps

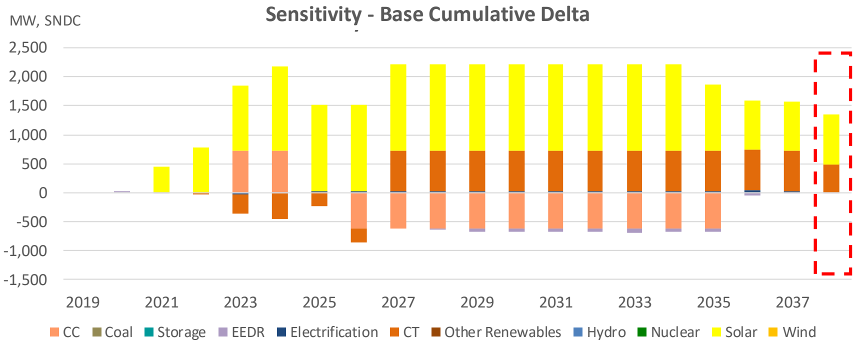
Accelerated Solar

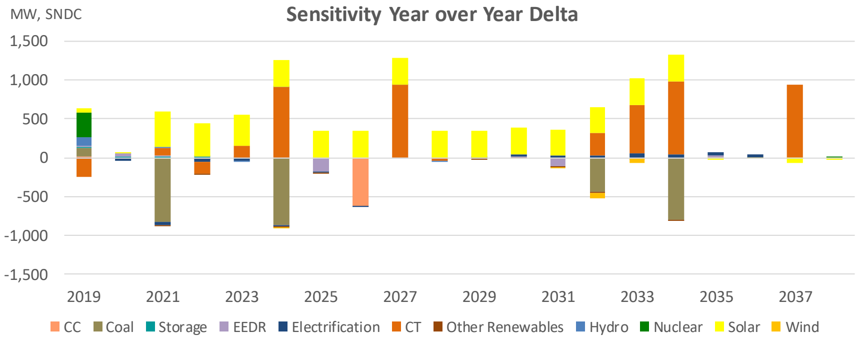
Objective: Perform a sensitivity case to evaluate the impact of accelerating solar builds to align with the potential timing of customer demand for renewables.

Approach: Reflect recent Facebook and Google solar signings of ~700 MW total scheduled to come online by 2021 and assume 500 MW per year accelerated solar additions thereafter until economic solar additions pick up in the mid-2020s, then rerun models to derive impact on capacity expansion plan and metric results

Accelerated Solar



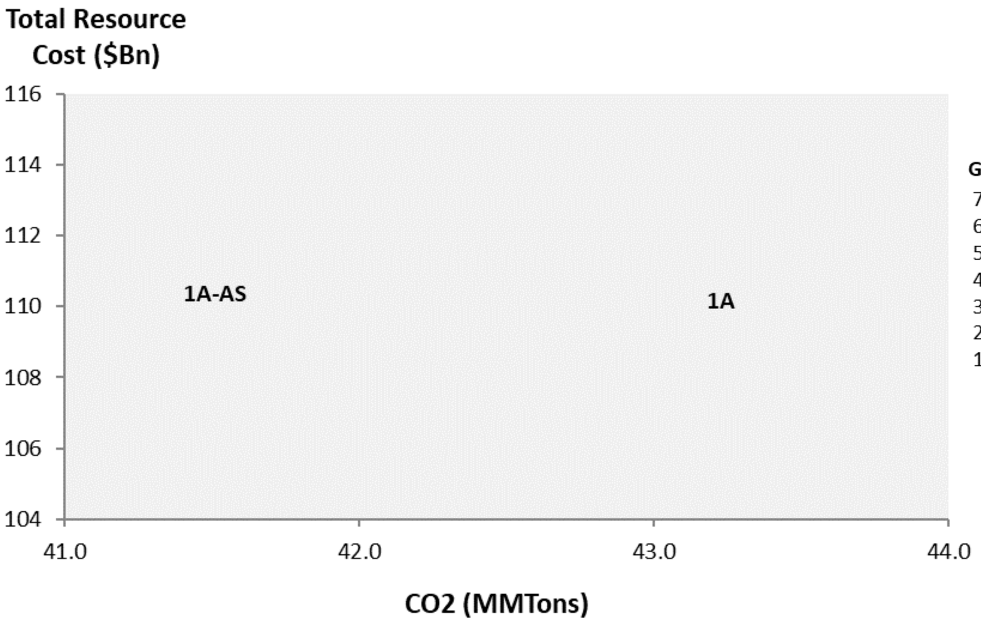


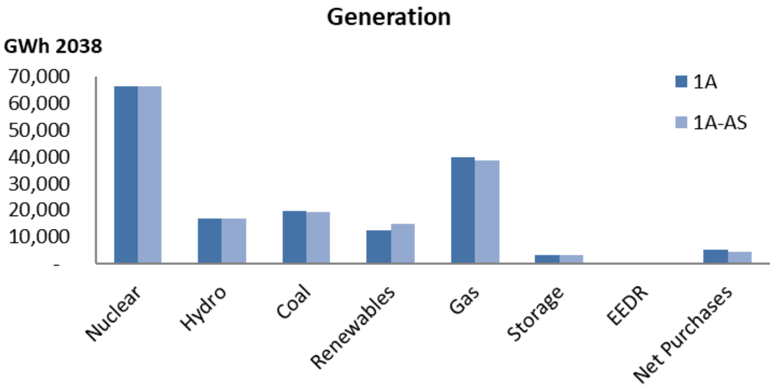


- Accelerating solar additions primarily has the effect of bringing the economic solar additions forward, resulting in an additional ~1,100 MW of solar nameplate by 2038, less than the total accelerated amounts
- Total nameplate MW of solar is below 10,000 MW in the both cases

Accelerated Solar

Given the overall impact on solar additions, renewable generation slightly displaces gas generation and leads to a reduction in carbon emissions.





Accelerated Solar

Sensitivity Metric Results

	PVRR ($Bn)	System Average Cost Years 1-20 ($/MWh)	Total Resource Cost ($Bn)	Risk/Benefit Ratio	Risk Exposure ($Bn)	CO2 (MMTons)	CO2 Intensity (lbs/MWh)	Water Consumption (MMGallons)	Waste (MMTons)	Land Use (Acres)	Flexible Resource Coverage Ratio	Flexibility Turn Down Factor (2038)	Percent Difference in Per Capita Income*	Percent Difference in Employment*
Accelerated Solar	110	70	110	1.04	119	42	520	53,408	2,191	52,564	1.88	51%	0.00%	0.00%
Base Case	110	70	110	1.06	119	43	541	54,053	2,269	43,365	1.98	50%	0.00%	0.00%
Delta from Base Case	0.22	0.19	0.22	-0.03	-0.04	-2	-21	-645	-78	9,199	-0.10	2%	0.00%	0.00%

**Economic analysis was not run for sensitivities*

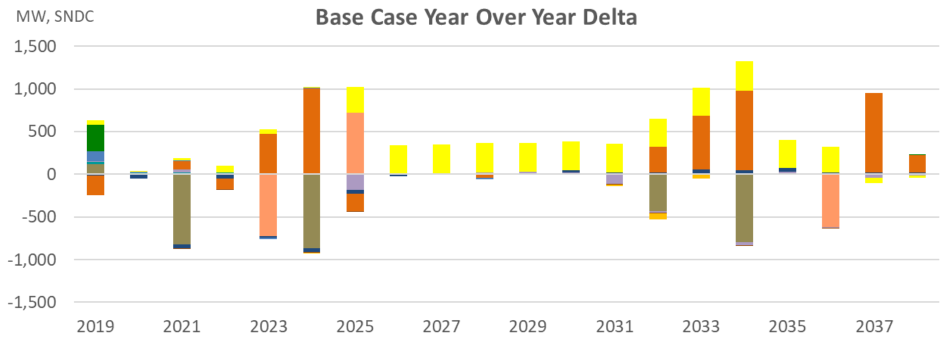
Double Annual Solar Cap

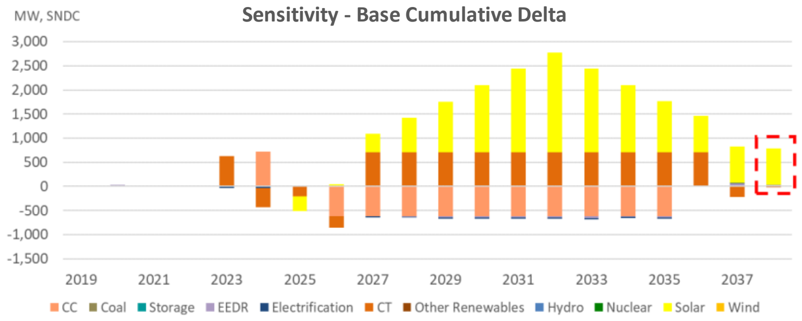
Objective: Perform a sensitivity case to evaluate the potential impact of increasing the annual cap on solar additions.

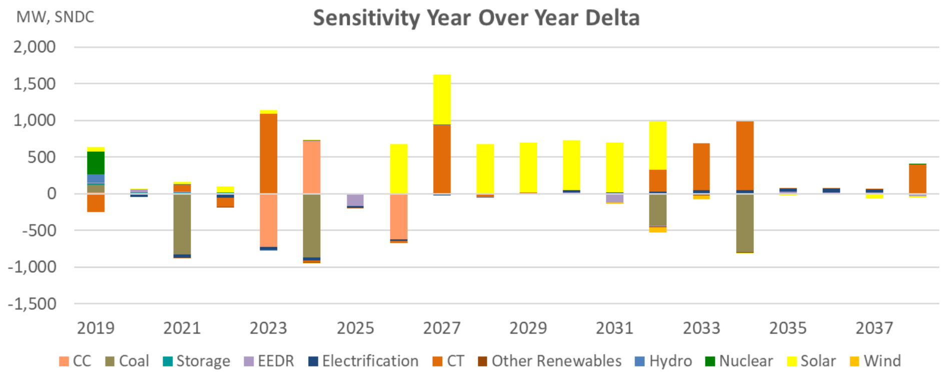
Approach: Double the annual solar cap to 1,000 MW and remove the cumulative cap on solar additions, then rerun models to derive impact on capacity expansion plan and metric results

Note: There are limitations on the timing of other resource additions, such as how many new gas builds can be planned for a given year, to reflect the practicality of when we have knowledge of the need and other project management considerations.

Double Annual Solar Cap



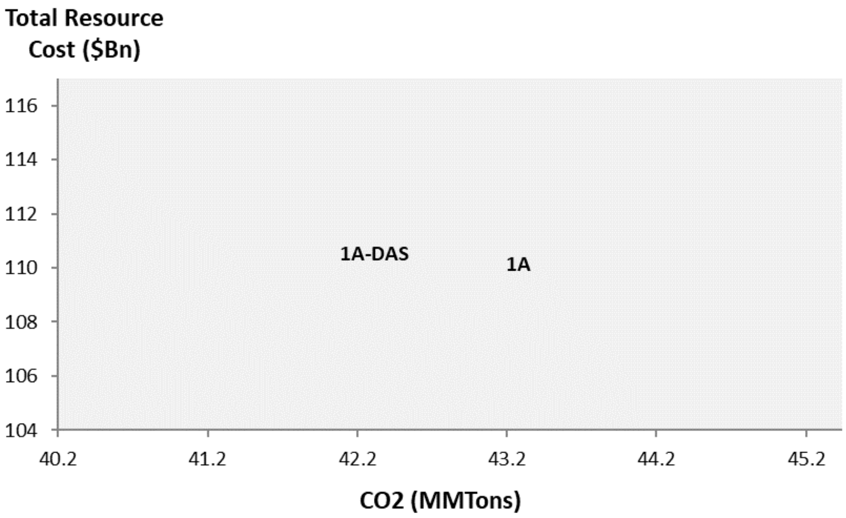


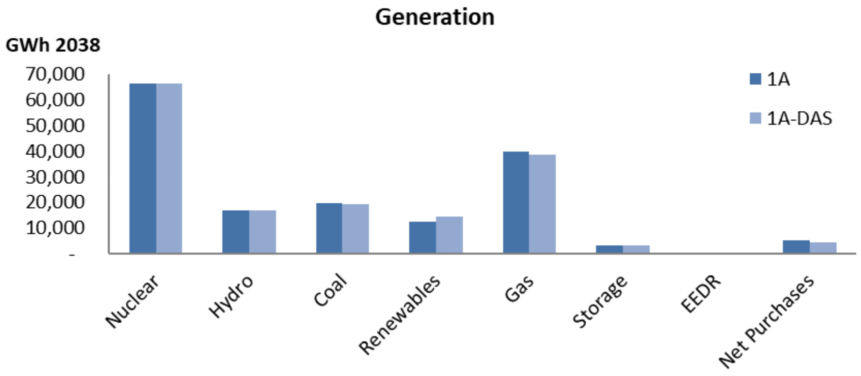


- In this case, solar capacity is accelerated due to favorable pricing in the mid to late 2020s
- By 2038, ~1,100 MW nameplate of additional solar capacity is added

Double Annual Solar Cap

Doubling the annual solar cap results in similar costs and lower carbon emissions, as renewable generation slightly displaces gas generation.





Double Annual Solar Cap

Sensitivity Metric Results

	PVRR ($Bn)	System Average Cost Years 1-20 ($/MWh)	Total Resource Cost ($Bn)	Risk/Benefit Ratio	Risk Exposure ($Bn)	CO2 (MMTons)	CO2 Intensity (lbs/MWh)	Water Consumption (MMGallons)	Waste (MMTons)	Land Use (Acres)	Flexible Resource Coverage Ratio	Flexibility Turn Down Factor (2038)	Percent Difference in Per Capita Income*	Percent Difference in Employment*
Double Annual Solar Cap	110	70	111	1.05	119	42	528	53,703	2,228	51,395	1.83	51%	0.00%	0.00%
Base Case	110	70	110	1.06	119	43	541	54,053	2,269	43,365	1.98	50%	0.00%	0.00%
Delta from Base Case	0.37	0.20	0.38	-0.01	0.25	-1	-12	-350	-41	8,030	-0.14	1%	0.00%	0.00%

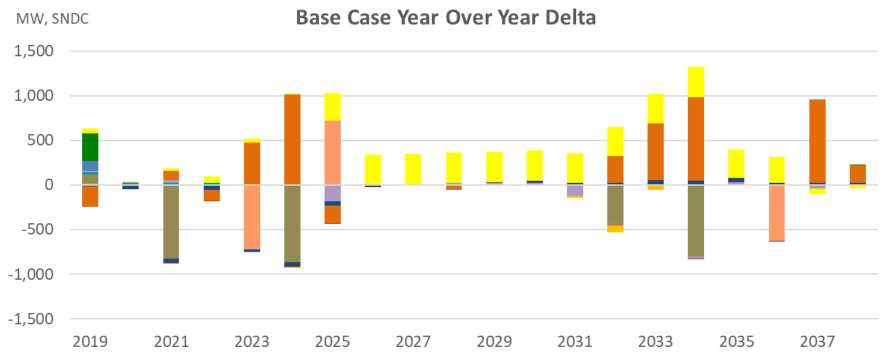
**Economic analysis was not run for sensitivities*

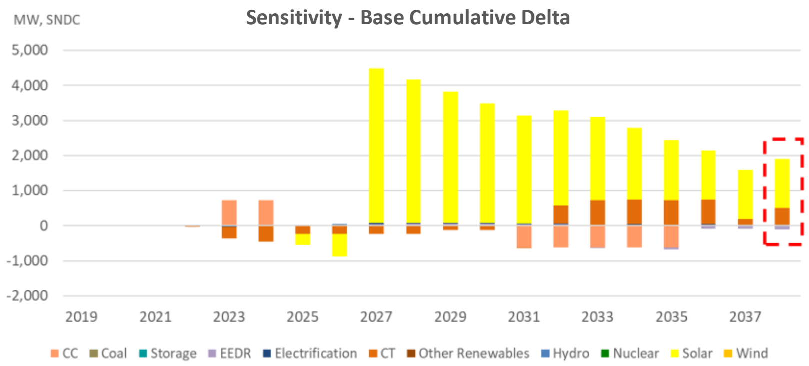
No Annual Solar Cap

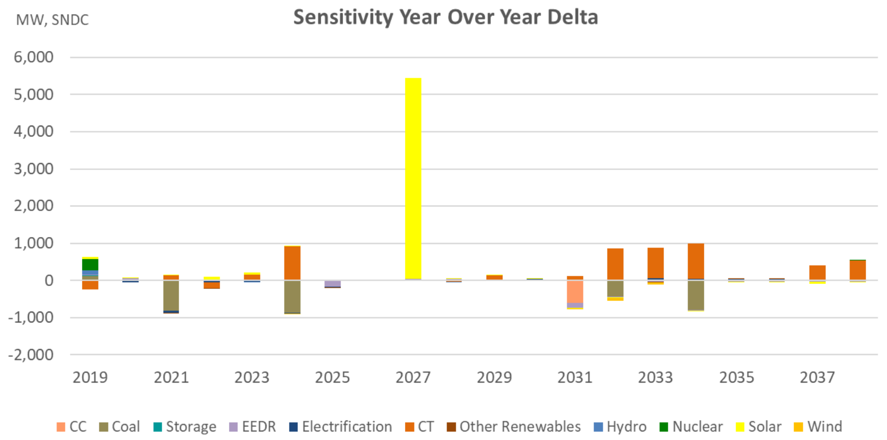
Objective: Perform a sensitivity case to evaluate the potential impact of removing annual solar limits.

Approach: Remove the annual and cumulative cap on solar additions, then rerun models to derive impact on capacity expansion plan and metric results.

No Annual Solar Cap



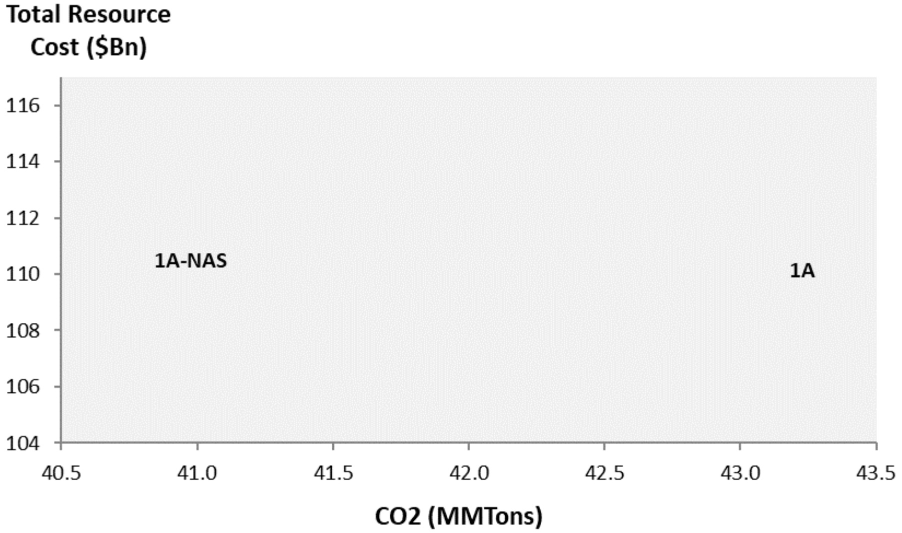


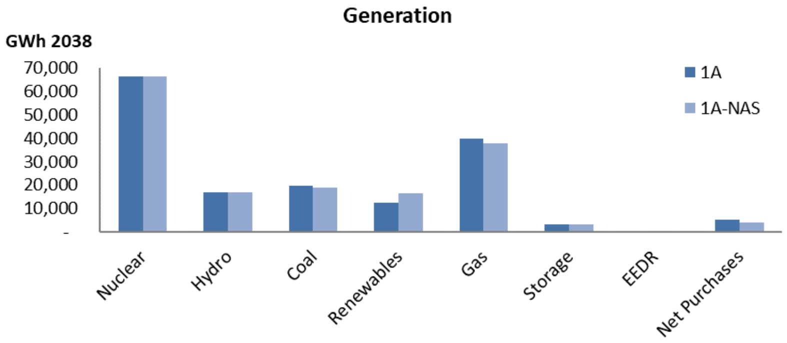


- By 2038, ~2,000 MW nameplate of additional solar capacity is added
- In practicality, it is unrealistic to have perfect foresight of the “optimal year” and to manage additions of this magnitude in a single year

No Annual Solar Cap

No annual solar cap results in additional solar capacity that further displaces some fossil generation and results in lower carbon emissions.





No Annual Solar Cap

Sensitivity Metric Results

	PVRR ($Bn)	System Average Cost Years 1-20 ($/MWh)	Total Resource Cost ($Bn)	Risk/Benefit Ratio	Risk Exposure ($Bn)	CO2 (MMTons)	CO2 Intensity (lbs/MWh)	Water Consumption (MMGallons)	Waste (MMTons)	Land Use (Acres)	Flexible Resource Coverage Ratio	Flexibility Turn Down Factor (2038)	Percent Difference in Per Capita Income*	Percent Difference in Employment*
No Annual Solar Cap	110	70	111	1.03	119	41	513	53,237	2,181	245,696	1.77	52%	0.00%	0.00%
Base Case	110	70	110	1.06	119	43	541	54,053	2,269	43,365	1.98	50%	0.00%	0.00%
Delta from Base Case	0.32	0.25	0.33	-0.03	-0.01	-2	-28	-816	-88	202,331	-0.21	3%	0.00%	0.00%

**Economic analysis was not run for sensitivities*

Breakeven Analysis: Wind, Storage, CHP & SMR

Breakeven Analysis

Objective: Perform a breakeven analysis for resources that were promoted but not selected based on economics. These resources include:

- Wind
- Battery Storage
- Combined Heat & Power
- Small Modular Reactors

Approach: Force each resource into the expansion plan at zero cost in the first year available to determine PVRR impacts from displaced energy and capacity, then derive the levelized breakeven cost or value of that resource.

Breakeven Analysis

Resource	COD Year	Length	MW/y	Levelized Breakeven	IRP Assumption
Wind	2023	20	200	$27/MWh	$83/MWh
Utility Battery	2023	20	200	$62/MWh	$241/MWh
CHP	2023	20	200	$43/MWh	$83/MWh
SMR	2028	40	600	$50/MWh	$125/MWh

- TVA IRP wind assumptions reflect PTC expiration and no decreasing technology curve, resulting in costs that are triple the breakeven; TVA will continue to monitor wind costs for changing economics
- Battery storage is a higher value resource, but costs are still triple the breakeven value; TVA will continue to monitor rapidly evolving battery storage costs for improving economics
- CHP is about double the breakeven; CHP also provides steam for space heating, driving additional value for the end use customer
- SMR investment is capital intensive and more than double the breakeven value; refinements in design improve costs, but cost and risk sharing are essential to close the gap

Thank you and Safe Travels!!