Note: This slide deck does not include confidential information covered under the IRP Working Group Confidentiality Agreement.

TVA

2019 IRP Working Group

Meeting 5: July 23-24, 2018


welcome

Safety Moment

Building Emergency Plan

Introductions

- Name
- Organization and Role

Agenda – July 23

11:00	Lunch (in Hotel Atrium)	
11:30	Welcome & Overview	Jo Anne Lavender
11:40	Recap of Meeting 4	Brian Child
11:50	IRPWG Confidentiality Agreement Review	Khurshid Mehta
11:55	2019 IRP: Strategy Voting Results	Hunter Hydas
12:50	BREAK	
1:05	Scenario Design	Tim Sorrell & Team
3:05	BREAK	
3:20	Scenario Design: Group Breakout	Jo Anne Lavender
4:00	Group Report Out	
5:00	Adjourn	

Agenda – July 24

7:00	Breakfast	
8:00	Welcome & Overview	Jo Anne Lavender
8:15	Discussion & Reponses – Scenario	Hunter Hydas & Tim Sorrell
8:45	BREAK	
9:00	IRP Model Framework & Discussion	Jane Elliott & Team
10:30	BREAK	
10:45	Current Resource Portfolio	Jane Elliott & Team
11:30	LUNCH	
12:30	Intro to Resource Options	Jane Elliott & Team
1:30	Group Discussion	
1:45	Closing Comments & Next Steps	Hunter Hydas & Jo Anne Lavender
2:30	Adjourn	

Purpose of the 2019 IRP Working Group (IRPWG)

- A key engagement mechanism for TVA and diverse stakeholders
- Provide in-depth ongoing discussion and feedback on the IRP process, approach and assumptions
- Validate the assumptions behind the analysis and the recommendations
- Real time stakeholder input results in greater efficiency
- Distributed Energy Resources will play a more prominent role in future planning.

IRPWG Meeting Protocols

Agenda

- TVA will prepare each meeting agenda and logistics
- Meeting materials will be sent to IRPWG members ahead of the meeting date using an external file sharing site

Meeting Notes and Actions

- TVA will maintain meeting notes and running action items and responses

Ground Rules

- One person speak at a time; be respectful of others; refrain from interrupting while someone is speaking
- Be succinct so that everyone has the opportunity to speak.
- Try to offer alternatives that accommodate your interests and the interests of others.
- Members reserve the right to disagree with any position
- ELMO (Enough Let’s Move On)

IRPWG Meeting Protocols

Meeting Frequency

- Meeting locations will likely rotate, with sites chosen in consultation with the IRPWG
- The IRPWG is expected to meet most months for 1-2 days.
- Identify an alternate who is informed and can attend in the event you are not available. If a member/alternate fails to attend three meetings in a row, TVA may seek a replacement

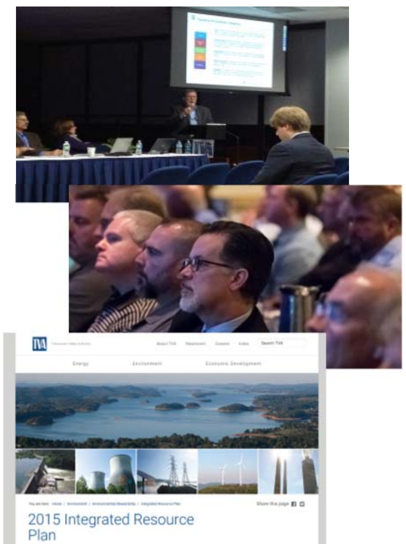
Confidential Information

- Non-disclosure agreements may be needed to facilitate TVA sharing confidential information.

Public Involvement

- While meetings and working sessions of the IRPWG will not be open to the general public, there are multiple ways TVA will be engaging other interested stakeholders and the general public.

Stakeholder & Public Involvement Opportunities



Forums for Public Input
➢ Public Scoping Meetings
➢ IRP Working Group (and other stakeholder groups)
➢ Quarterly Public Briefings / Webinars
➢ Draft IRP Public Comment Period
➢ External Web Page

Early 2018 ← *Input will be incorporated throughout the process* → *Summer 2019*

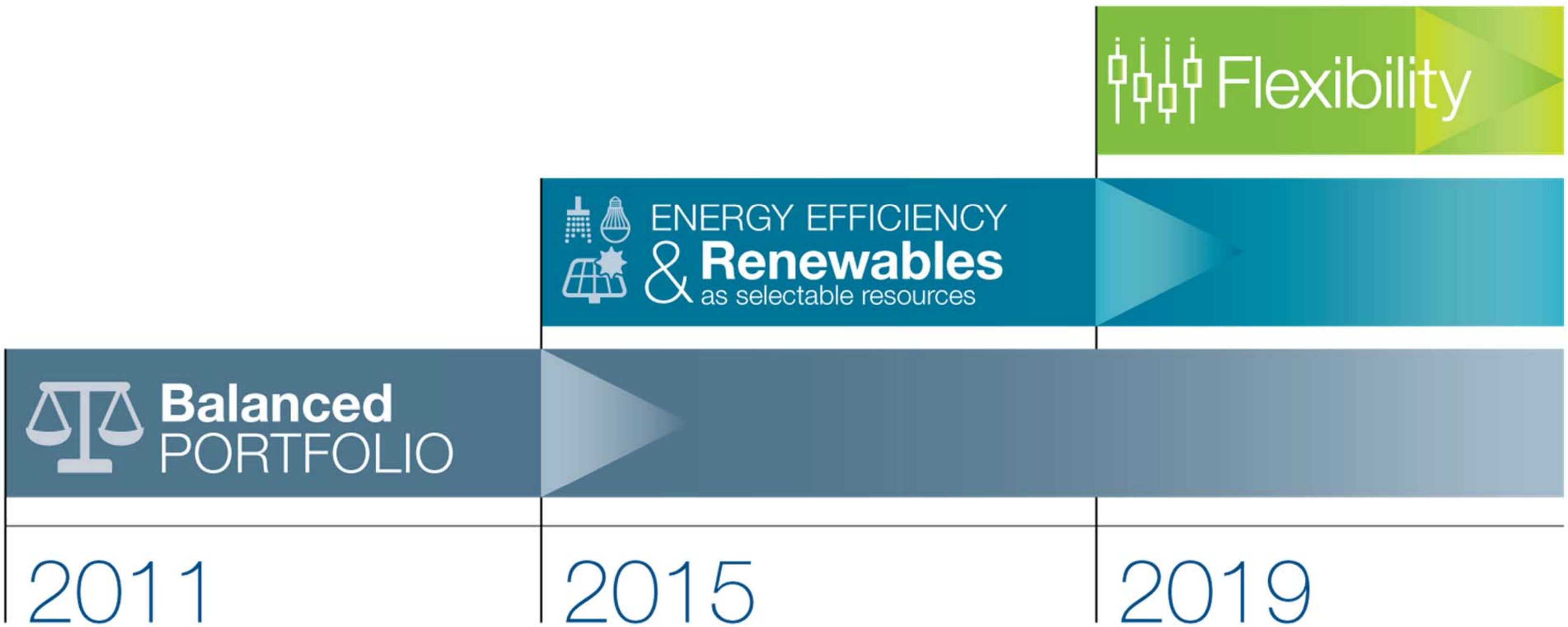
Recap of Meeting 4

Brian Child

June Meeting Highlights

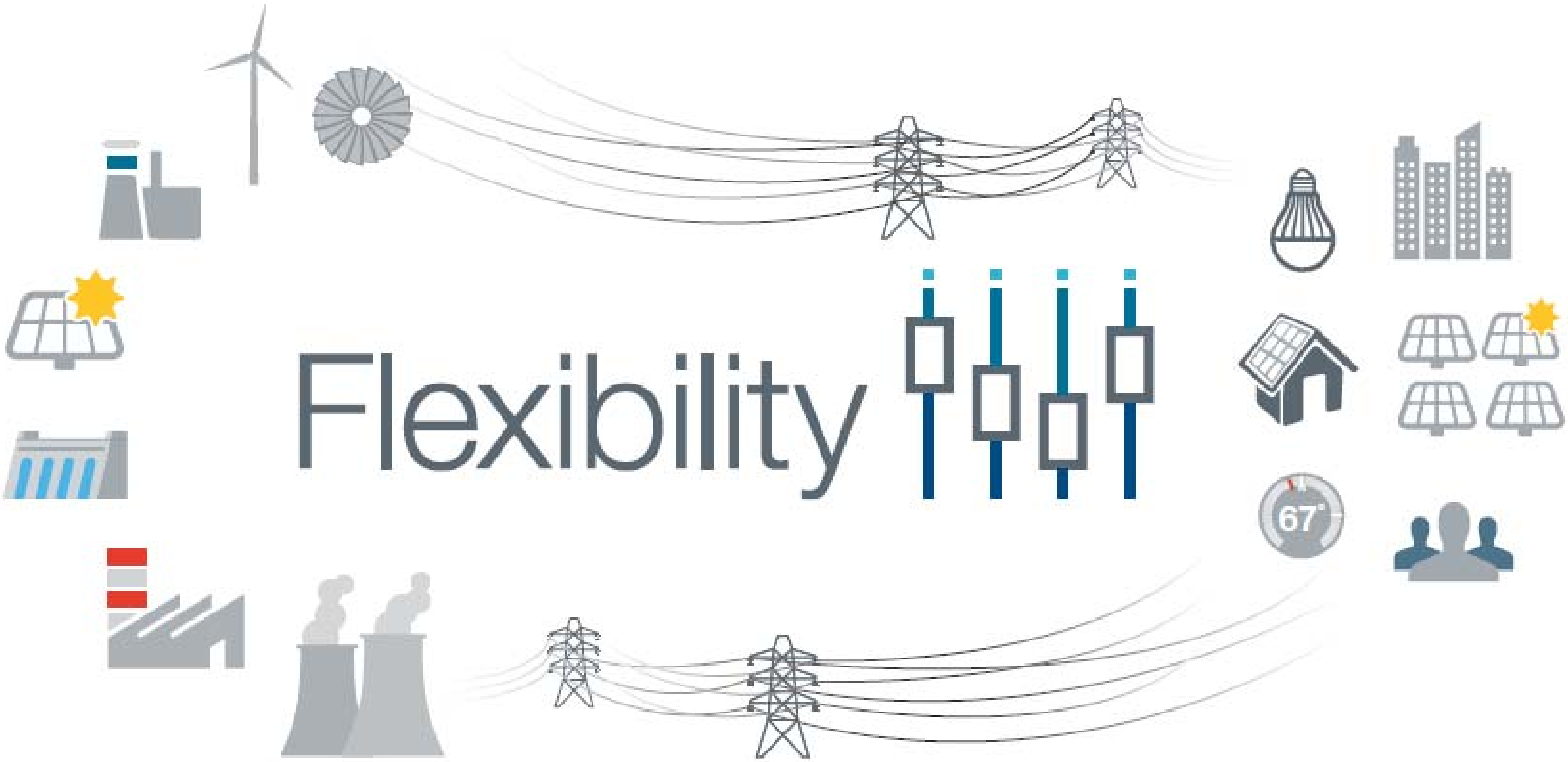
- Introduction to Resource Planning
- Resource Panels (Utility Scale & Distributed Resources)
- Scenario Recap and Voting Results
- Peer Utility Benchmarking on Attributes & Strategies
- Group Discussion and Final List of Strategies for Voting
- Introduction to Resource Technologies

INTEGRATED **Resource Plan** 2019



2019 IRP Focus Areas

- Distributed Energy Resources
- System flexibility
- 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)
- Initial modeling (June 2018)
- Publish draft EIS and IRP (Feb 2019)
- Complete public meetings (April 2019)
- Board approval and final publication of EIS and IRP (expected Summer 2019)

IRP Working Group Meeting Objectives

June 6th-7th	July 23rd-24th	August 29th-30th	September 26th-27th
• Finalize scenarios • Review attributes and brainstorm/review strategies • Discuss proposed strategies and develop short list • Introduce resource options	• Finalize strategies • Scenario design preview • Resource options (draft) • Modeling framework	• Scenario design (final) • Strategy design preview • Resource options (final) after 3rd party review • Scorecard development	• Strategy design (final) • Scorecard design • EIS outline

Vote on scenarios

Vote on strategies

Other TVA Updates

Brian Child

2019 President's Budget Proposal

Divesting Federal Transmission Assets

Department of Energy and Tennessee Valley Authority

The Administration proposes to sell the transmission assets owned and operated by the Tennessee Valley Authority (TVA) and the Power Marketing Administrations (PMAs) within the Department of Energy, including those of Southwestern Power Administration, Western Area Power Administration, and Bonneville Power Administration.

The Administration believes that eliminating the Federal Government's role in owning and operating transmission assets encourages a more efficient allocation of economic resources and mitigates unnecessary risk to taxpayers.

Timeline of Privatization Proposals

Reagan / Bush Budget Proposal

President's Budget Proposal regarding sale of PMAs and termination of certain TVA non-power programs, such as economic development

(No Congressional vote)

Clinton Administration

Interagency review regarding the transfer of TVA transmission system assets to ISO

(No action taken)

Obama Budget Proposal

President's Budget Proposal regarding the possible divestiture of TVA (in whole or in part)

(No action taken beyond strategic review)

1986 1990 1994 1998 2002 2006 2010 2014 2018

Legislative Proposals

Legislation introduced by Scott Klug (R-WI) directing the sale of all TVA assets

(Rejected by Congressional vote 248 to 144)

Legislation introduced by Bob Franks (R-NJ) privatizing the PMAs and certain facilities of TVA

(Never advanced out of committee)

Bush Administration

OMB Passback – Transmission Asset Sale Review

(Not included in President's Budget)

Trump Budget Proposal

President's Budget Proposal regarding the sale of TVA and PMA transmission assets

(No action to date)

2019 IRP Scoping Report

- TVA will post the Public Scoping Report to the IRP website in early August, 2018.
- The Appendix will include a copy of all public and agency comments received during scoping period.

Scoping Report Table of Contents

- Background
- Purpose and Need
- Proposed Alternatives (Resource Planning Scenarios and Strategies)
- Environmental Review Process
- Public Outreach during Scoping Period
- Summary of Public Scoping Feedback
- Applicable Federal Laws and Executive Orders
- Relevant Environmental Documents and Reviews
- Potential Mitigation Measures

Major IRP Scoping Themes

- Encouragement of clean energy initiatives, renewable energy, R&D on DERs
- Call for special attention to environmental justice/ affected environment analyses on impacts to limited income households
- General interest in energy efficiency measures and energy storage alternatives
- General input on modeling, metrics/ calculations and evaluation criteria
- General comments on fuel diversification options

RERC Meeting, June 14, 2018

Meeting Topics included the 2019 IRP and EIS, IRP Focus Areas and Public Engagement in the IRP

Advice Received from the RERC:

- The TVA Regional Energy Resource Council (RERC) has reviewed the focus areas defined for the 2019 Integrated Resource Plan (IRP): Distributed Energy Resources; System Flexibility; Portfolio Diversity; and agrees with the focus areas that TVA has identified. However, the RERC recommends that TVA incorporate other features such as grid stability and low income energy efficiency in the overall analysis.
- The RERC recognizes that it is difficult to engage the general public in the IRP without the assistance of the Local Power Companies (LPCs) and recommends that TVA directly involve the LPCs to interact with and gain input from the public.

Non Disclosure Agreement Overview

Khurshid Mehta
Office of the General Counsel

2019 IRP: Strategy Voting Results

Hunter Hydas

TVA is Considering 7 Strategies*

Emissions

- Meet an Emission Target

Market Reliance

- No TVA builds

Renewables/DER

- Promote DER
- Promote Renewables
- Promote Resiliency

Flexibility

- Promote Efficient Energy Usage
- Add Small, Agile Capacity

* In addition to the Reference Plan

Initial Strategy Ranking Results

IRPWG Sum of Occurrences by Rank Order

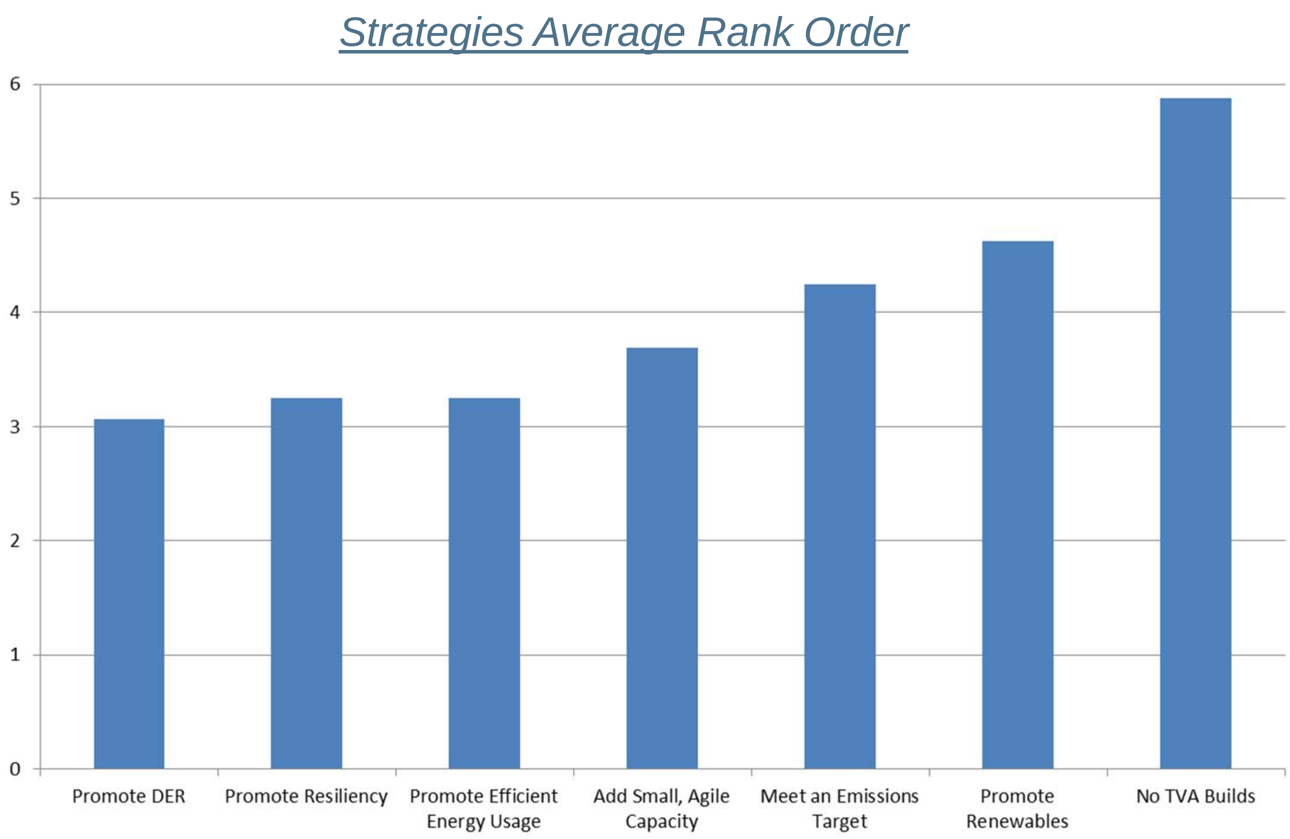
	Meet an Emissions Target	No TVA Builds	Promote DER	Promote Renewables	Promote Resiliency	Promote Efficient Energy Usage	Add Small, Agile Capacity
1	0	0	4	2	6	3	1
2	2	1	2	1	2	1	7
3	4	1	3	1	1	4	2
4	4	0	3	2	1	6	0
5	2	2	4	3	3	1	1
6	2	5	0	5	1	1	2
7	2	7	0	2	2	0	3

TVA Sum of Occurrences by Rank Order

	Meet an Emissions Target	No TVA Builds	Promote DER	Promote Renewables	Promote Resiliency	Promote Efficient Energy Usage	Add Small, Agile Capacity
1	1	1	4	0	5	1	1
2	0	1	3	2	2	1	4
3	1	3	0	3	2	2	2
4	2	0	5	3	1	0	2
5	1	1	0	5	2	2	2
6	5	3	1	0	1	2	1
7	3	4	0	0	0	5	1

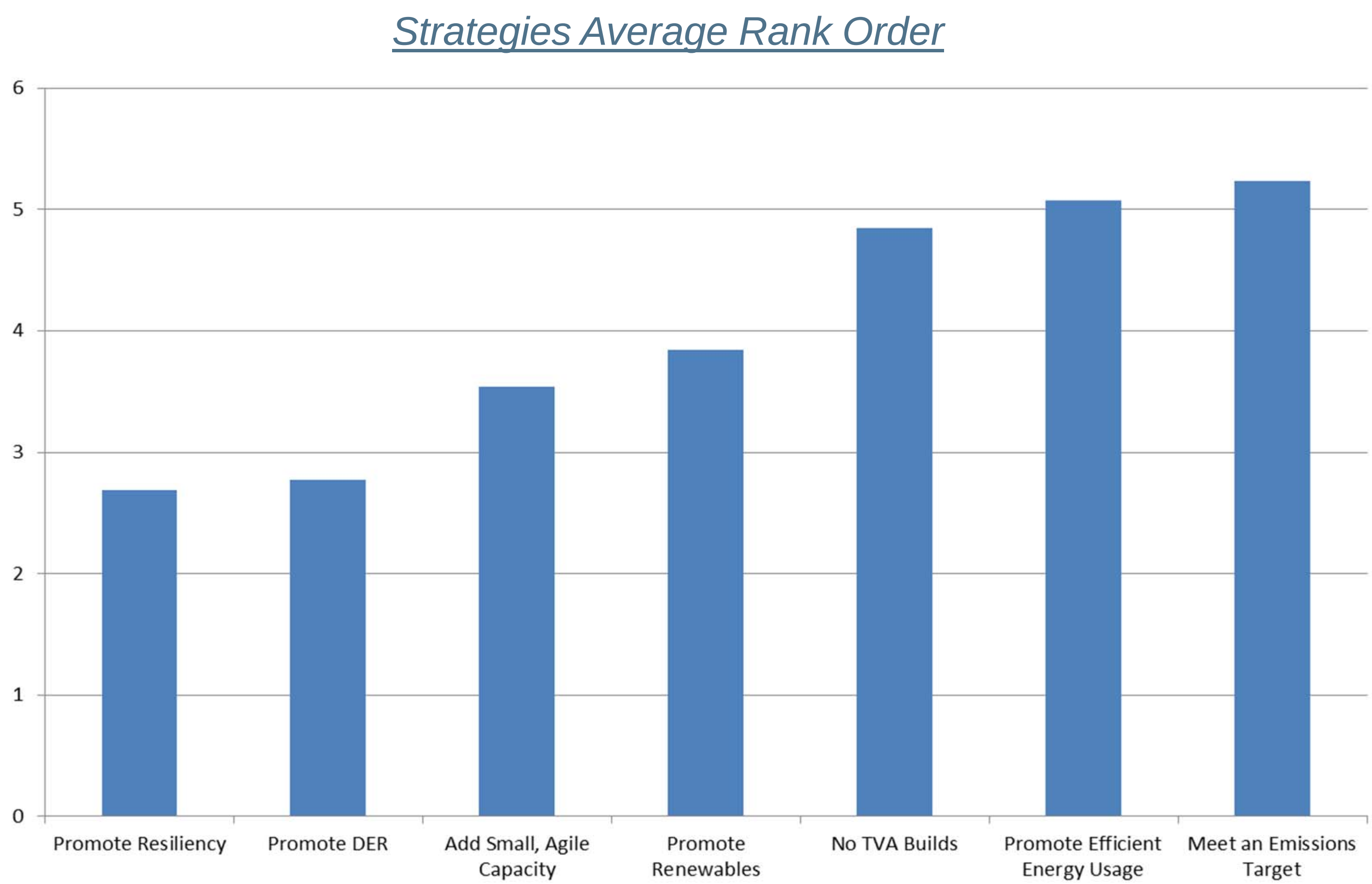
- IRPWG and TVA ranked strategies 1 to 7 with 1 being the preferred choice.
- The heat maps report the number of occurrences of each rank for each of the strategies.

Initial Ranking Results by IRPWG



- The Average Rank Order is calculated as the sum of the ranking values (between 1 and 7) received by a particular strategy divided by the number of people performing the ranking (13 in the case of TVA and 16 in the case of the IRPWG)
- Since strategies are ranked with values between 1 and 7, the lower the Average Rank Order reflects a higher preference for a particular scenario

Initial Ranking Results by TVA



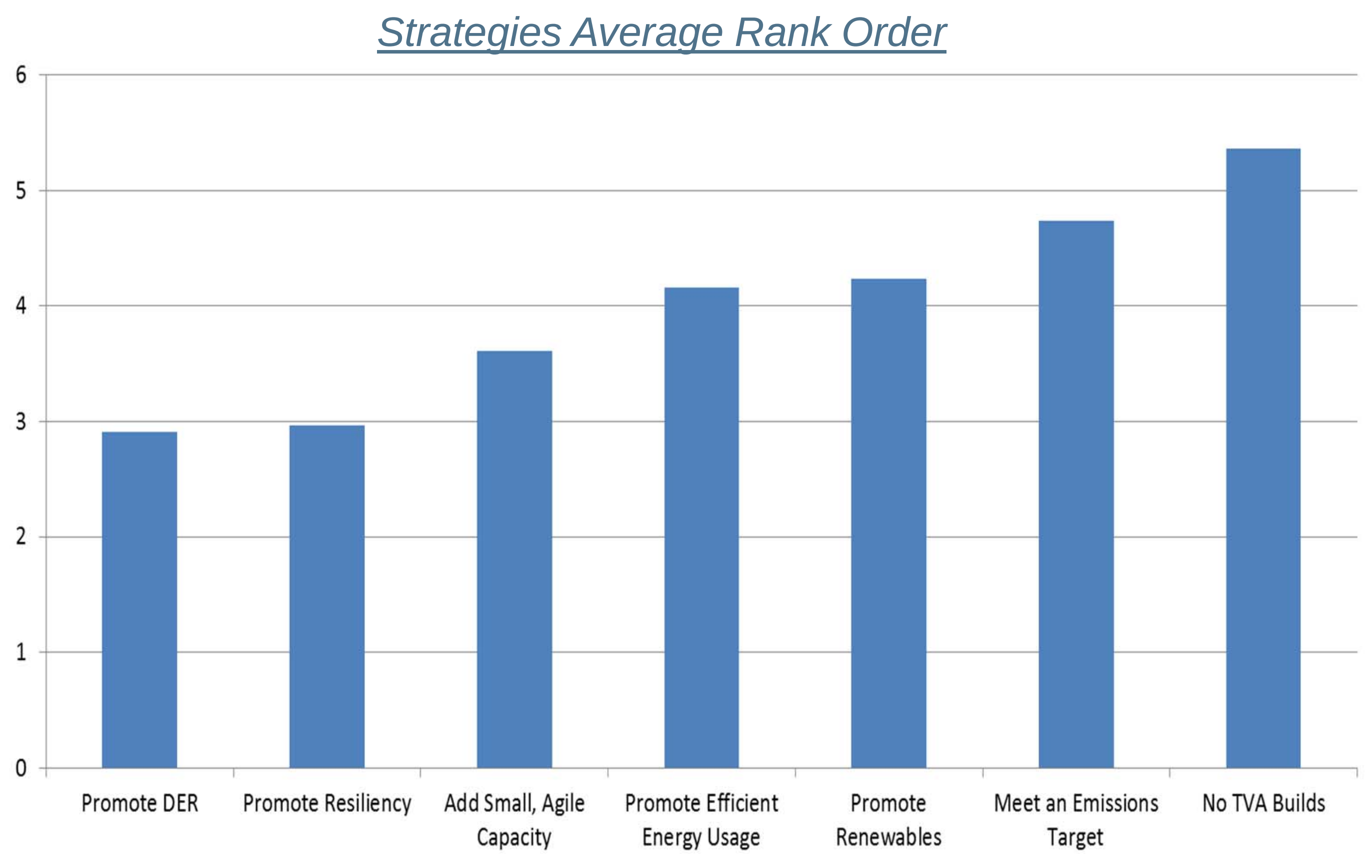
Comparison of Rankings

IRPWG	TVA
1) *Promote DER*	1) *Promote Resiliency*
2) *Promote Resiliency*	2) *Promote DER*
3) *Promote Efficient Energy Usage*	3) *Add Small, Agile Capacity*
4) *Add Small, Agile Capacity*	4) *Promote Renewables*
5) *Meet an Emissions Target*	5) *No TVA Builds*
6) *Promote Renewables*	6) *Promote Efficient Energy Usage*
7) *No TVA Builds*	7) *Meet an Emissions Target*

- *Promote DER* and *Promote Resiliency* are the top two choices in both rankings
- *Promote Efficient Energy Usage* is the largest mover between the two rankings (#3 vs. #6)

Initial Composite Ranking Results

- The Average Weighted score is based on a 50/50 weighting between IRPWG and TVA
- Strong preference shown for Promote DER and Promote Resiliency as the top two



Strategy Combinations for Consideration

Composite Ranking

1) *Promote DER*
2) *Promote Resiliency* (Incorporate *Add Small, Agile Capacity*)
3) ~~*Add Small, Agile Capacity*~~
4) *Promote Efficient Energy Usage*
5) *Promote Renewables*
6) ~~*Meet an Emissions Target*~~
7) ~~*No TVA Builds*~~

Promote DER

- DER is incented to achieve high-end of long-term penetration levels.
- New coal is excluded. All other technologies are available while EE, DR, distributed generation and storage are promoted.

Promote Resiliency

- Add small, agile capacity to maximize flexibility and promote resiliency to be able to respond to short-term disruptions on the power system.
- All technologies are available while nuclear additions (SMRs), gas additions (aero derivatives, RICE), DR, storage and distributed generation are promoted. Combinations of storage and distributed generation could be installed as microgrids.
- Flexible loads and DERs are aggregated to provide synthetic reserves to the grid to promote resiliency.

Promote Efficient Energy Usage

- Incent targeted electrification, demand and energy management to minimize peaks and troughs across a daily load shape and promote efficient energy usage.
- All technologies are available but those that minimize load swings are promoted (e.g., EE, DR, storage, distributed generation).
- Programs targeting low-income customers will be a part of EE promotion.

Promote Renewables

- Commitment to renewables at all scales to meet growing prospective or existing customer demands for renewable energy.
- New coal is excluded. All other technologies are available while renewables are promoted.

Recommended IRP Strategies

Composite Ranking

1) *Reference Plan*

2) *Promote DER*

3) *Promote Resiliency*

4) *Promote Efficient Energy Usage*

5) *Promote Renewables*


BREAK

2019 IRP Scenarios

Tim Sorrell

Agenda

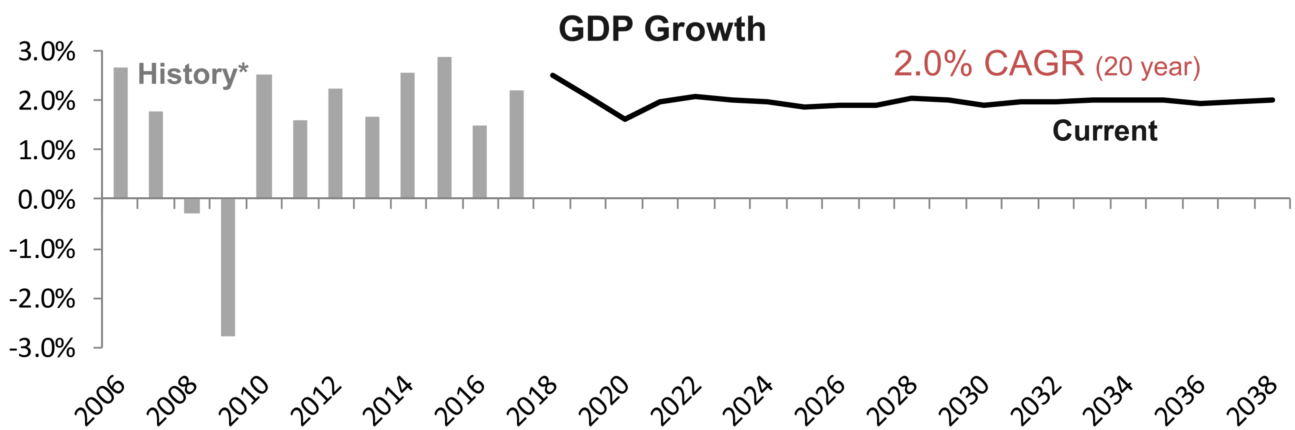
- Current Outlook Refresh
- Economic Downturn
- Valley Load Growth
- Decarbonization
- Rapid DER Adoption
- No Nuclear Extension
- 2015 and 2019 IRP Scenario Comparison
- Summary

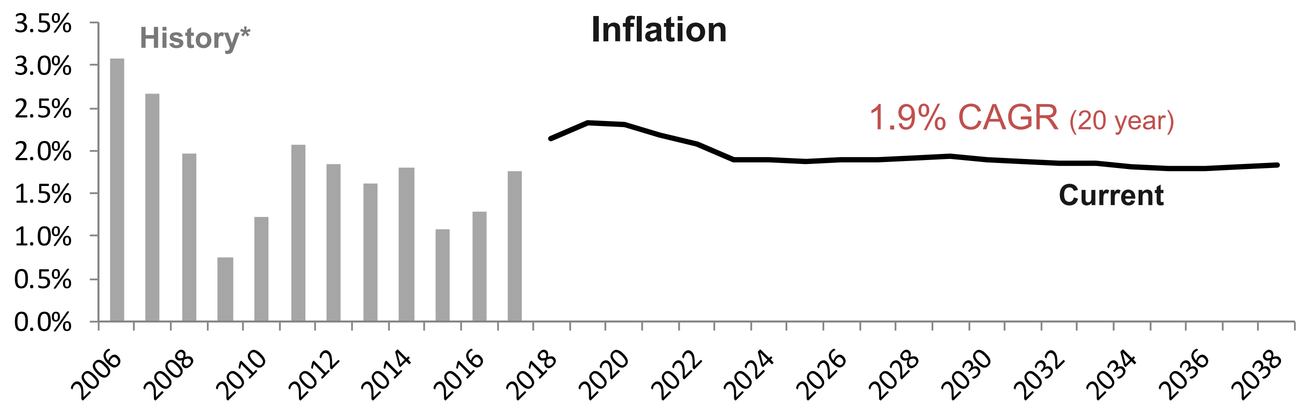
1. Current Outlook

1. Current: Economic Fundamentals

Forecast

- National
  - U.S. Gross Domestic Product averages 2% per year
  - GDP- Implicit Price Deflator remains under 2% long-term
  - Labor force participation is stable despite aging population



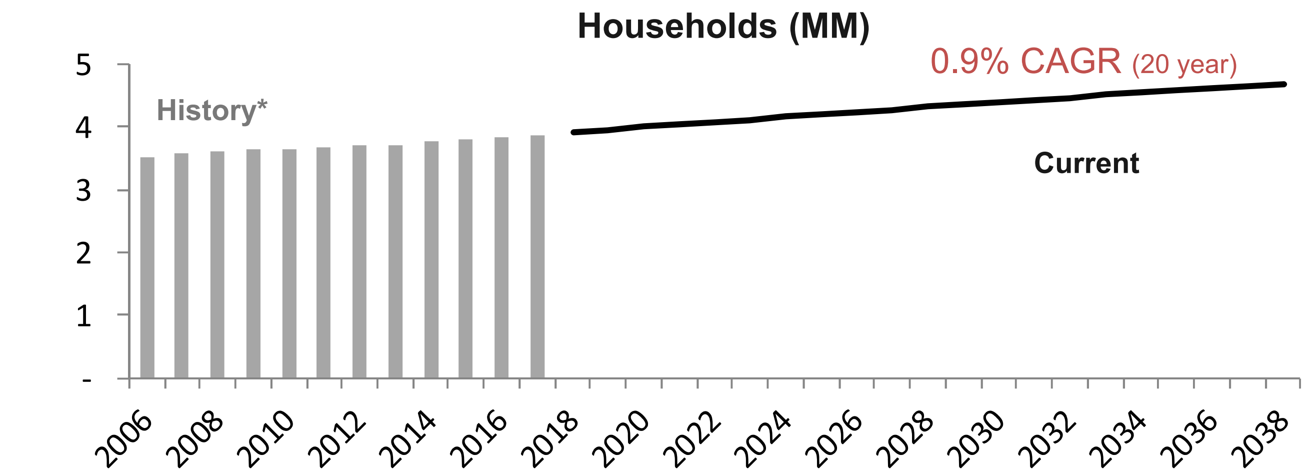


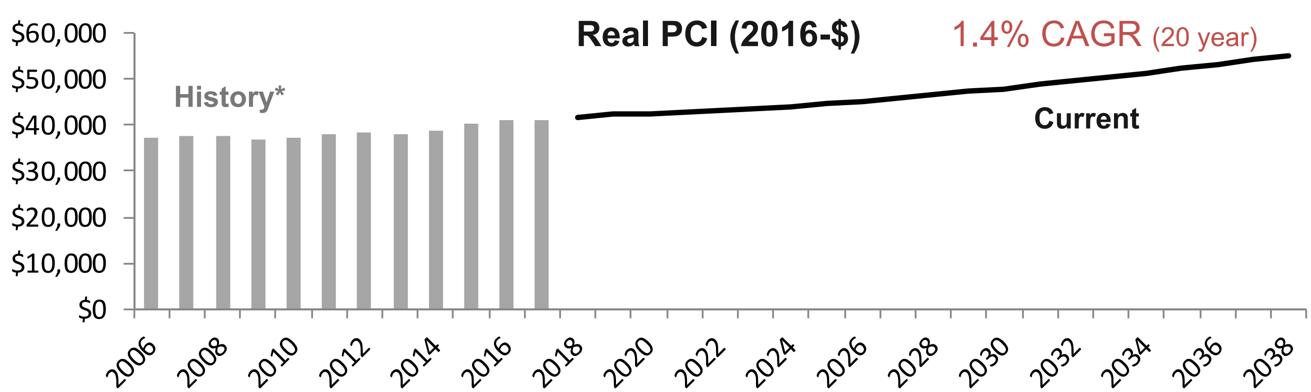
*Source: U.S. Bureau of Economic Analysis; internal TVA forecast

1. Current: Household & RPCI Growth

Forecast

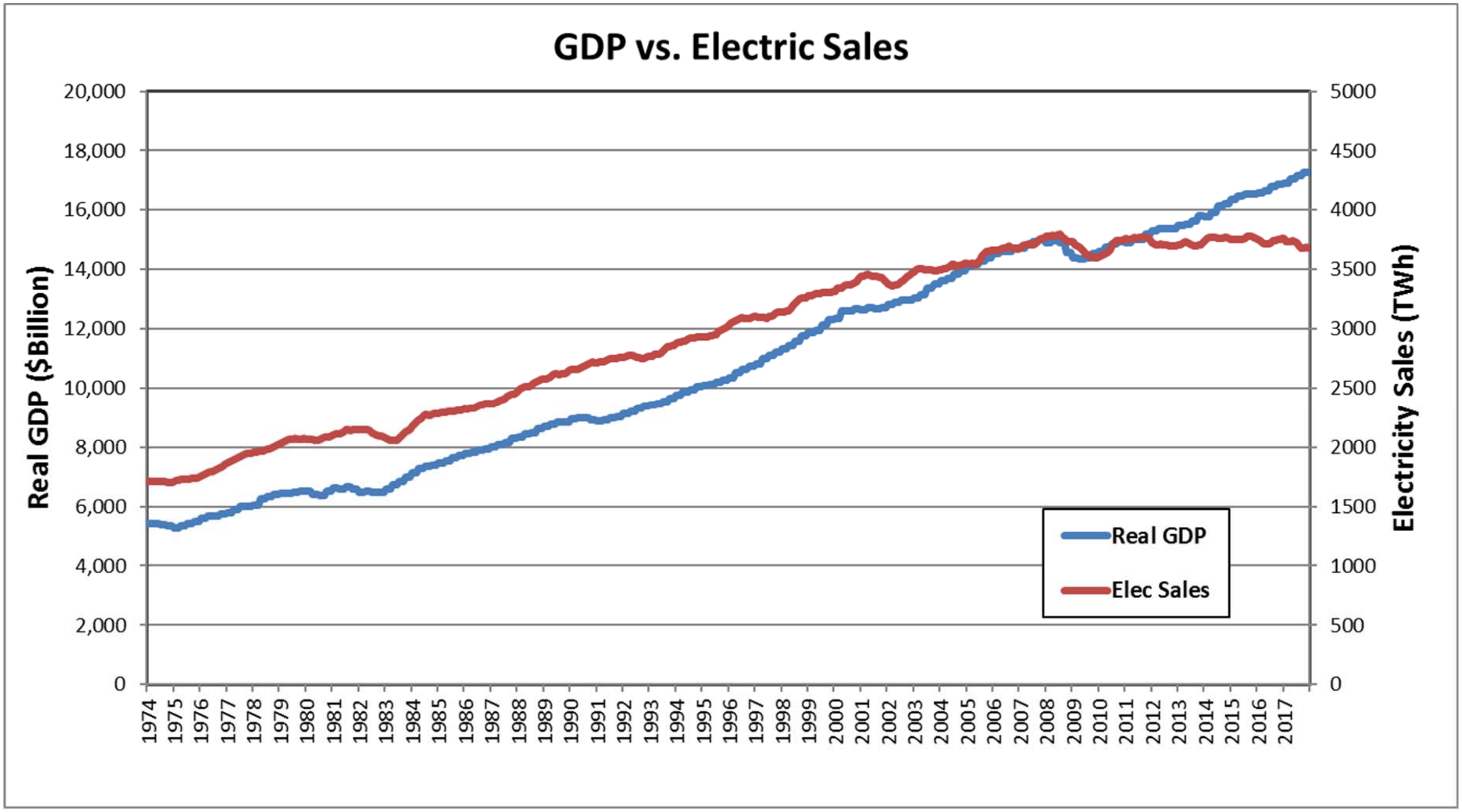
- TVA
  - The number of households increase 0.9% per year, exceeding the rate of population growth
  - Real per capita income grows by 1.4% per year





*Source: Internal TVA data or forecast

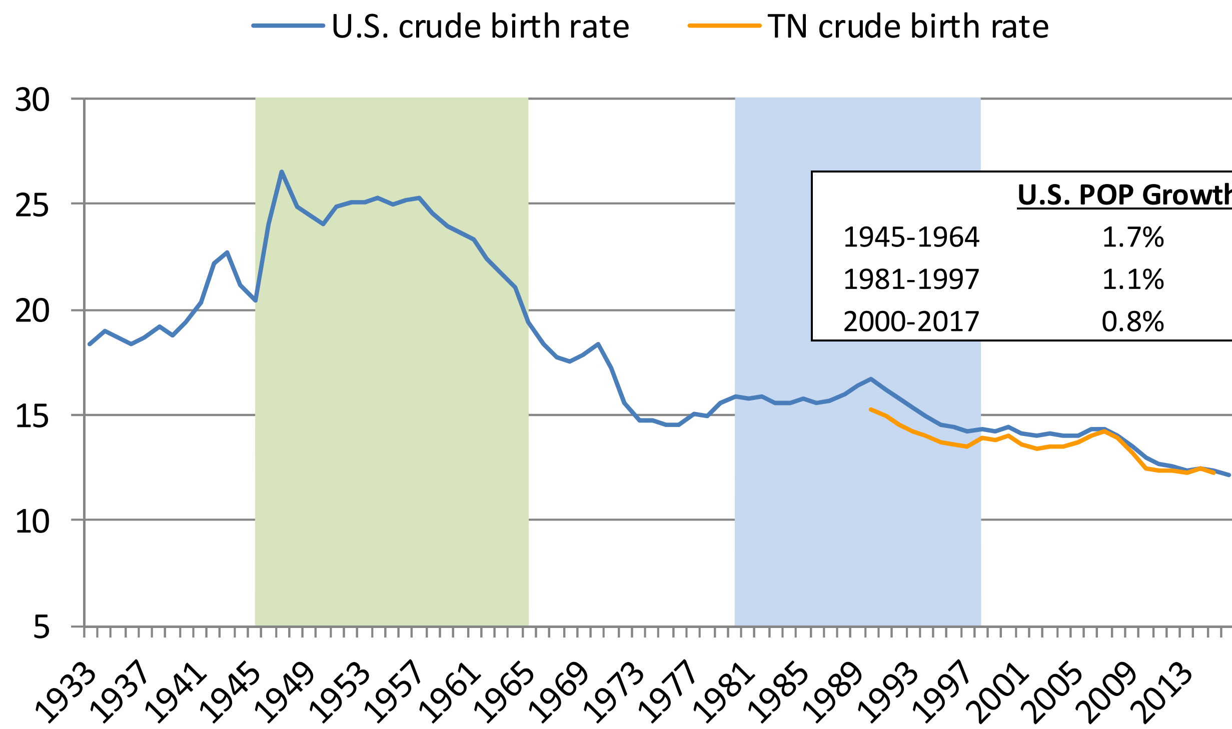
Economic Impact on Load



*Source: Itron

U.S. & Tennessee Crude Birth Rates

- Population growth has slowed; TVA mirrors the U.S.
- 2018 – 2028: 0.7% & 0.2%



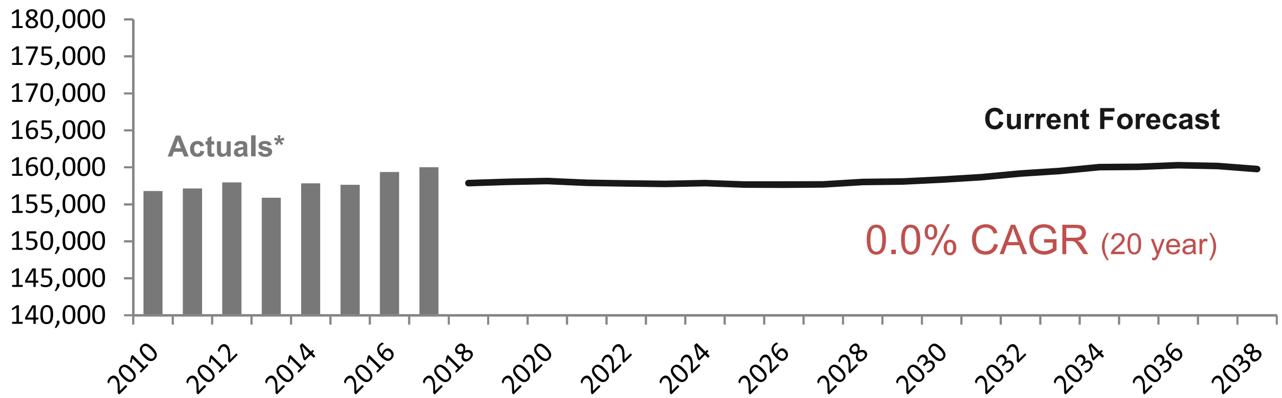
	U.S. POP Growth
1945-1964	1.7%
1981-1997	1.1%
2000-2017	0.8%

**The crude birth rate represents live births per 1,000 total population by year*

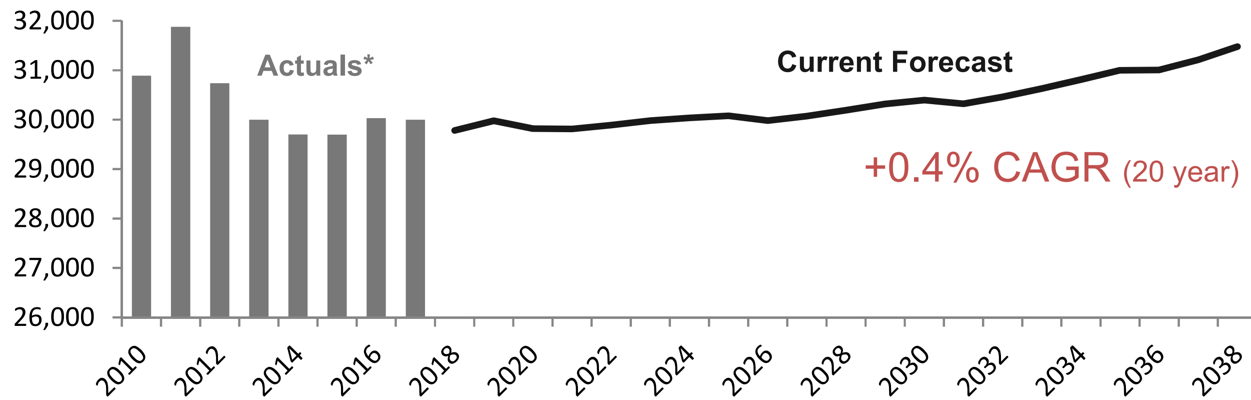
1. Current Outlook: Energy & Demand Growth

Forecast*

- TVA 20-year CAGR growth
  - Energy is flat at 0.0% per year
  - Peaks grow by 0.4% per year
  - Winter peaking throughout forecast period



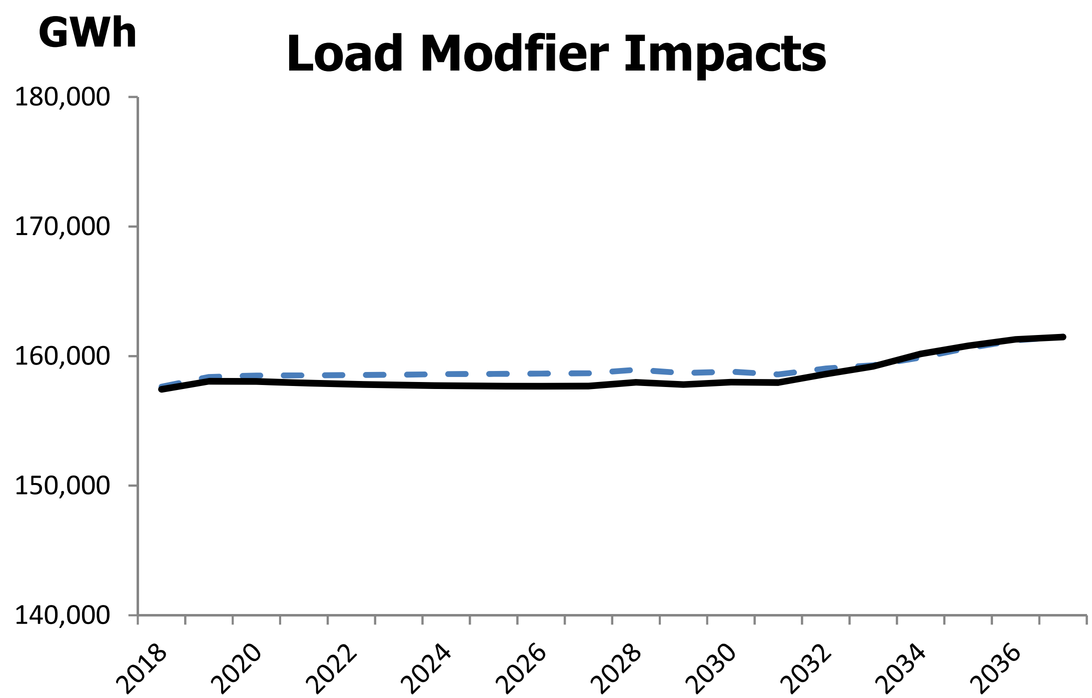
- National
  - 10-yr Energy CAGR of 0.3%
  - 20-yr Energy CAGR of 0.3%



*Source: Internal TVA data or forecast

1. Current Outlook: Load Adjustments

- Distributed solar*
  - 2% residential & commercial customer count by 2028; 4% by 2038
  - Residential: 5 kW, Commercial: 30 kW
  - Solar tariff slows adoption for next four years
- Electric Vehicle (Light Duty)*
  - 170,000 vehicles by 2028 (615 GWh)
  - 750,000 vehicles by 2038 (2,500 GWh)
- 80 MW DER Risk adder impacts energy more than peak*
  - Energy impacts similar in scale to the solar assumption

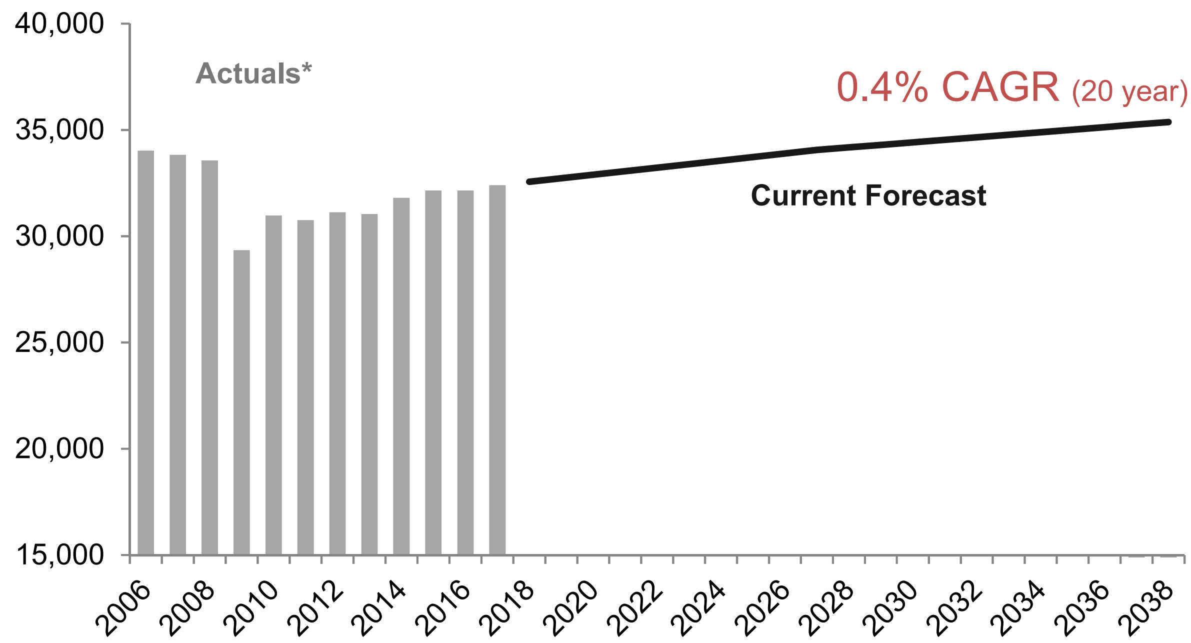


* Internal TVA analysis

1. Current Outlook: Large C&I Sales

Forecast*

- Manufacturing continues to grow in the TVA region
- Lost 12% of sector in last recession
- Returns to pre-recession levels by end of period
- Customers >1 MW



*Source: Internal TVA data or forecast

1. Current: ILB Coal Prices (Nominal)

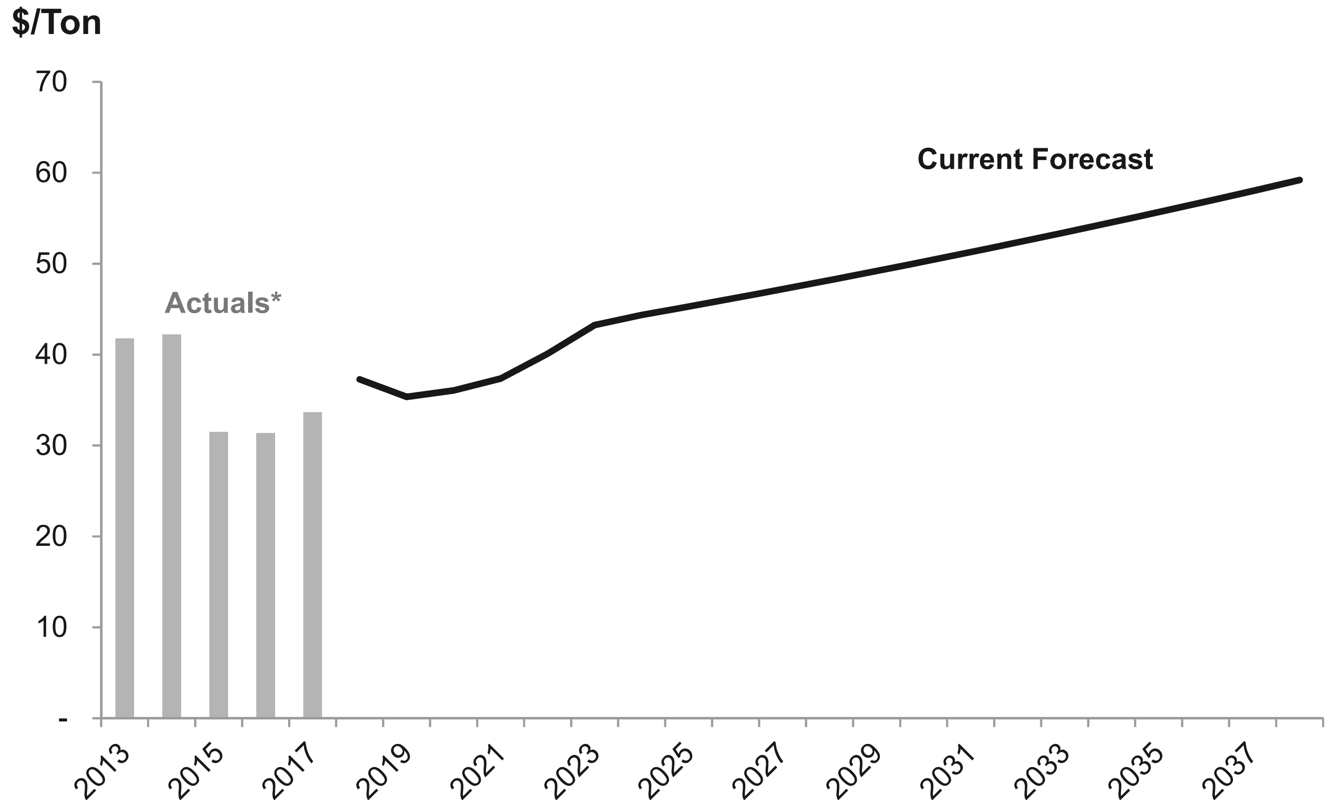
Forecast**

Illinois Basin coal

Gas prices to drive lower growth in coal prices

Coal's competitive position remains unchanged even as regulatory landscape becoming less onerous

Focus will be on efficient & lower-cost mining operations



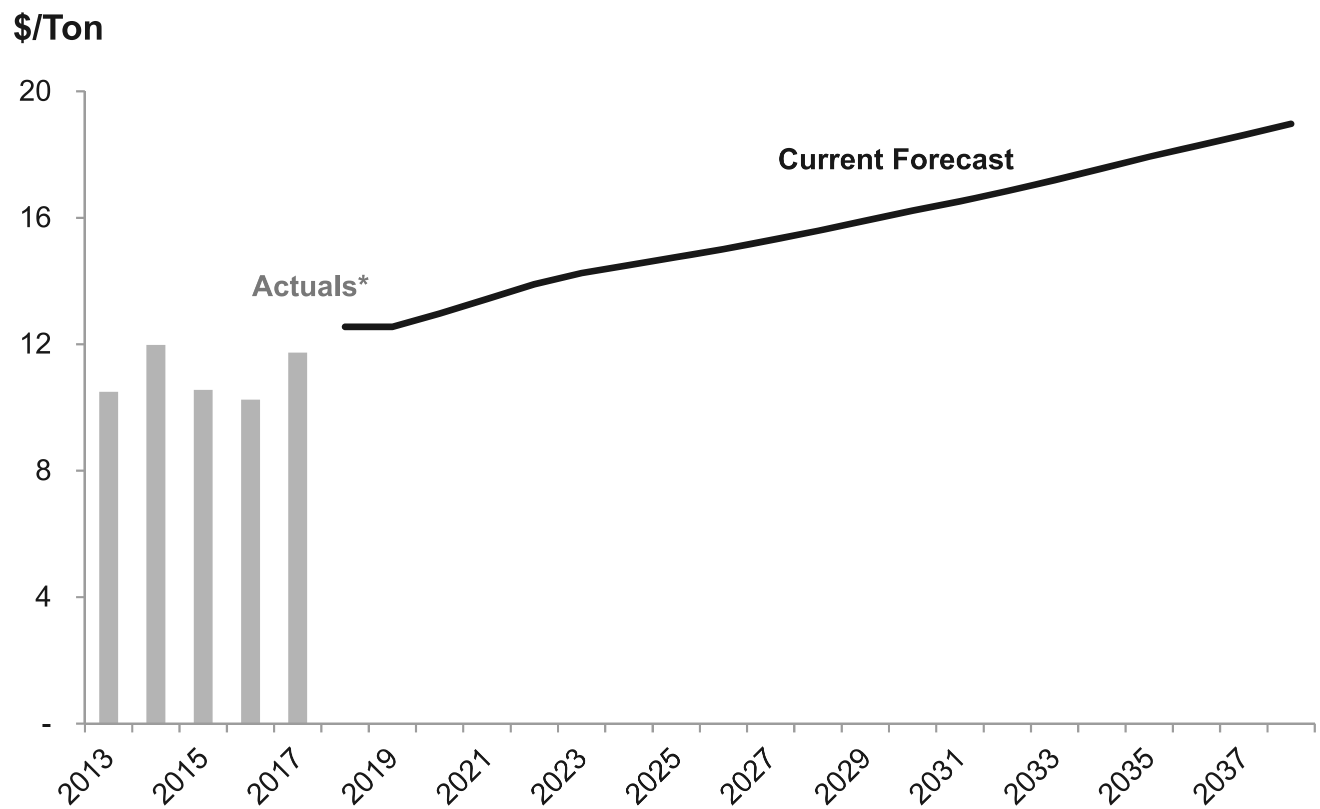
*CoalDesk
** Internal TVA analysis

1. Current: PRB Coal Prices (Nominal)

Forecast**

Powder River Basin, a western coal

Export demand is limited by West Coast export capacity, with prospects of new capacity looking less likely.

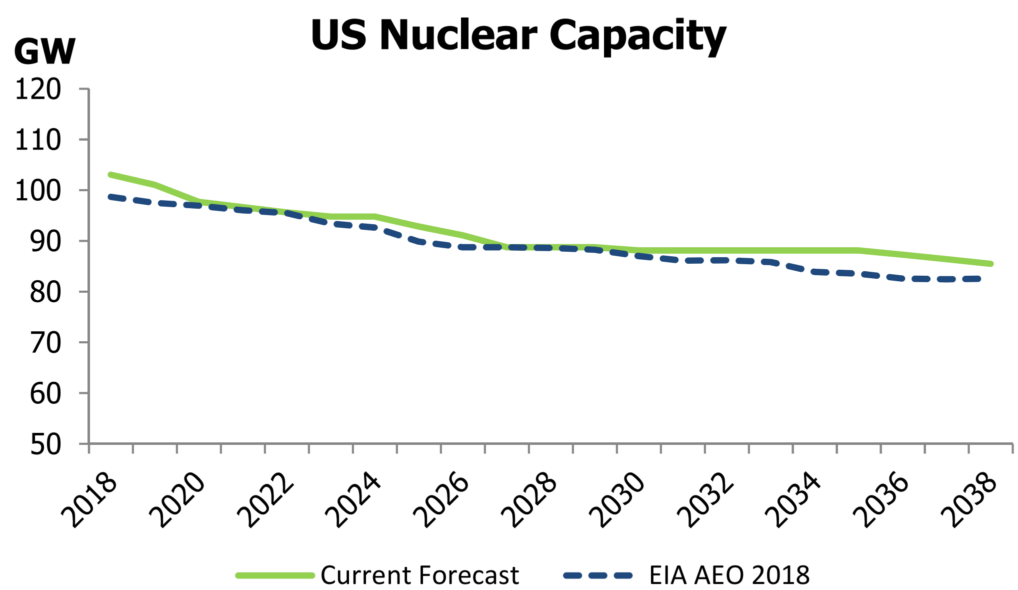


*CoalDesk
** Internal TVA analysis

1. Current: National Model Assumptions

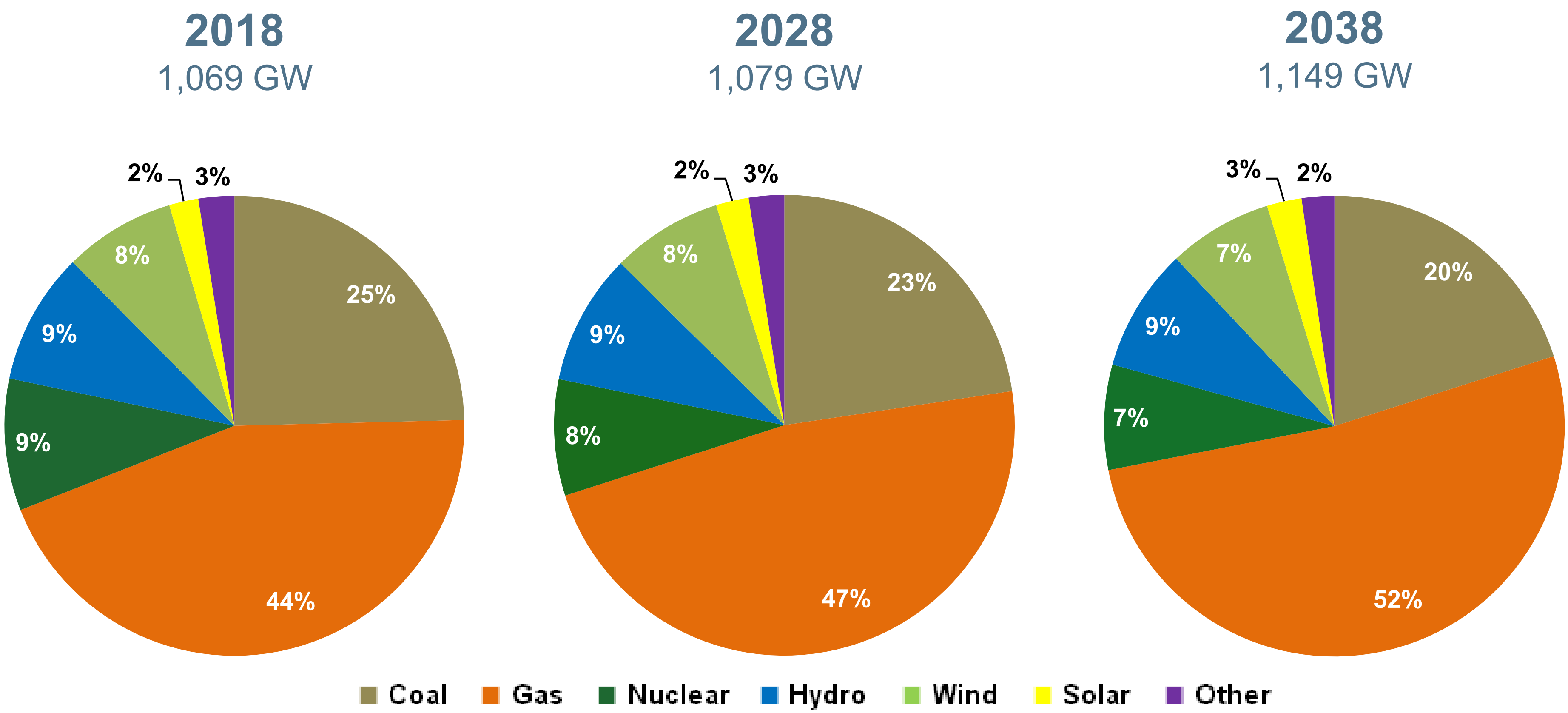
Forecast

- $0 Carbon Adder
- Nuclear
  - Announced retirements incorporated
  - Most units' licenses extend 80 years



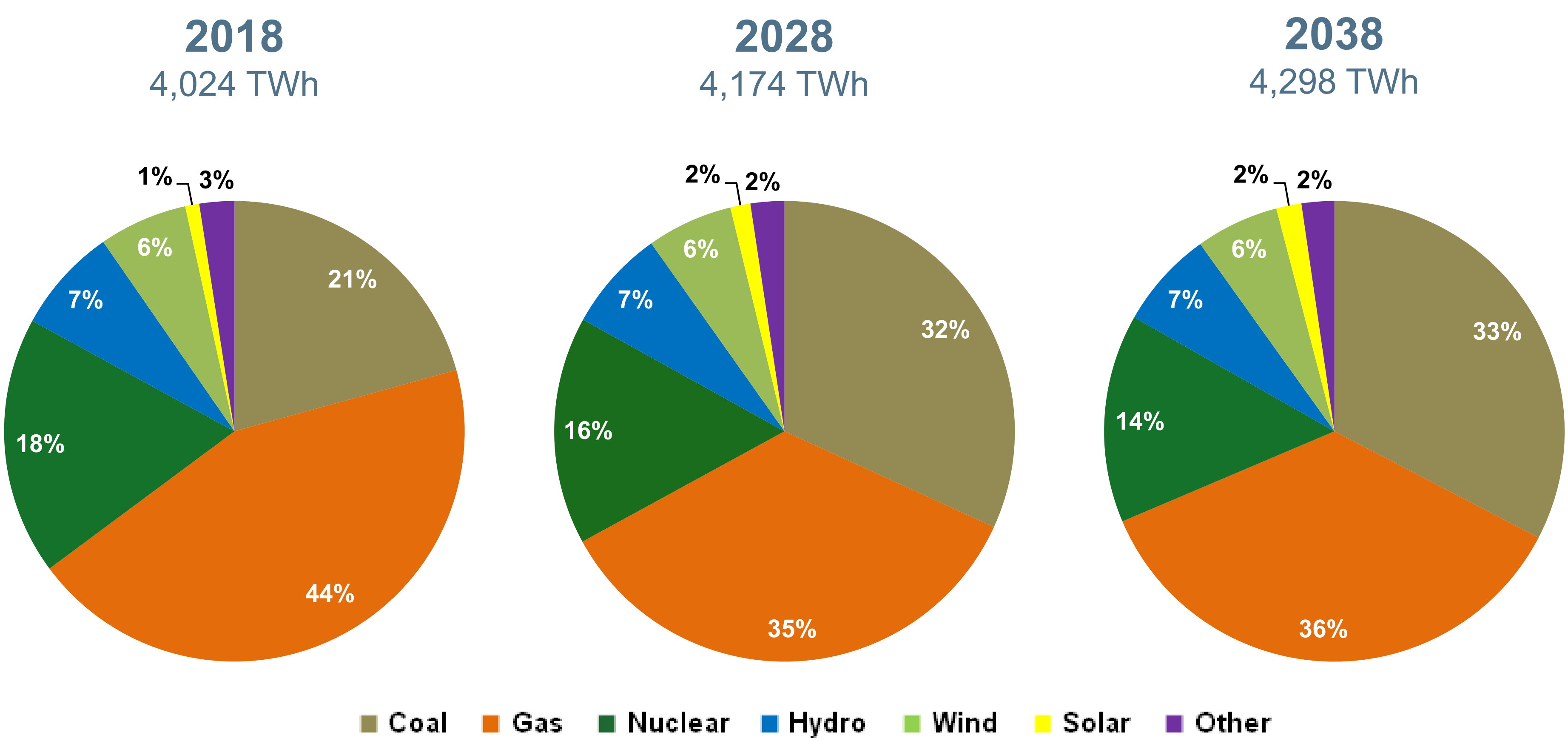
Source: Internal TVA analysis

1. Current: National Capacity



Source: Internal TVA forecast

1. Current: National Generation



Source: Internal TVA forecast

Scenario Impacts

	Current Outlook	Economic Downturn	Valley Load Growth	Decarbonization	Rapid DER Adoption	Nuclear
Economics		Change	Change	Change	No Change	No Change
Load & DER		Change	Change	Change	Change	No Change
Commodity Prices		Change	Change	Change	Change	Change

2. Economic Downturn

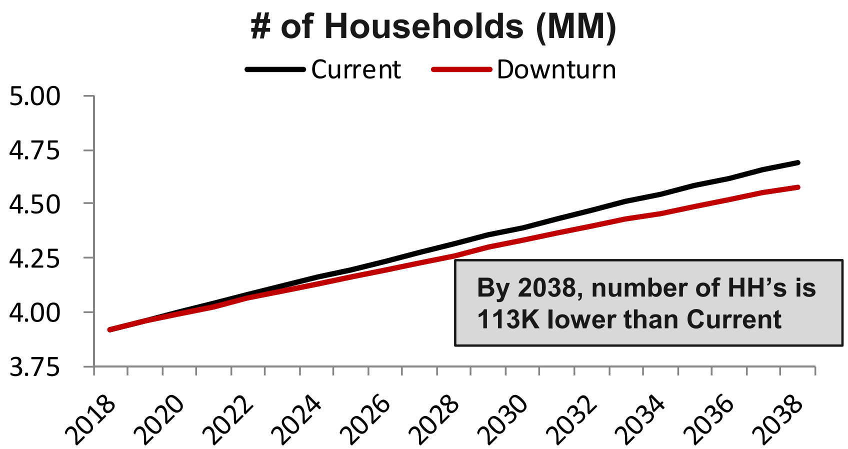
Economic Downturn

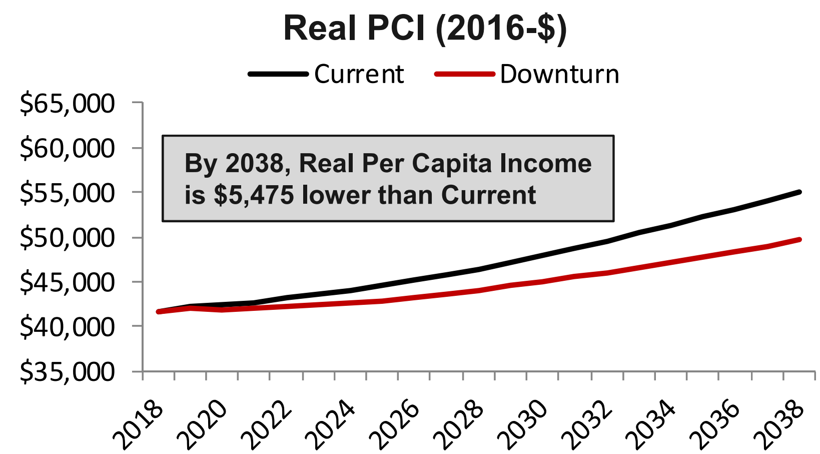
- Prolonged, stagnant economy results in declining loads and delayed expansion of new generation
- Labor force participation weakens; productivity stagnates due to weak investment
- Stringent environmental regulations delayed due to concerns of adding further pressure to the economy
- Weaker demand lowers cost of new plant construction, partially offset by higher inflation

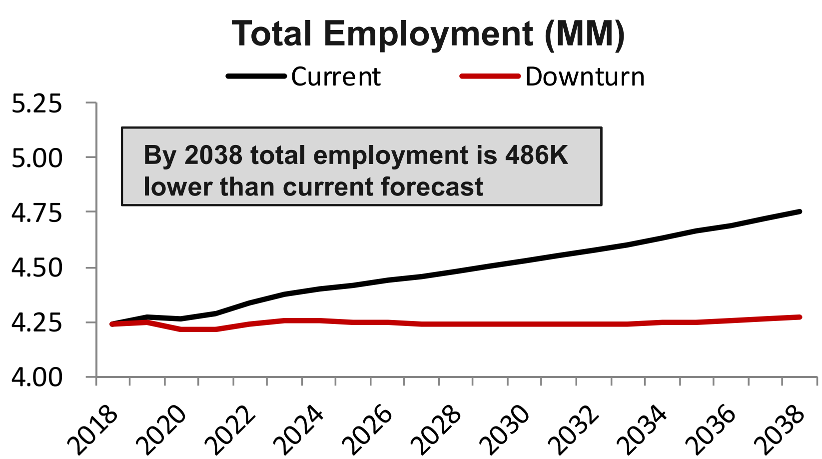
2. Downturn: Economics

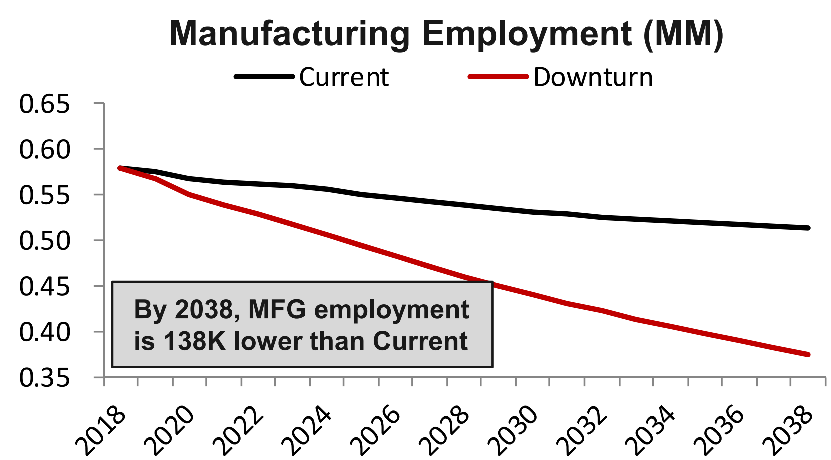
Drivers	Description
U.S. Gross Domestic Product (GDP)	• U.S. economy grows at average rate of 2001/Q1 – 2009/Q2 period: 1.5% / year • This period was framed by two recessions
U.S. Inflation	• U.S. inflation (GDP-IPD) mirrors 2001/Q1 – 2009/Q2 period: 2.3% average • This period was framed by two recessions
TVA Region variables	• Based on historical correlations and input variations in GDP and inflation, our model simulates TVA economic and demographic variables to produce corresponding TVA region forecasts.
Labor Force Participation	• Continues to erode, reaching new lows; resulting TVA region employment is stagnant over the forecast horizon.

2. Downturn: Economic Characteristics





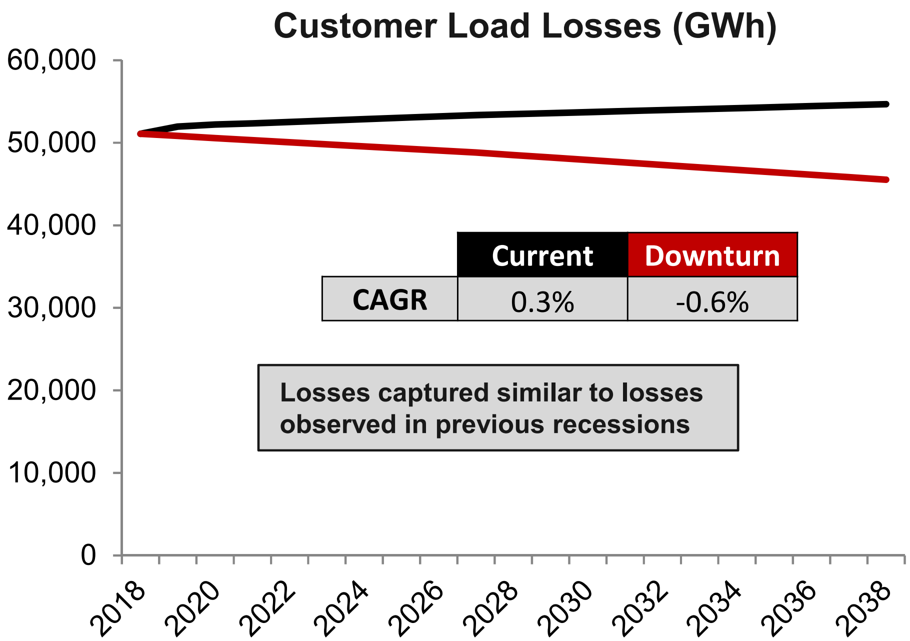




2. Downturn: Load Assumptions

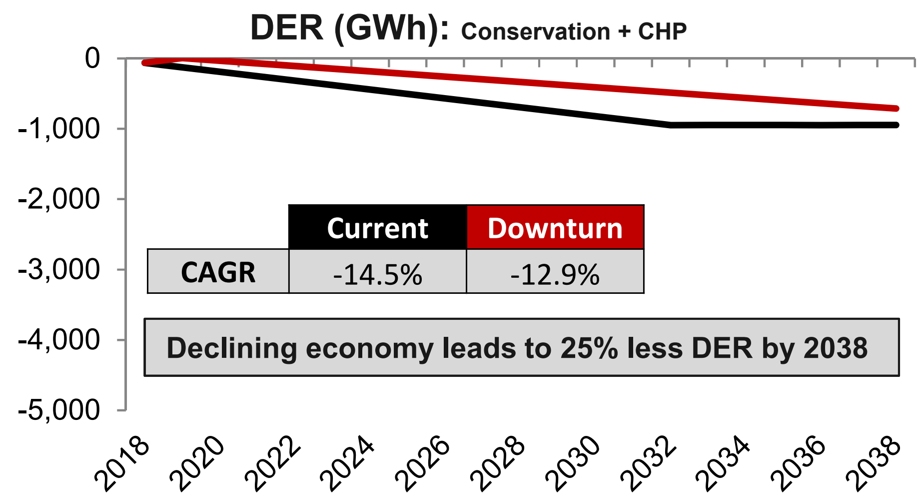
Drivers	Description
Renewables (BTM)	• Behind the meter growth same as base case
Loss of customer load	• 16% reduction due to customer load losses in the commercial and industrial (C&I) sectors
Electric Vehicles	• Slowed growth due to lower median income (2,100 GWh by 2038; 600,000 EVs) • 22% EV load decline compared to the base case by 2038
Energy Conservation	• Implemented to prevent electricity consumption and high bills
Combined Heat and Power	• CHP slowed to first five years of study (compared to 10 years in current outlook) due to customer loss and depressed economy
Demand Drivers	• Customer Loss • Technology Growth Dampened

2. Downturn: Load Characteristics



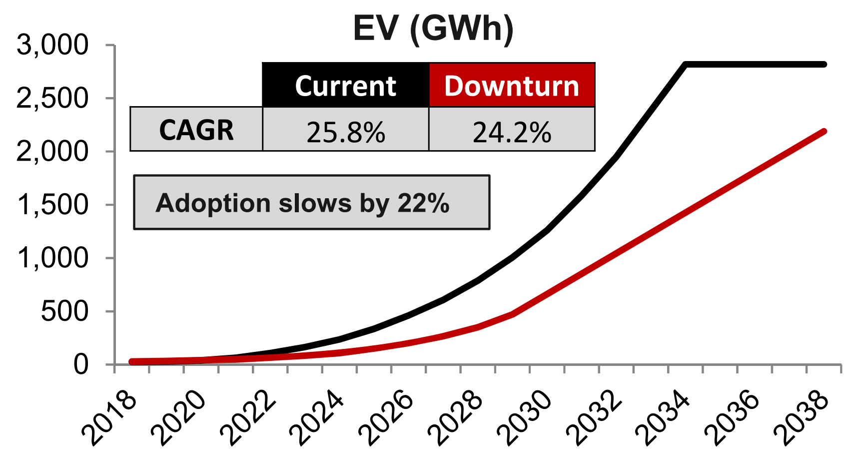
	Current	Downturn
CAGR	0.3%	-0.6%

Losses captured similar to losses observed in previous recessions



	Current	Downturn
CAGR	-14.5%	-12.9%

Declining economy leads to 25% less DER by 2038

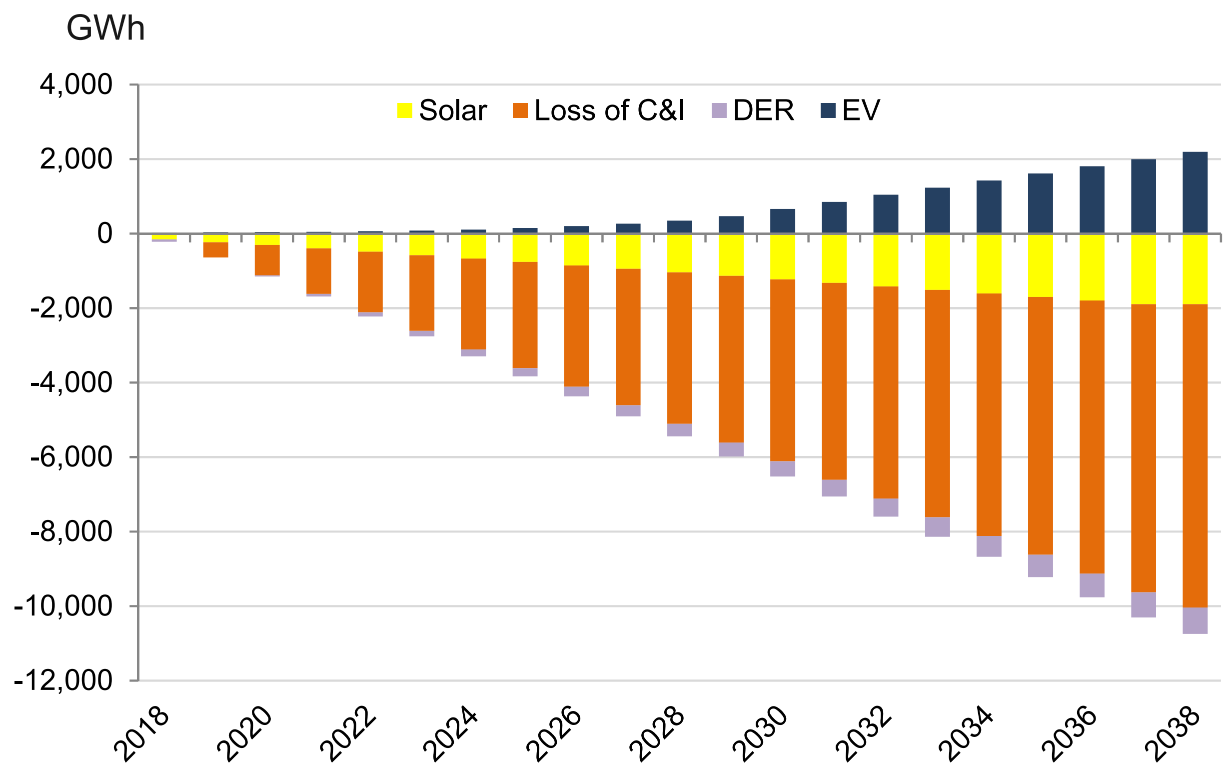


	Current	Downturn
CAGR	25.8%	24.2%

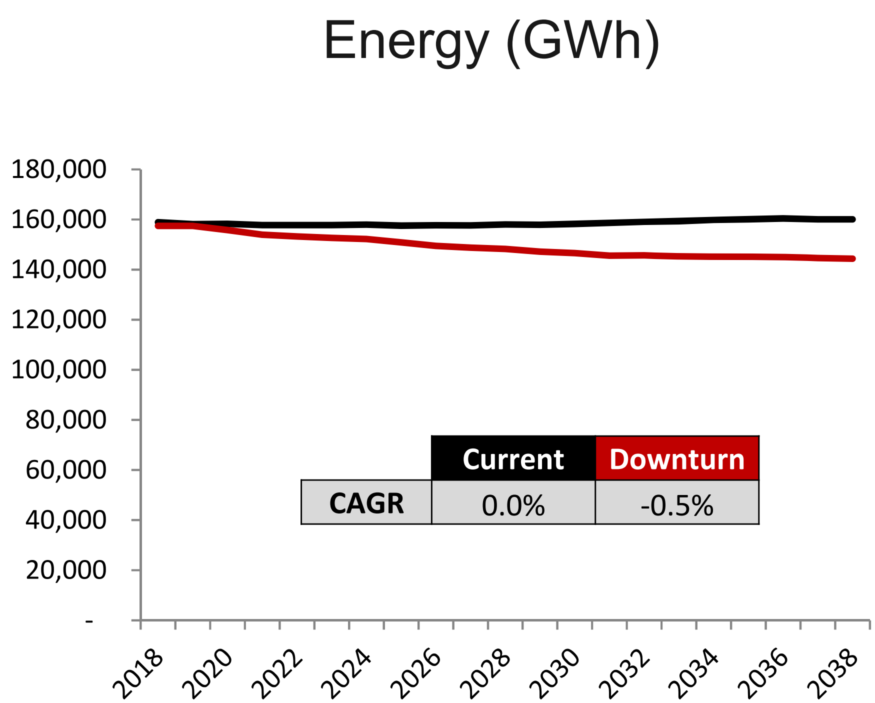
Adoption slows by 22%

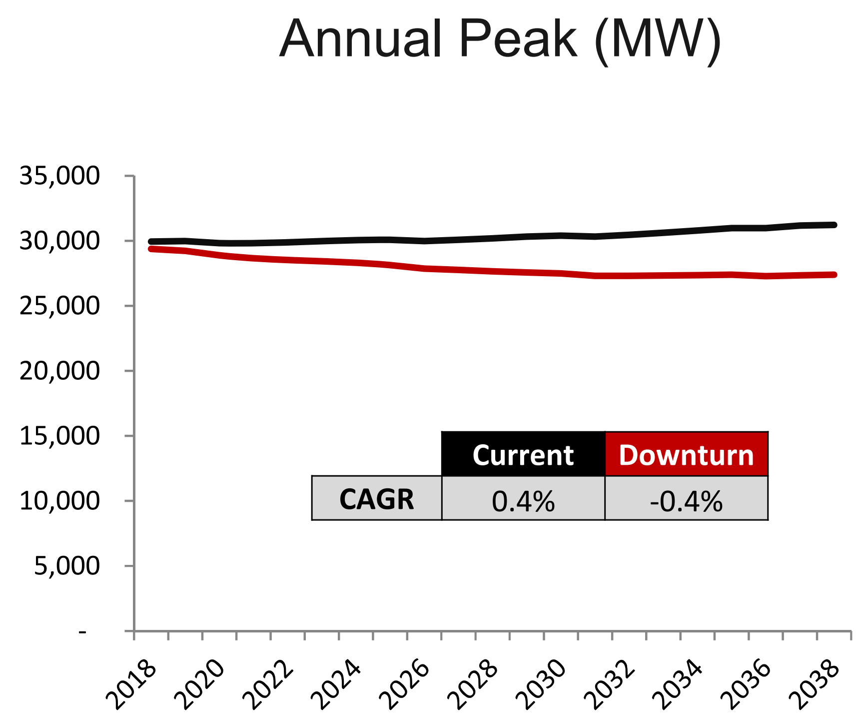
2. Downturn: Scenario Assumption Impacts

- Reduced productivity yields C&I sector decline
- Lower real per capita income slows DER and EV adoption

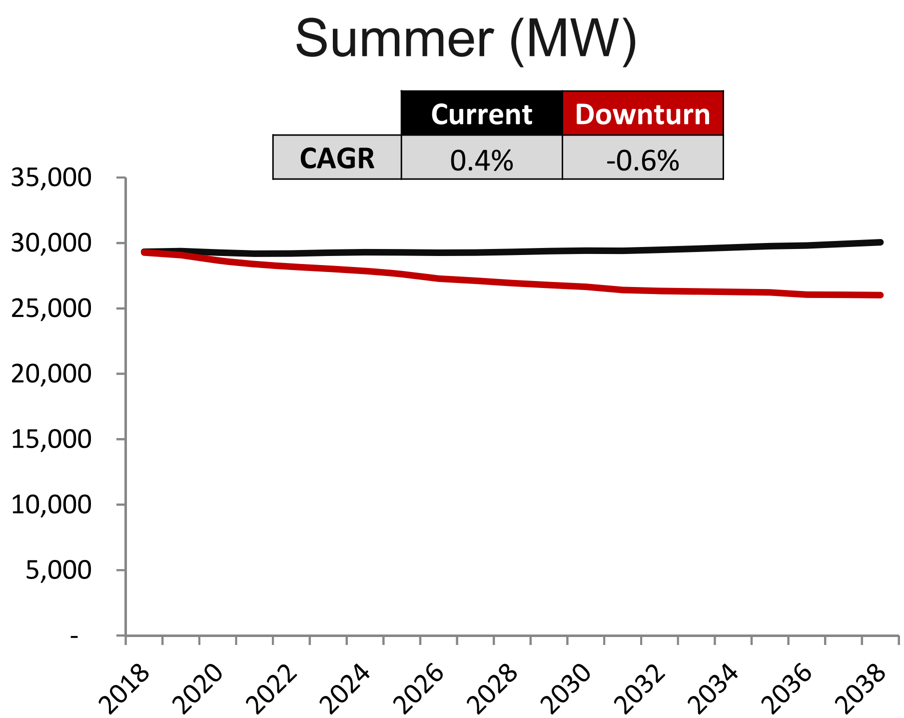


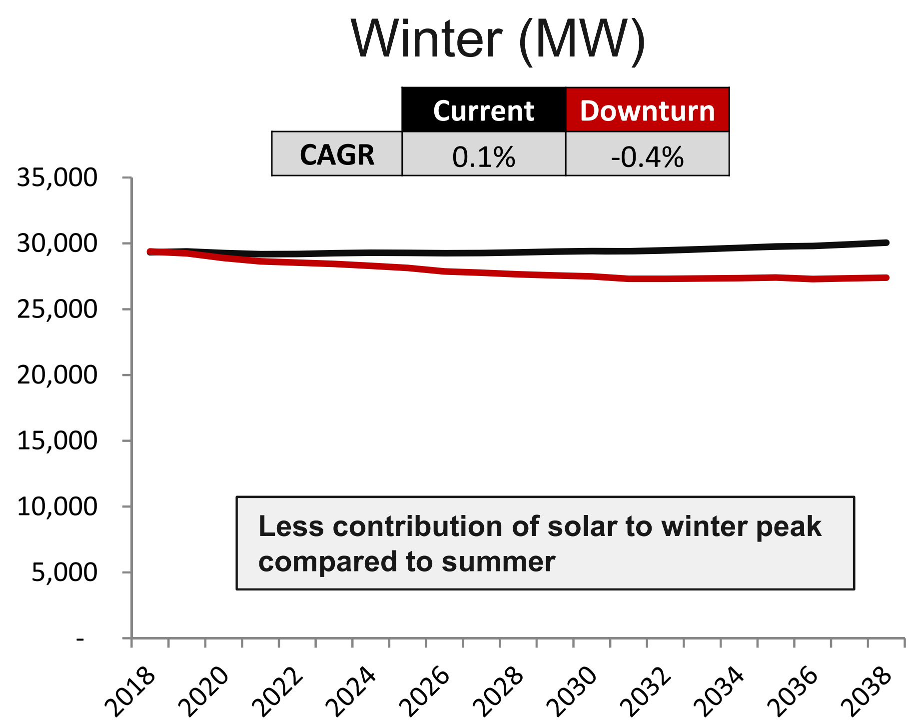
2. Downturn: Energy & Peak





2. Downturn : Seasonal Peaks

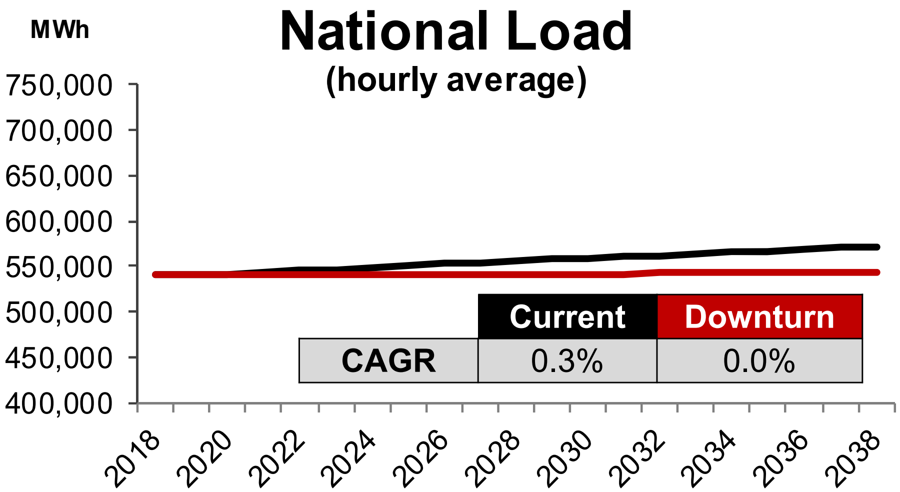




2. Downturn: Commodity Assumptions

Drivers	Description
National Demand Growth	• U.S. demand growth declines from 0.3% to flat growth (0.0%)
CO2 Regulations	• No change to CO2 cost assumptions ($0/ton)
Solar Prices	• Recent technology cost trends reverse resulting in high solar costs
Gas Prices	• Lower Henry Hub gas prices due to lower gas demand
Gas Exports	• Higher gas exports due to lower gas prices
Coal Prices	• Lower coal prices due to lower demand
National Capacity Mix	• Slight decrease in solar construction; coal capacity continues to decline at same pace; new natural gas capacity declines as there is no demand growth.

2. Downturn: National Impacts



	Current	Downturn
CAGR	0.3%	0.0%

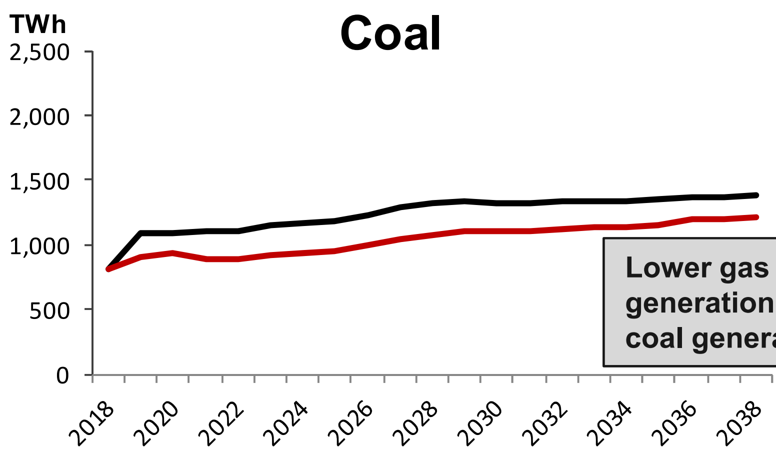
Note: "Hourly Average" removes visual effect of leap year.

National Capacity Mix by 2038

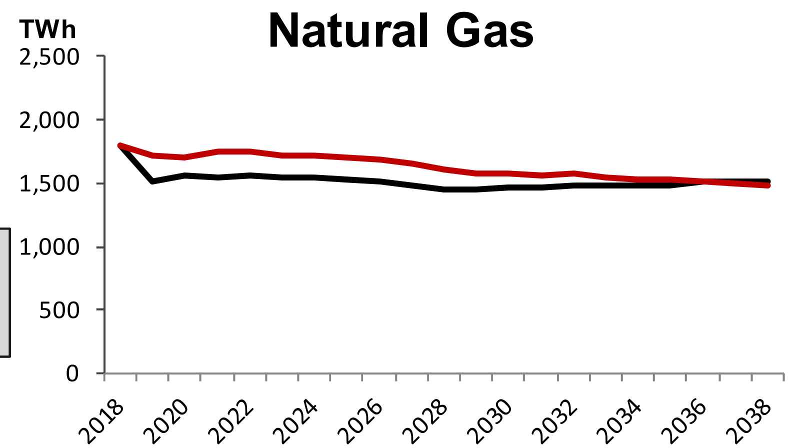
	Coal	NatGas	Nuclear	Hydro	Wind	FuelOil	Solar	Other
Current	20%	52%	7%	9%	7%	1%	3%	1%
Downturn	22%	47%	8%	9%	8%	1%	3%	1%

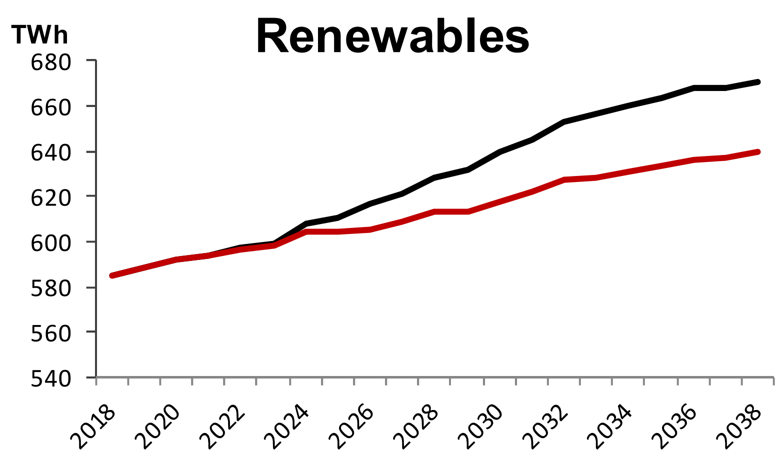
No actual gain in coal, nuclear or wind generation. Natural gas capacity build is lower as overall demand is lower.

2. Downturn: National Generation by Fuel



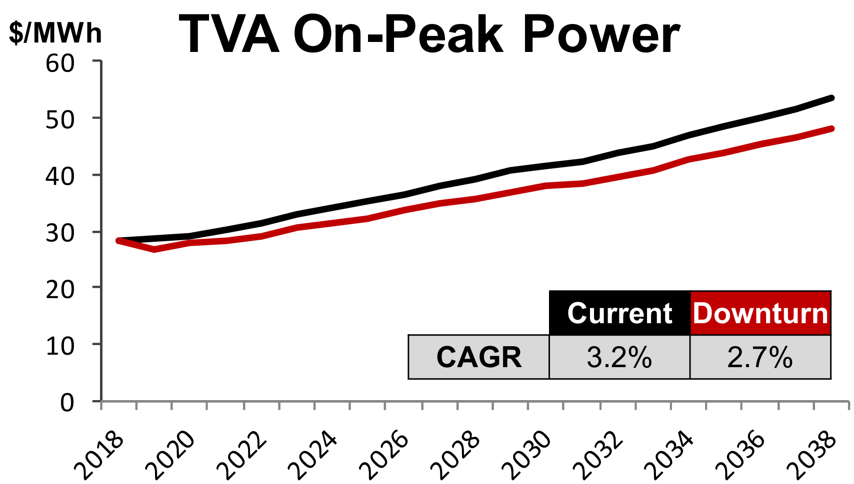
Lower gas prices favor gas generation at the expense of coal generation.

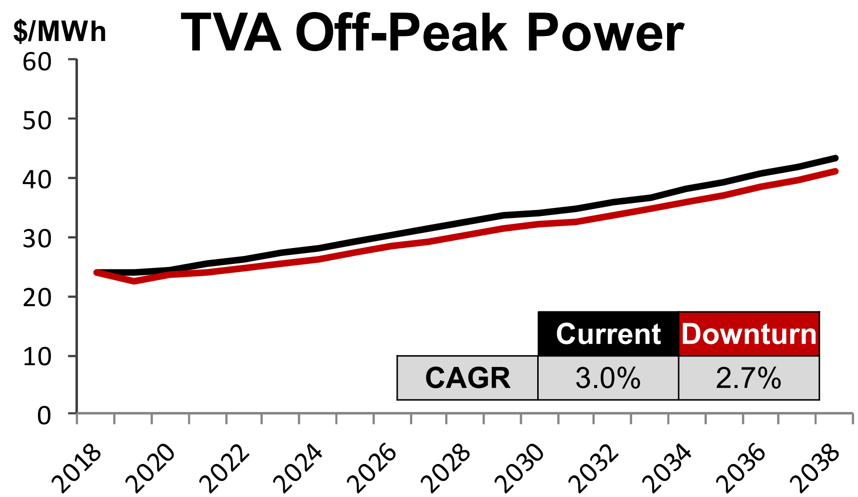




High solar prices push solar generation lower.

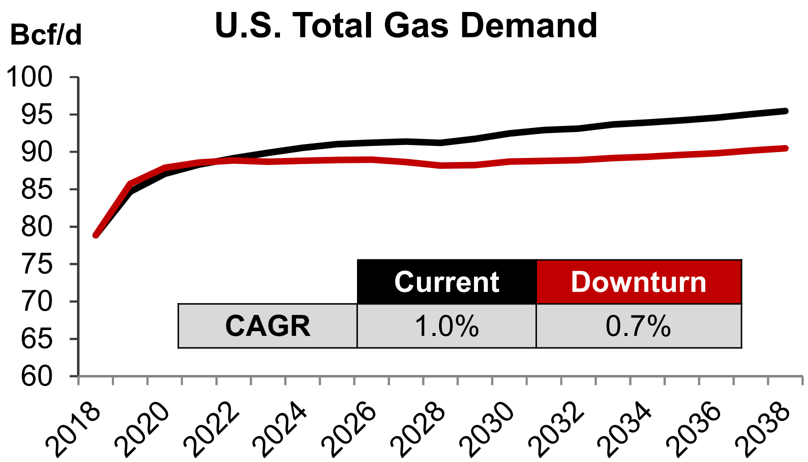
2. Downturn: TVA Wholesale Power Prices



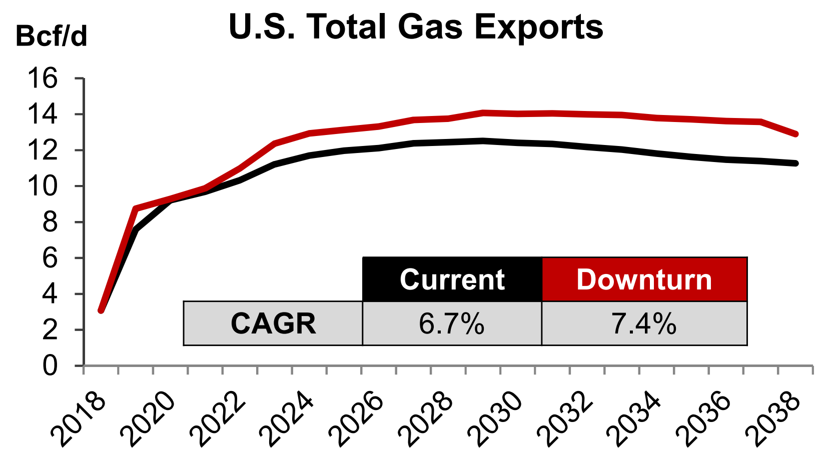


Lower natural gas and coal prices, along with lower demand depress both on and off-peak power prices.

2. Downturn: Natural Gas Demand & Exports



	Current	Downturn
CAGR	1.0%	0.7%



	Current	Downturn
CAGR	6.7%	7.4%

Lower gas demand due to weak overall demand & lower gas burn

Lower gas prices improve gas export economics, resulting in higher exports

3. Valley Load Growth

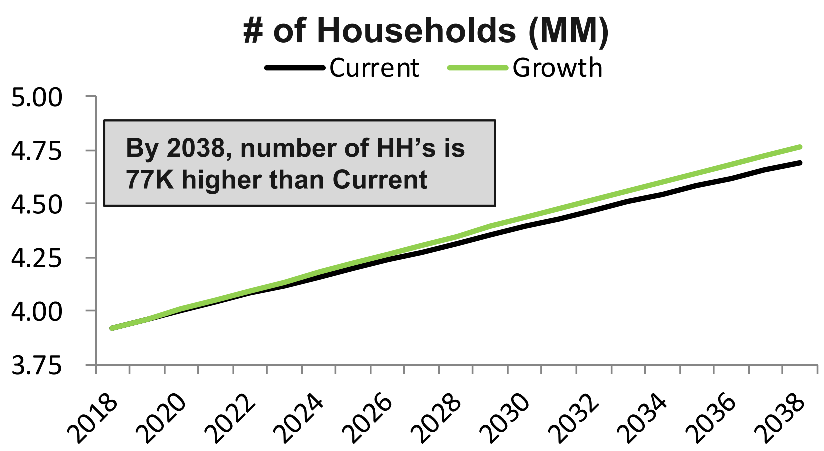
Valley Load Growth

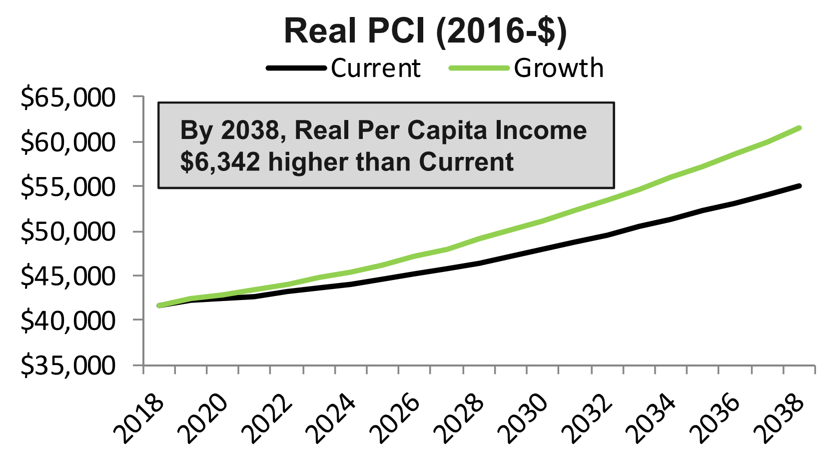
- Technology-driven investment in automation and AI raise electricity use and boost labor productivity & economic growth while lowering inflation
- Economic growth, driven by migration into the Valley and growth in emerging markets and developing economies, translates into higher energy sales
- Lower battery prices due to economies of scale drive increased electrification of transportation, magnifying growth
- Preference for lower emissions, DER and EE reduces demand for emitting generation, translating into lower gas and coal prices

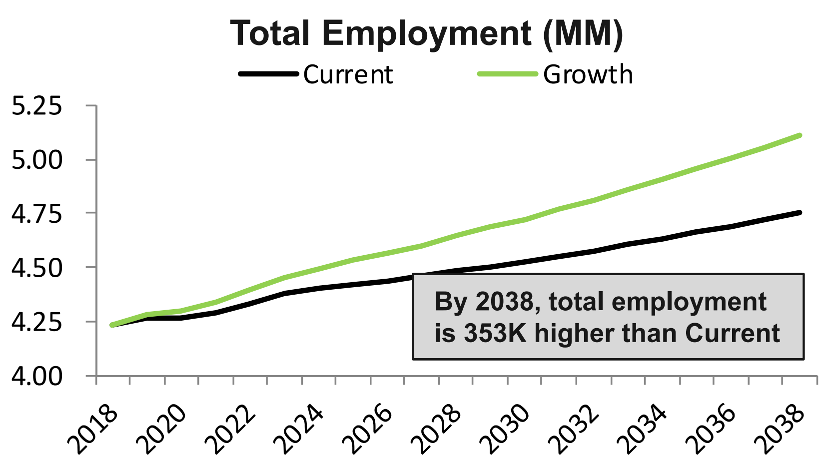
3. Growth: Economics

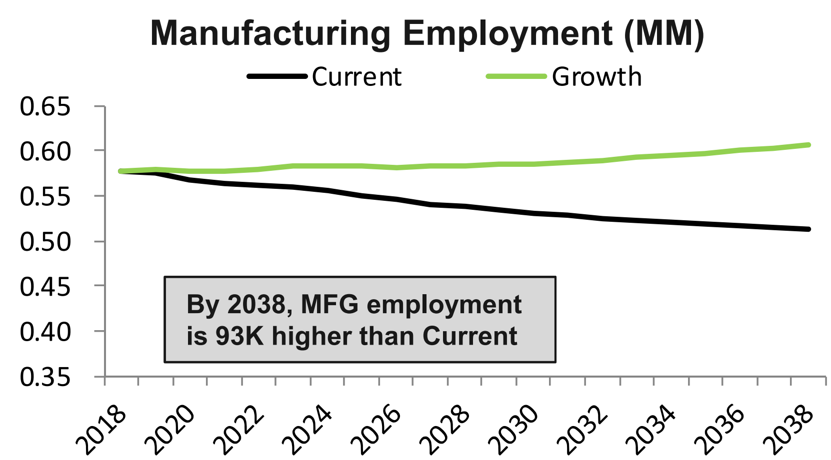
Drivers	Description
U.S. GDP	• U.S. economy grows at average rate of post – 2009/Q2 period: 2.2% / year • Economic expansion continues at post-Great Recession rate aided by new technology which boosts labor productivity
U.S. Inflation	• U.S. inflation (GDP-IPD) mirrors post – 2009/Q2 period: 1.6% average • Resulting technology change also suppresses inflation
TVA Region variables	• Based on historical correlations and input variations in GDP and inflation, our model simulates TVA economic and demographic variables to produce corresponding TVA region forecasts.
Labor Force Participation	• Rebounds reaching 2007 – 2008 level; resulting TVA region employment expands consistent with post-Great Recession pace.

3. Growth: Economic Characteristics





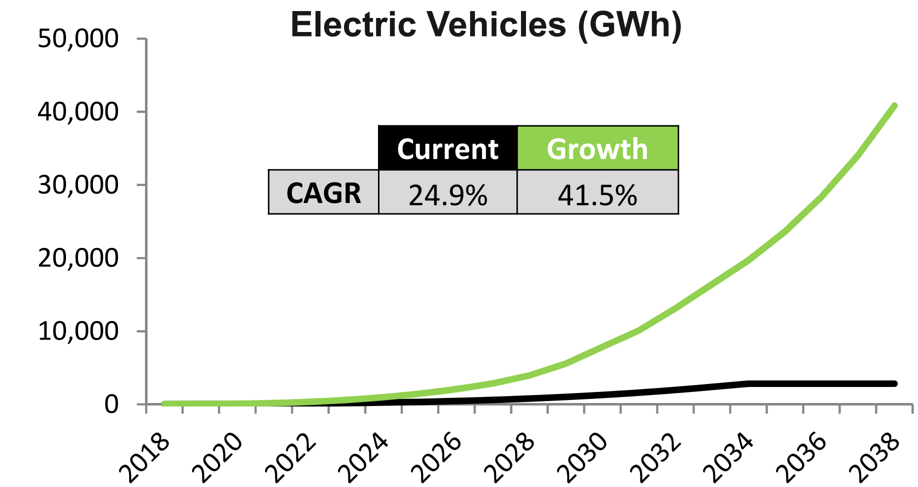




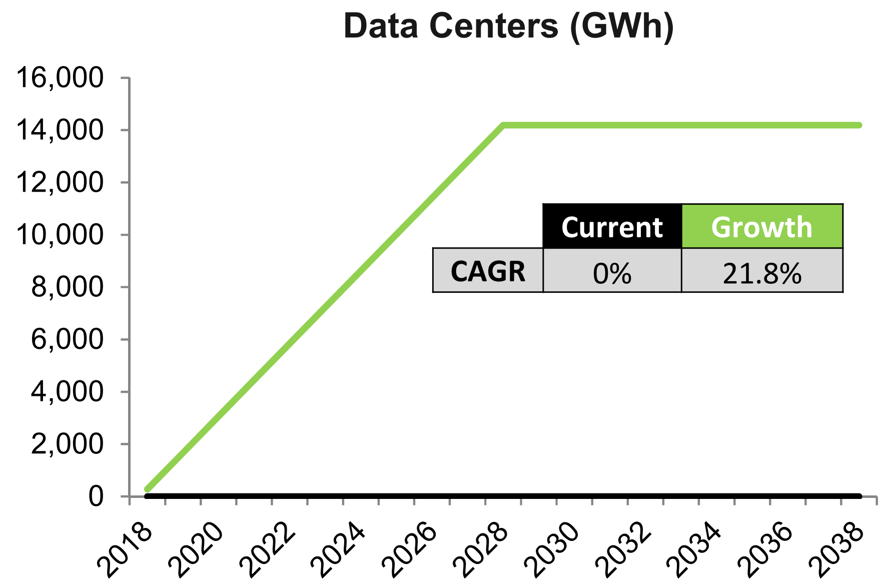
3. Growth: Load Assumptions

Driver	Description
Renewables (BTM)	• Rising incomes, declining technology costs, and social influences contribute to increased adoption of residential and commercial solar despite phase out of ITC • Up to 3,000 GWh by 2038
Customer Growth	• Migration into the valley leads to customer growth, especially in C&I sectors
Electric Vehicle	• Valley electrification leads to large penetration rates of EVs • Growth as a result of EVs reaches 30,000 GWh by 2038 (4.2M EVs)
Data Center Growth	• Valley currently seeing an electrification potential for 14,000 GWh of data center growth (assumed by 2028)
Energy Efficiency	• Due to increased real per capita income, EE adoption increases due to codes and standards
Combined Heat and Power	• Due to increased C&I growth and profits, more customers adopting CHP • 1,400 GWh by 2028, and no additional CHP after 2028
Demand Drivers	• Technology Adoption Growth (EV, Data Centers, CHP, DER, Renewables, Automation) • Customer Growth

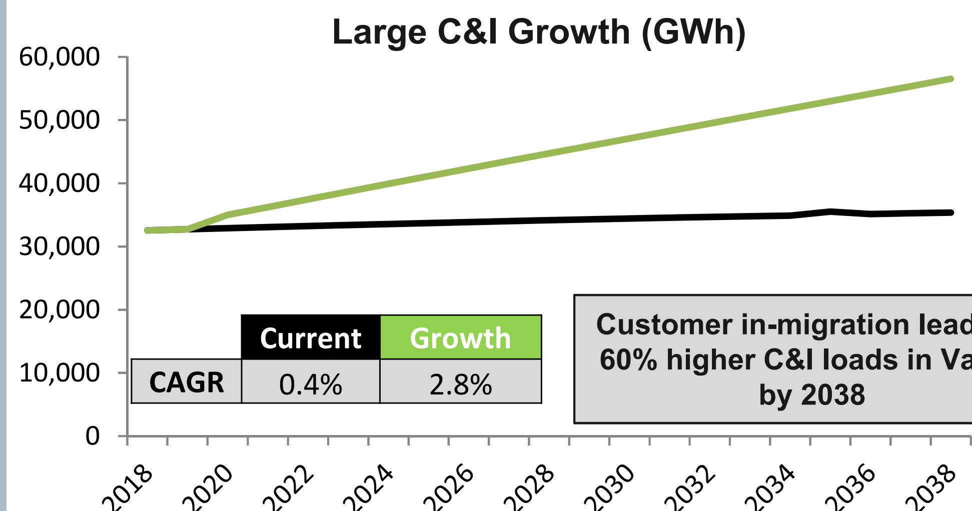
3. Growth: Load Characteristics



	Current	Growth
CAGR	24.9%	41.5%



	Current	Growth
CAGR	0%	21.8%



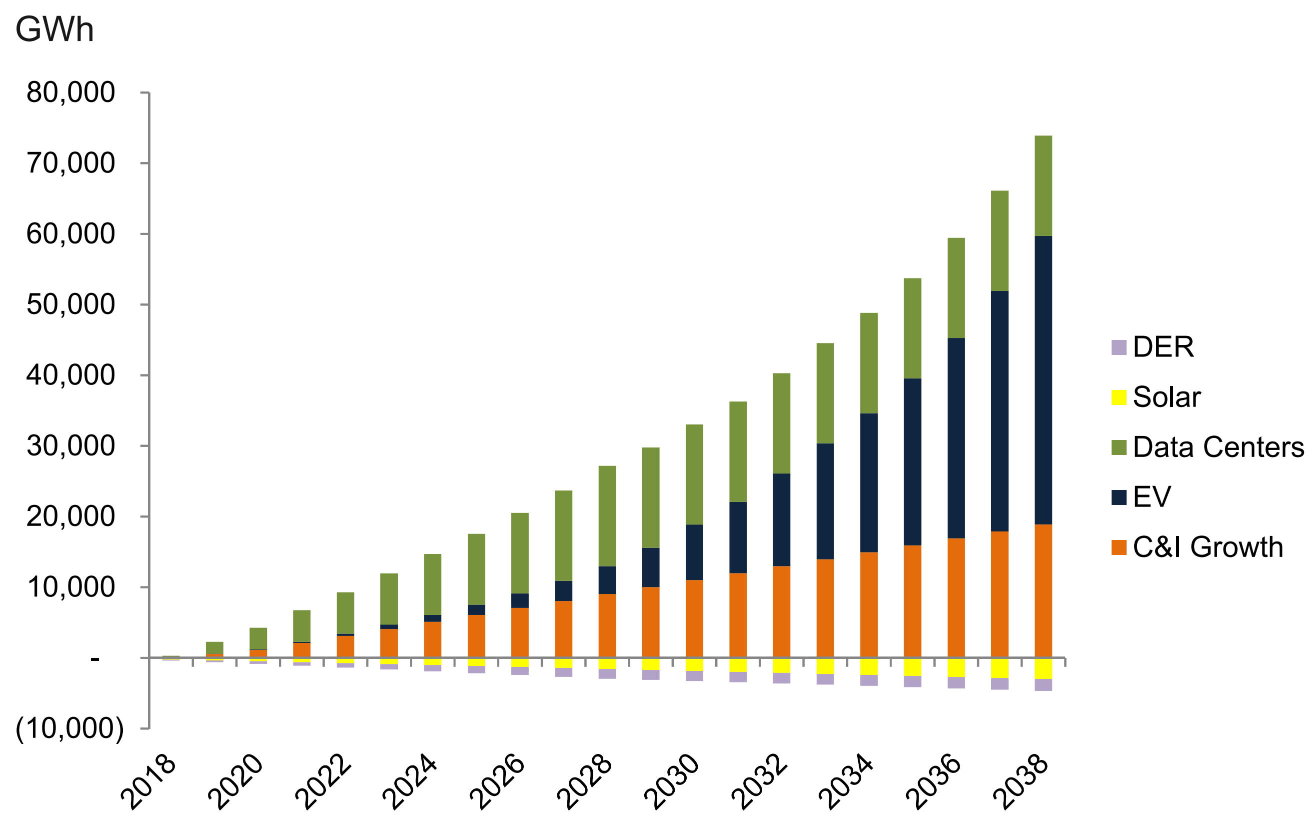
	Current	Growth
CAGR	0.4%	2.8%

Customer in-migration leads to 60% higher C&I loads in Valley by 2038

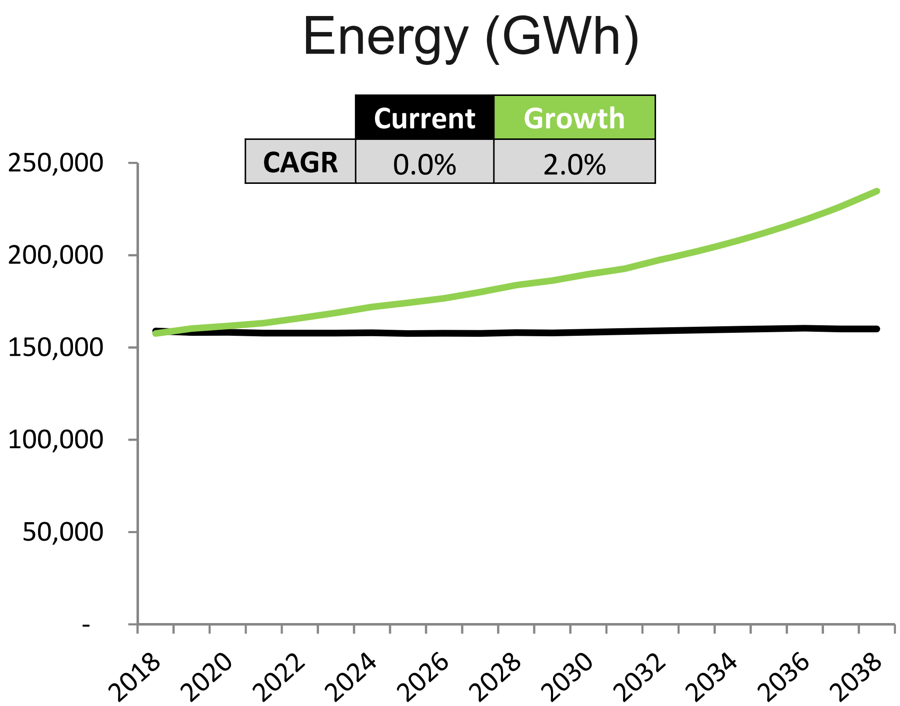
Minor growth in Data Centers in current outlook. Recent developments indicate the potential of significant increase in penetration

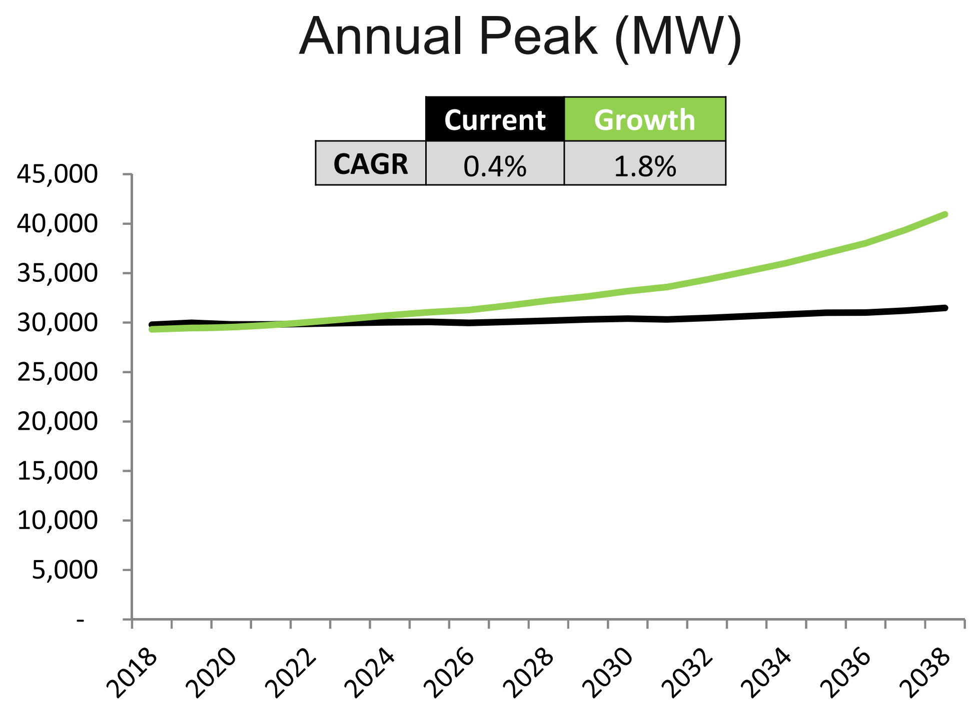
3. Growth: Scenario Assumption Impacts

- Higher productivity yields in C&I sector lead to demand growth
- Real per capita income increases DER, Solar PV, and EV adoption
- Electrification comes from EV and Data Centers

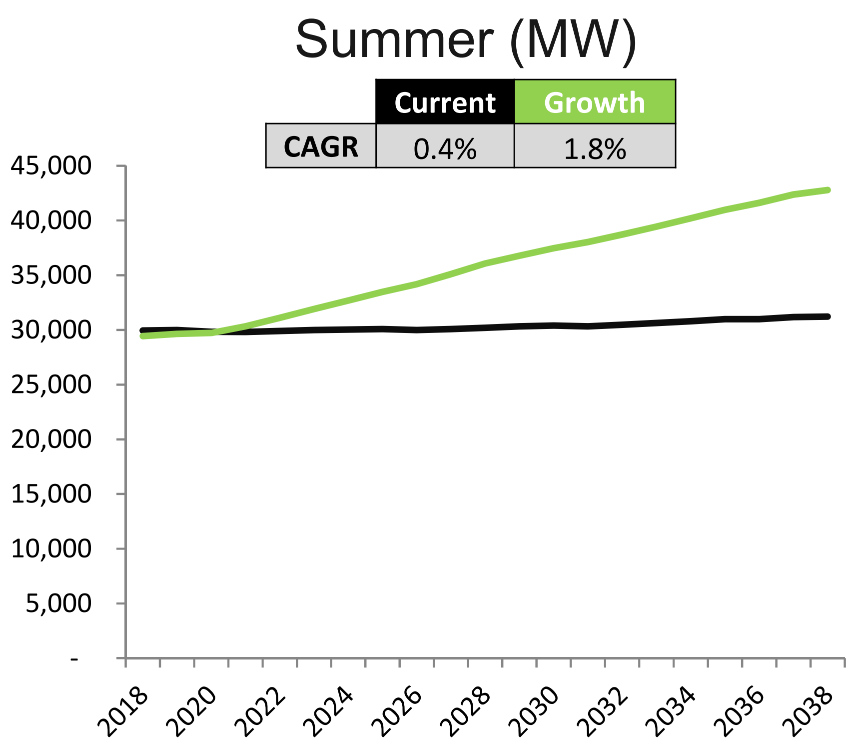


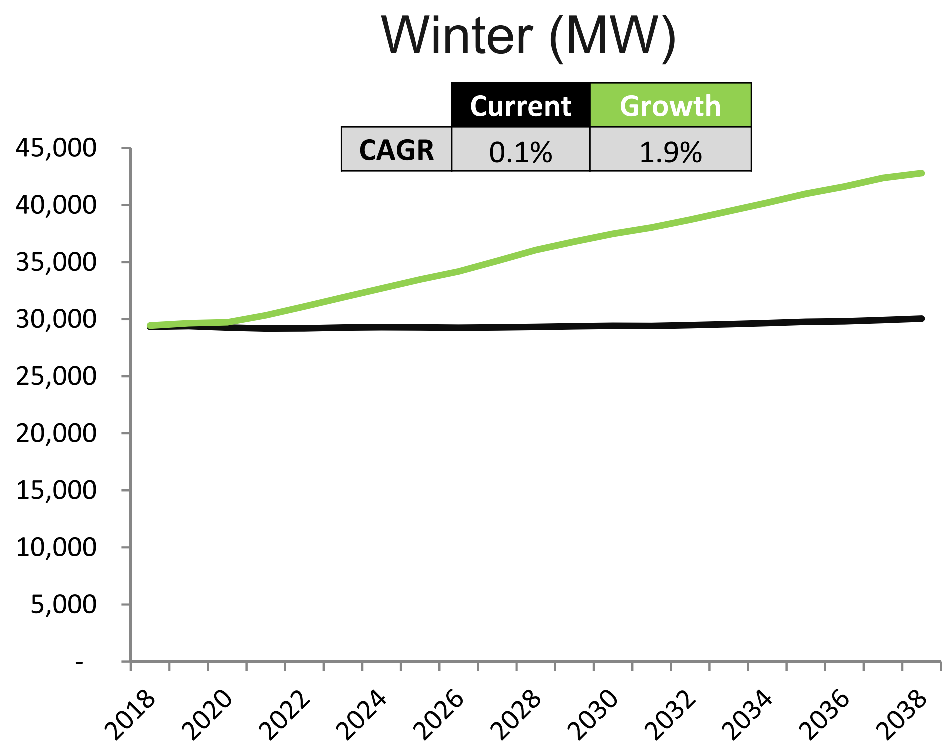
3. Growth: Energy & Peaks





3. Growth: Seasonal Peak

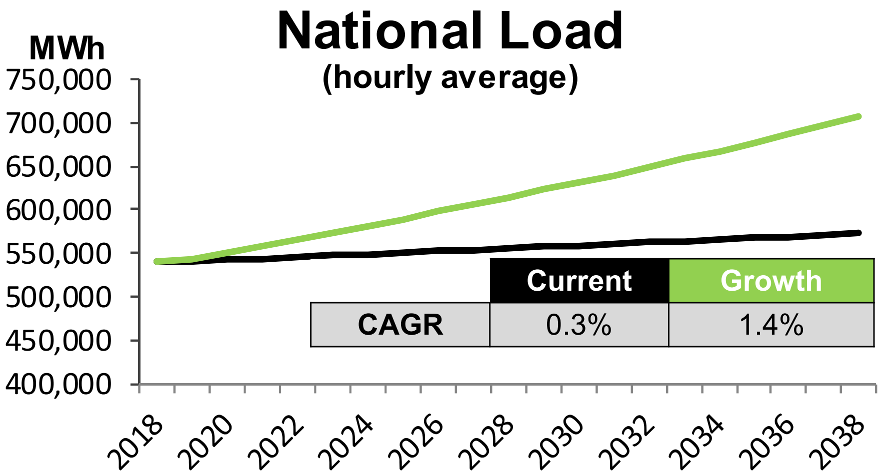


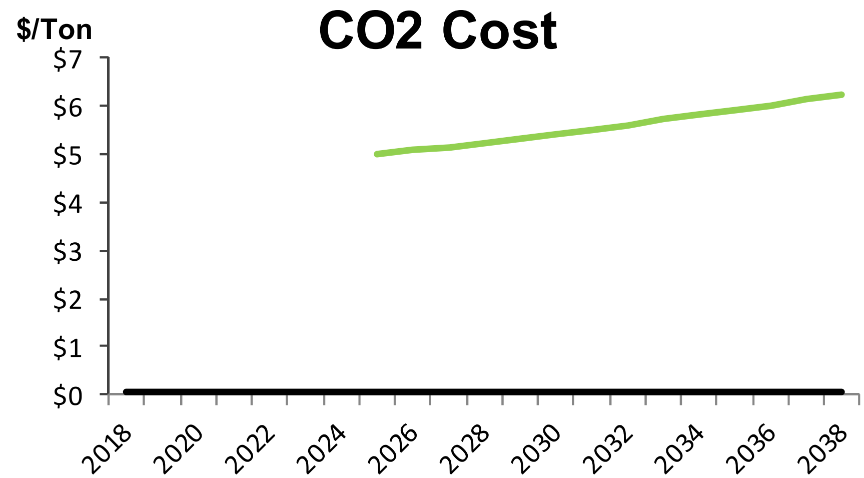


3. Growth: Commodity Assumptions

Drivers	Description
National Demand Growth	• Strong U.S. demand growth: increases from 0.3% to 1.4%
CO2 Regulations	• High CO2 costs ($5/ton) starting in 2025 and increasing with inflation
Solar Prices	• No change in solar costs
Gas Prices	• Higher Henry Hub gas prices due to higher gas demand
Gas Exports	• Lower gas exports due to higher gas prices
Coal Prices	• No change in coal prices
National Capacity Mix	• No change in solar construction; coal capacity continues to decline at same pace; new natural gas capacity increases to meet demand growth.

3. Growth: National Impacts



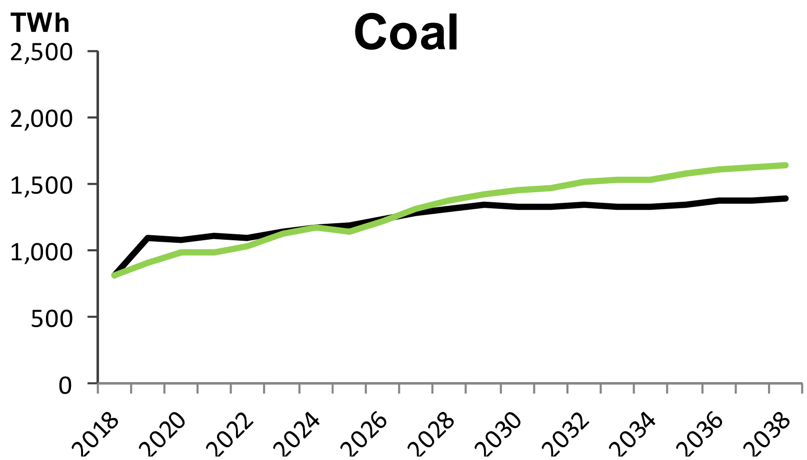


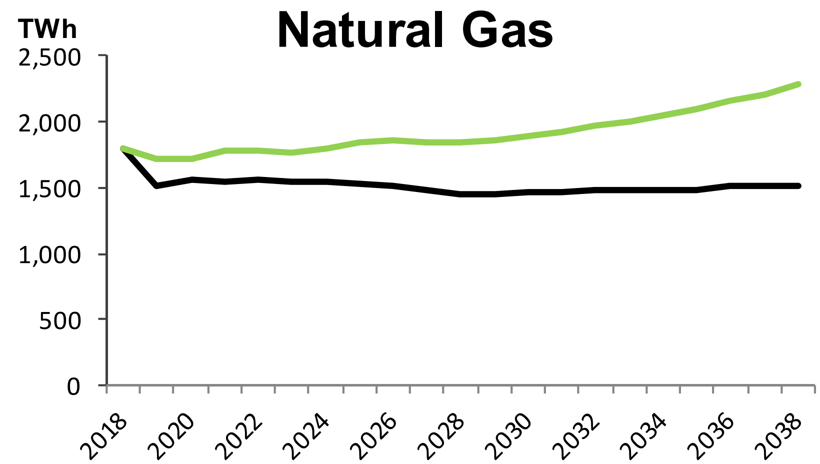
National Capacity Mix by 2038

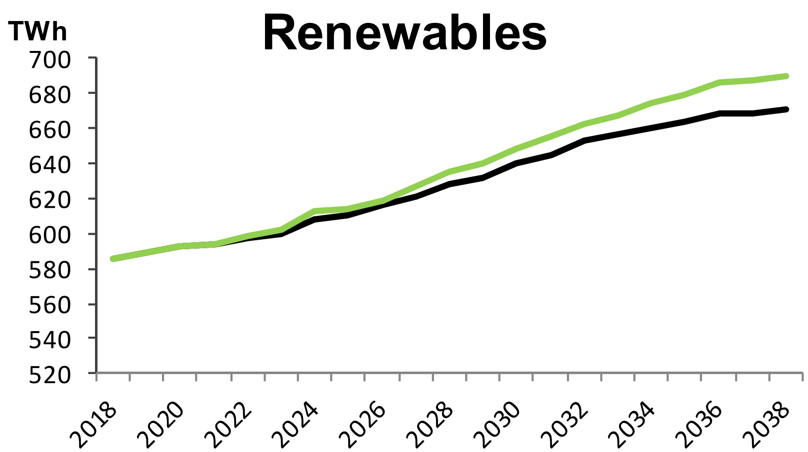
	Coal	NatGas	Nuclear	Hydro	Wind	FuelOil	Solar	Other
Current	20%	52%	7%	9%	7%	1%	3%	1%
Growth	20%	53%	7%	8%	7%	1%	3%	1%

Natural gas capacity is added to meet increased national demand.

3. Growth: National Generation by Fuel



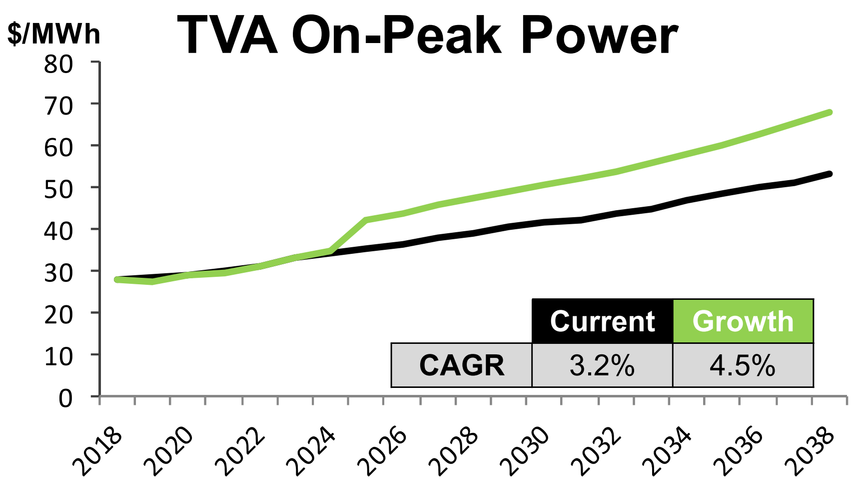




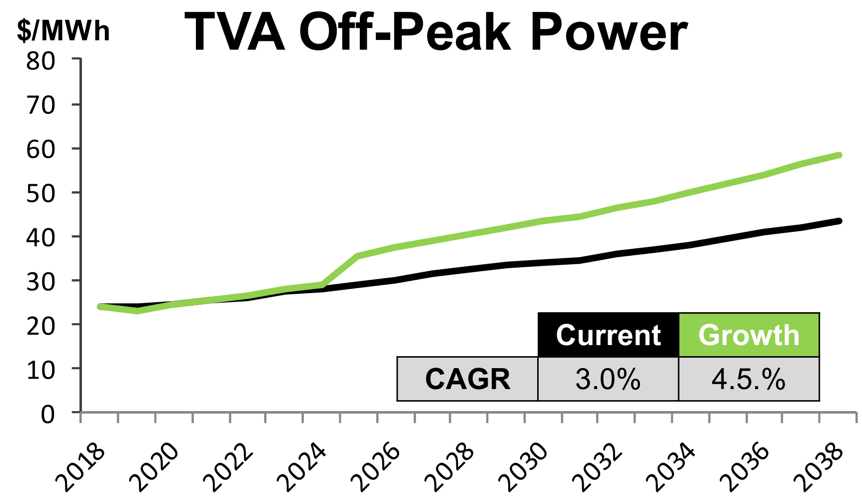
Increased generation from all sources needed to meet high demand escalation.

Natural gas has the largest increase while CO2 costs depress coal generation.

3. Growth: TVA Wholesale Power Prices



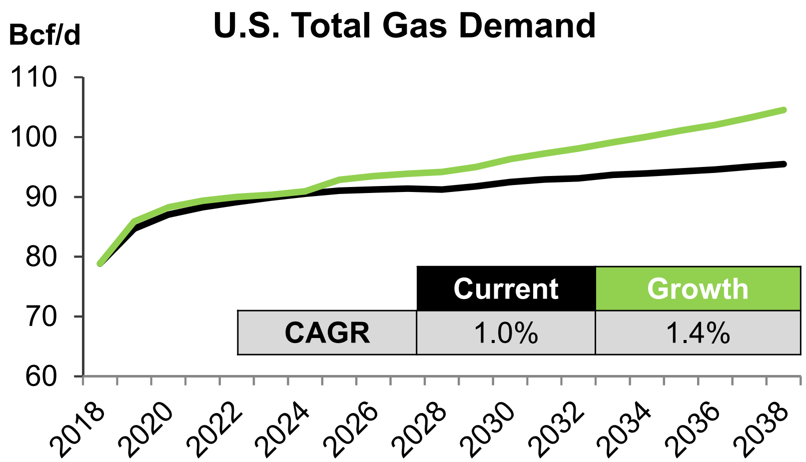
	Current	Growth
CAGR	3.2%	4.5%

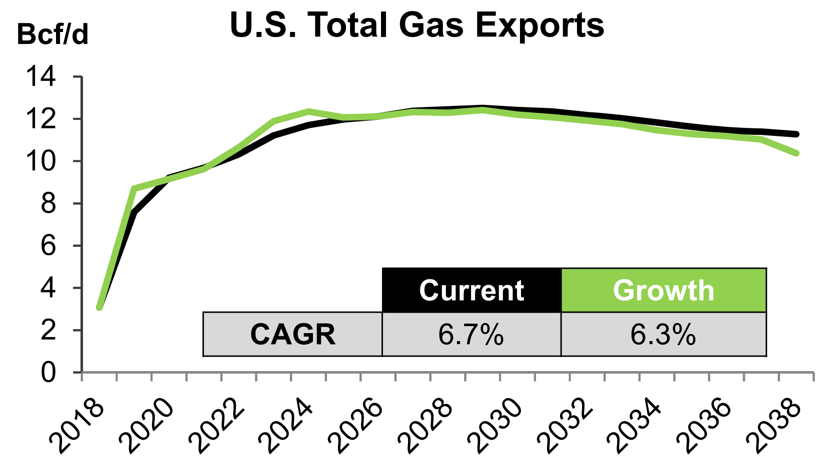


	Current	Growth
CAGR	3.0%	4.5.%

The combination of higher natural gas prices and CO2 costs drive power prices higher in 2025.

3. Growth: Natural Gas Demand & Exports





Higher gas demand due to strong overall demand & higher gas burn

Higher gas prices adversely impact the gas export economics, resulting in lower exports

4. Decarbonization

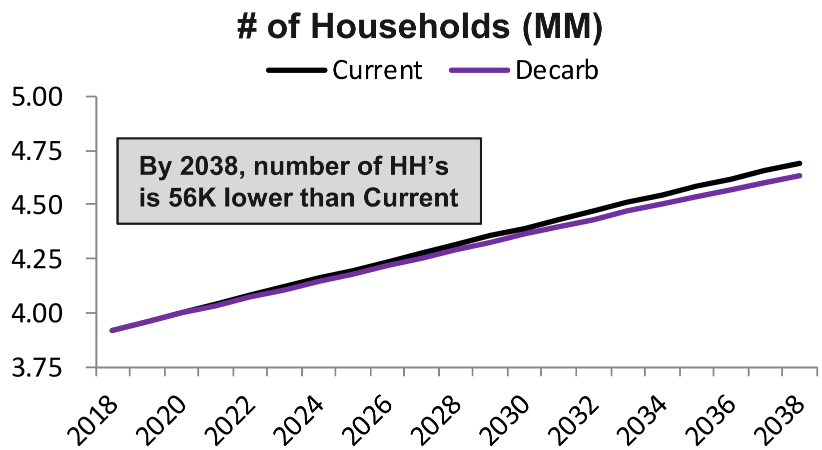
Decarbonization

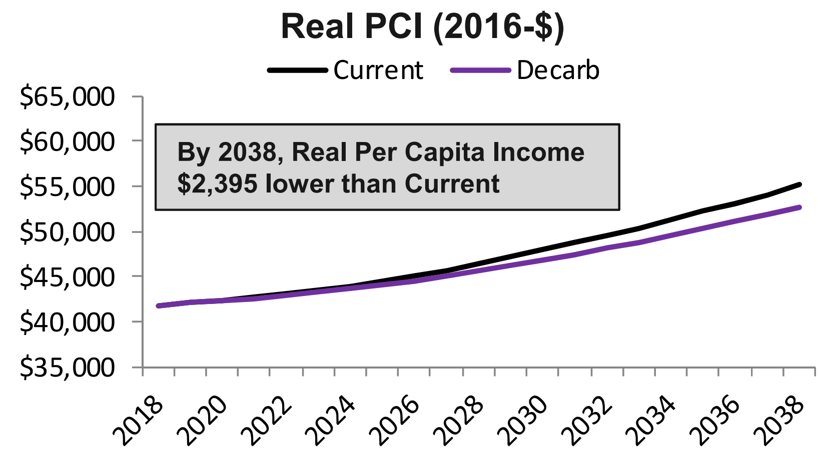
- Concern over climate change creates strong federal push to curb GHG emissions, increasing CO2 emission penalties for utilities and incentives for non-emitting technologies
- Compliance with new rules increases energy prices and inflation; US-based industry becomes less competitive, resulting in lagging economic growth that fails to rebound to trend levels
- Fracking regulations never materialize, but gas demand impacted by CO2 penalty
- New expansion units necessary to replace existing CO2-emitting fleet

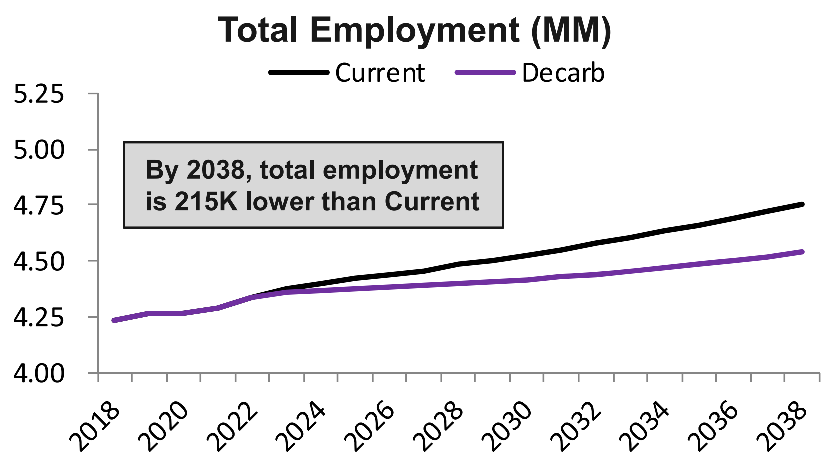
4. Decarb: Economics

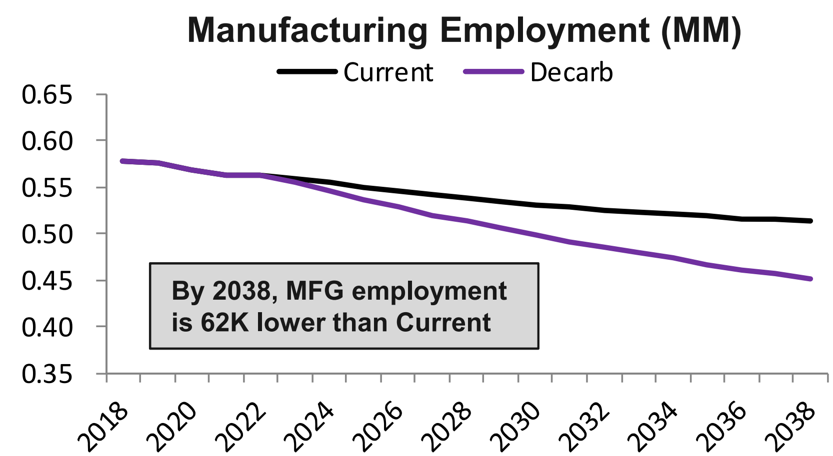
Drivers	Description
U.S. GDP	• U.S. economy grows at rate midway between Current and Economic Downturn: 1.8% / year • Regulatory impacts raise U.S. energy costs thereby reducing economic growth
U.S. Inflation	• U.S. inflation (GDP-IPD) rate midway between Current and Economic Downturn: 2.1% average • Increase in energy costs impacts capital investment, adding to business costs
TVA Region variables	• Based on historical correlations and input variations in GDP and inflation, our model simulates TVA economic and demographic variables to produce corresponding TVA region forecasts.
Labor Force Participation	• Erodes, returning to post-Great Recession lows; resulting TVA region employment reflects modest growth over the forecast period.

4. Decarb: Economic Characteristics





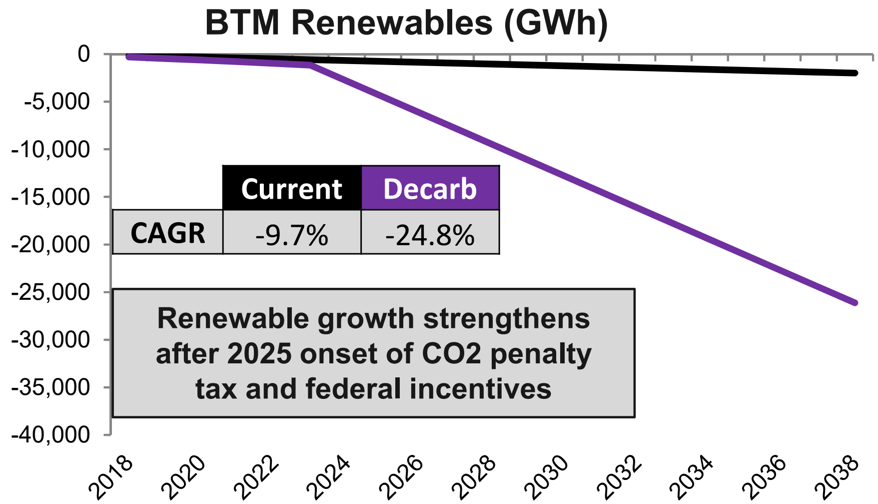


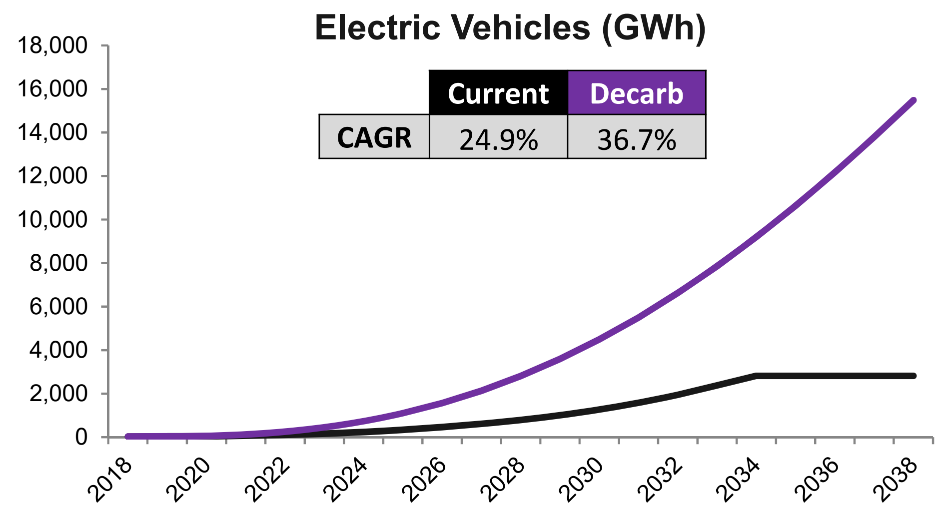


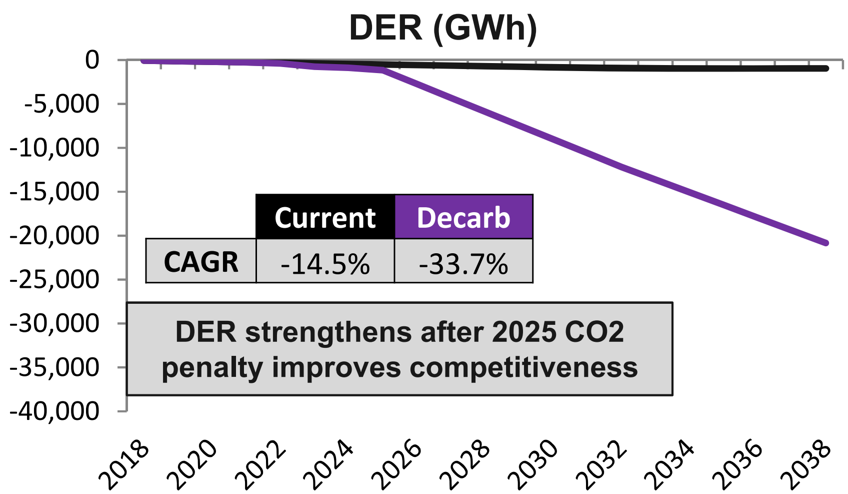
4. Decarb: Load Assumptions

Driver	Description
Renewables (BTM)	• Increased behind-the-meter solar penetration due to increased federal incentives lowering the effective consumer cost of solar (+ battery) systems • Up to 26,000 GWh by 2038
Electric Vehicle Growth	• Increased EV incentive leads to higher penetration rates relative to base case • EV's grow to 15,000 GWh by 2038 (2m EVs)
Energy Efficiency	• Increases in EE lower emissions for industries due to DOE standards
Combined Heat and Power	• CHP becomes economic, and we see adoption among C&I customers • 1,900 GWh by 2028 with no additional CHP after 2028
Demand Drivers	• Federal incentives lead to higher EV adoption • Federal incentives drive residential, commercial and industrial renewable growth

4. Decarb: Load Characteristics





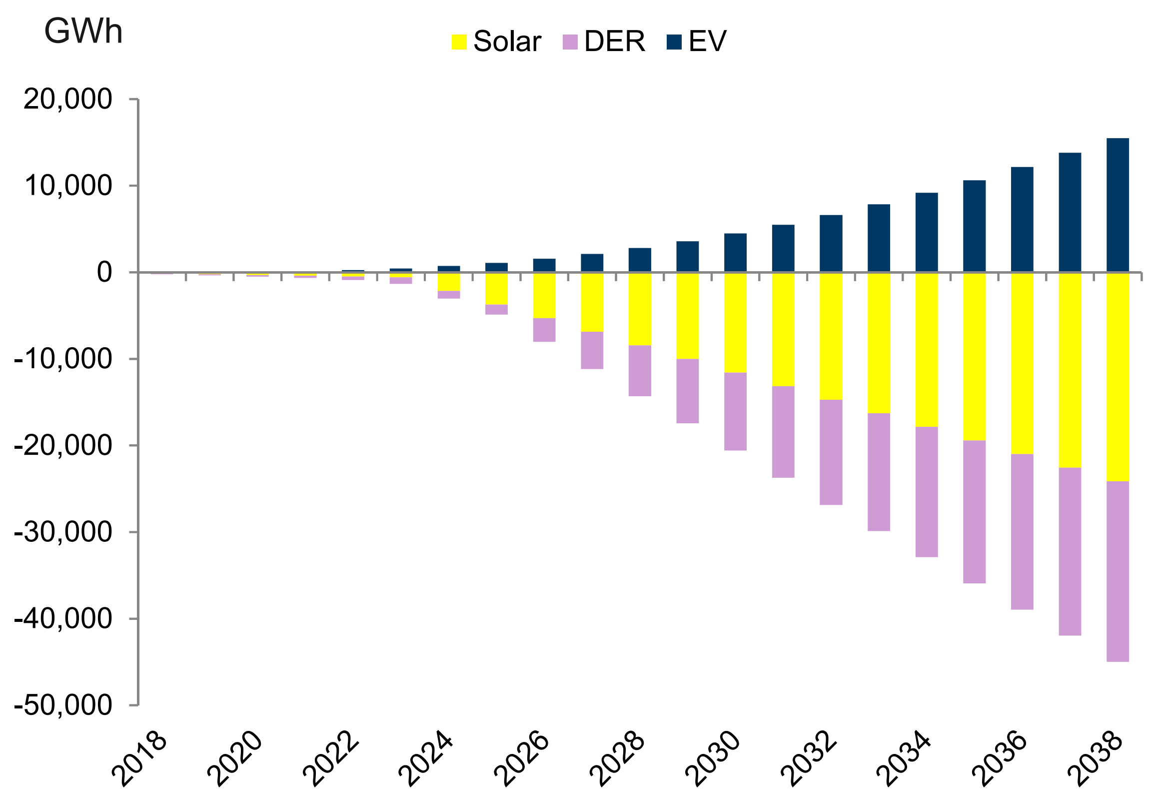


To promote CO_2 reduction:

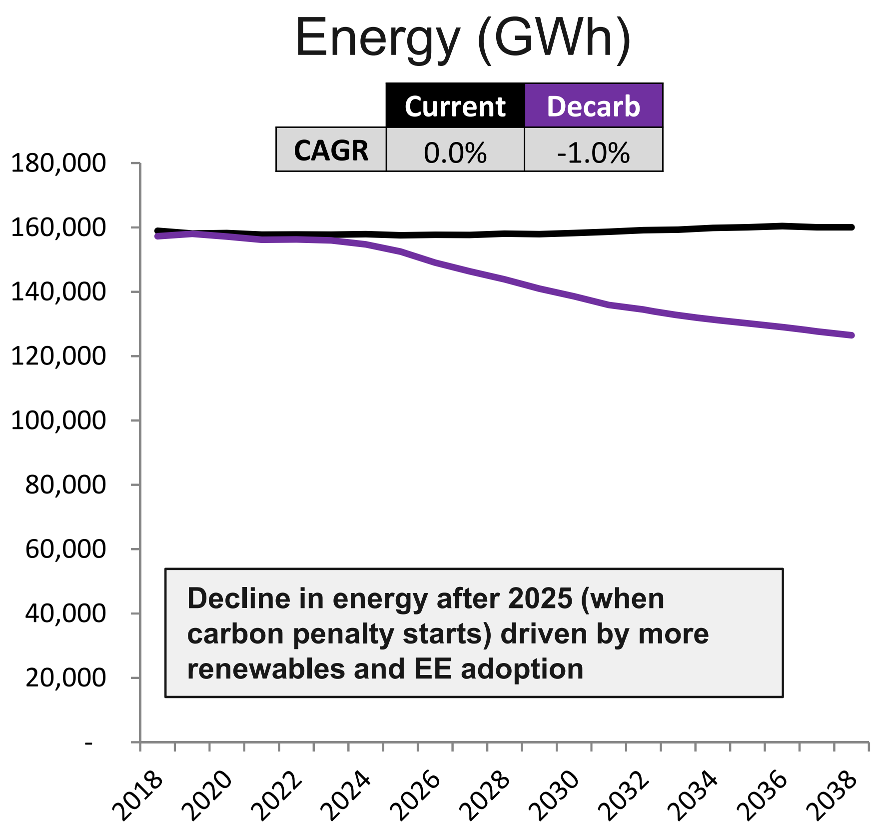
- Extension of Fed ITC until end of study
- Additional federal incentives after 2025 with respect to reducing upfront costs of renewables
- EV incentive to reduce emissions

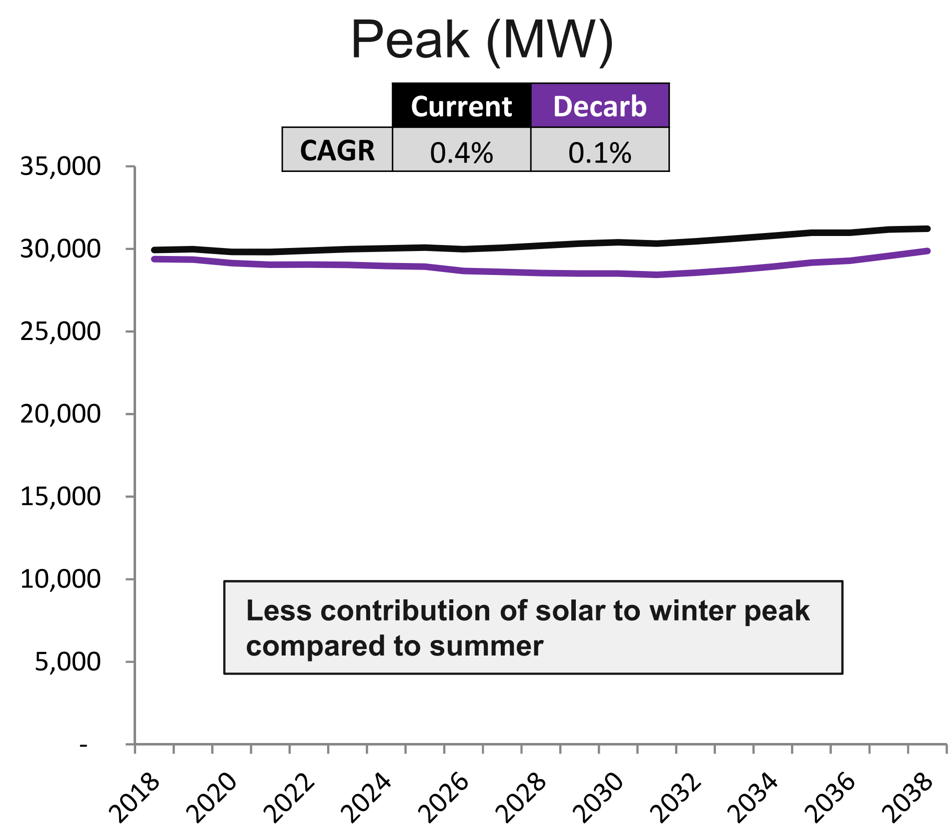
4. Decarb: Scenario Assumption Impacts

- Carbon penalty starts in 2025
- Federal incentives leads to more solar, battery and EV growth
- EV growth also driven by increased residential solar and storage installations



4. Decarb: Energy & Peak

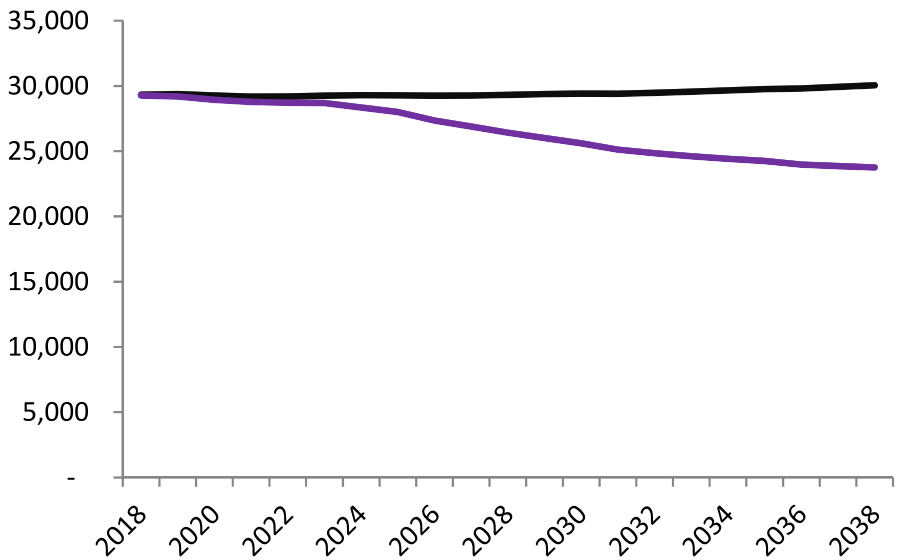




4. Decarb: Seasonal Peak

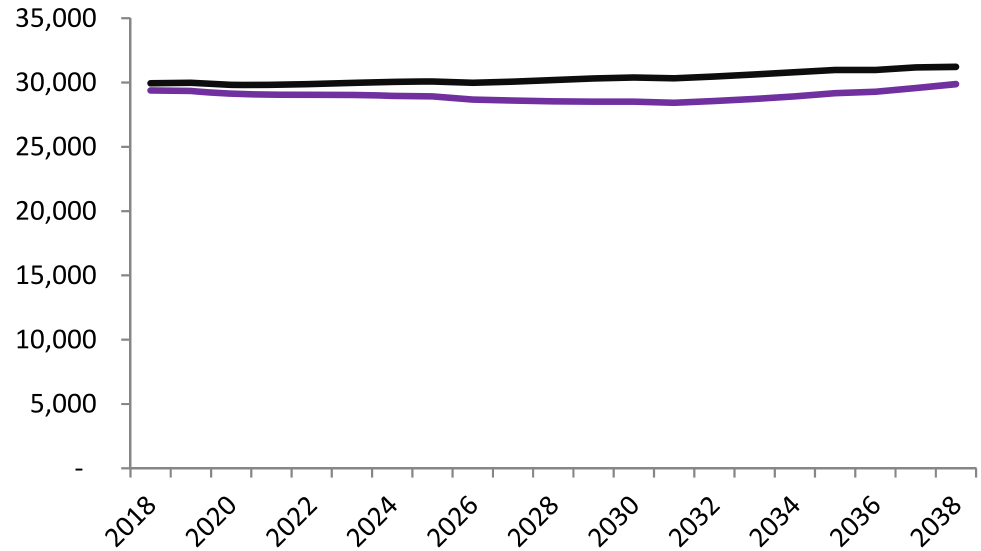
Summer (MW)

	Current	Decarb
CAGR	0.4%	-1.0%



Winter (MW)

	Current	Decarb
CAGR	0.1%	0.1%



4. Decarb: Commodity Assumptions

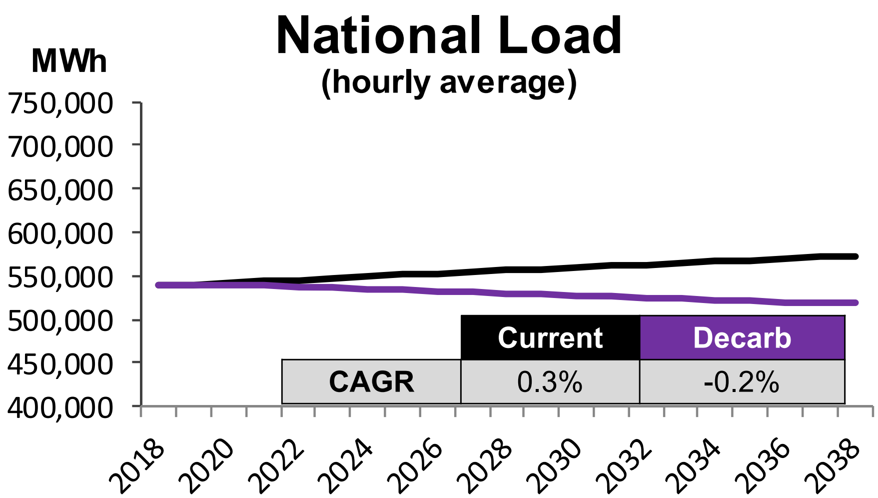
Drivers	Description
National Demand Growth	• Declining U.S. demand growth: from 0.3% to -0.2%
CO2 Regulations	• Very high CO2 costs increasing with inflation: $25/ton in 2025 with additional $10/ton in 2035
Solar Prices	• Lower solar costs
Gas Prices	• Higher Henry Hub gas prices due to decarbonization
Gas Production	• Higher gas production drop due to decarbonization
Coal Prices	• Lower coal prices due to high CO2 costs depressing demand
National Capacity Mix	• Strong increase in solar construction; coal capacity continues to decline at same pace tds1 new natural gas capacity is flat as overall power demand is declining.

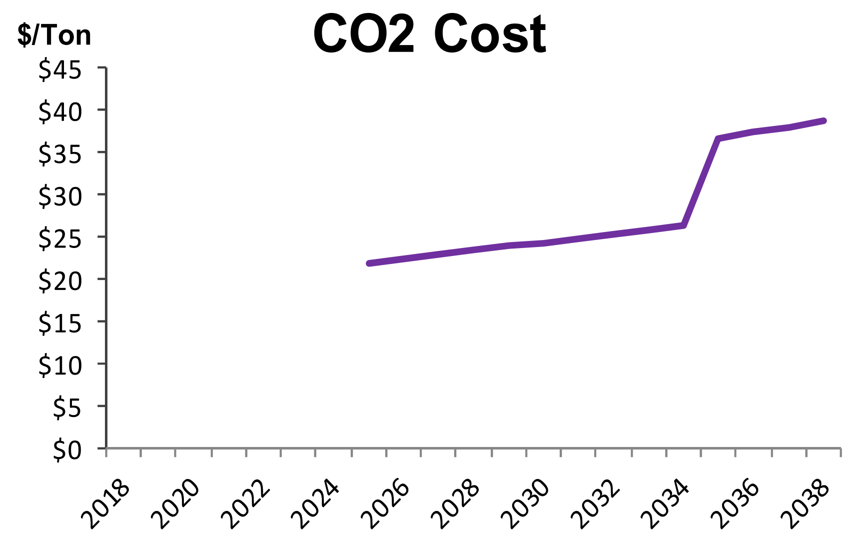
Slide 92

tds1 please check with Scott

Sorrell, Timothy Dean, 7/16/2018

4. Decarb: National Impacts



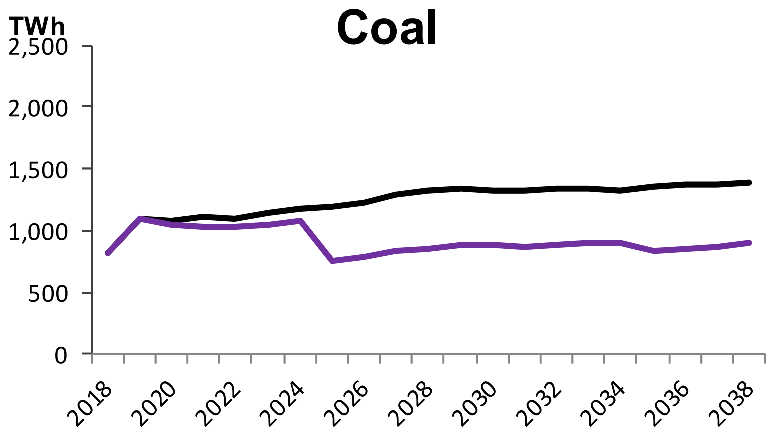


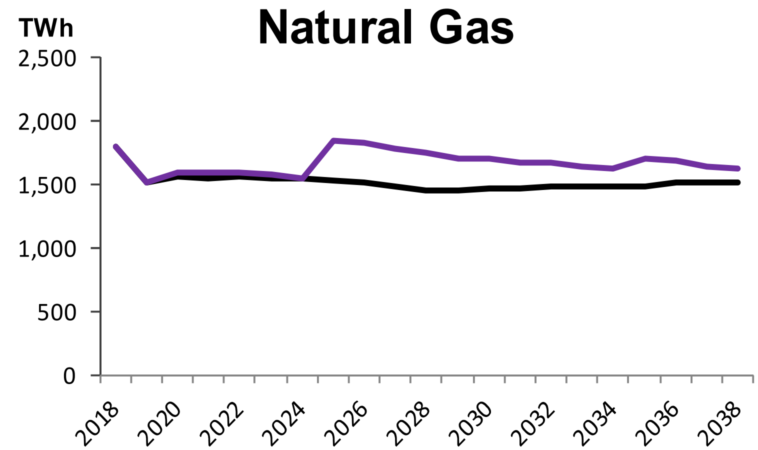
National Capacity Mix by 2038

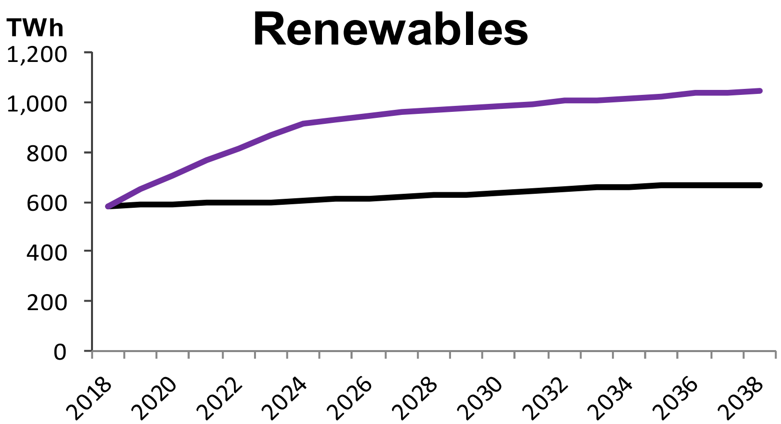
	Coal	NatGas	Nuclear	Hydro	Wind	FuelOil	Solar	Other
Current	20%	52%	7%	9%	7%	1%	3%	1%
Decarb	23%	42%	8%	9%	8%	1%	8%	1%

Lower solar costs push solar capacity builds higher, offsetting some need for increased natural gas capacity.

4. Decarb: National Generation by Fuel





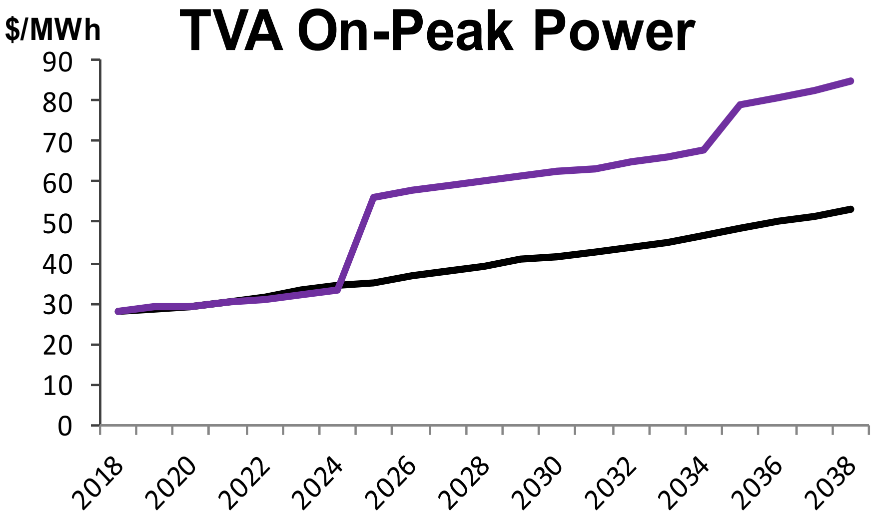


Very high CO2 costs starting in 2025 depresses coal generation.

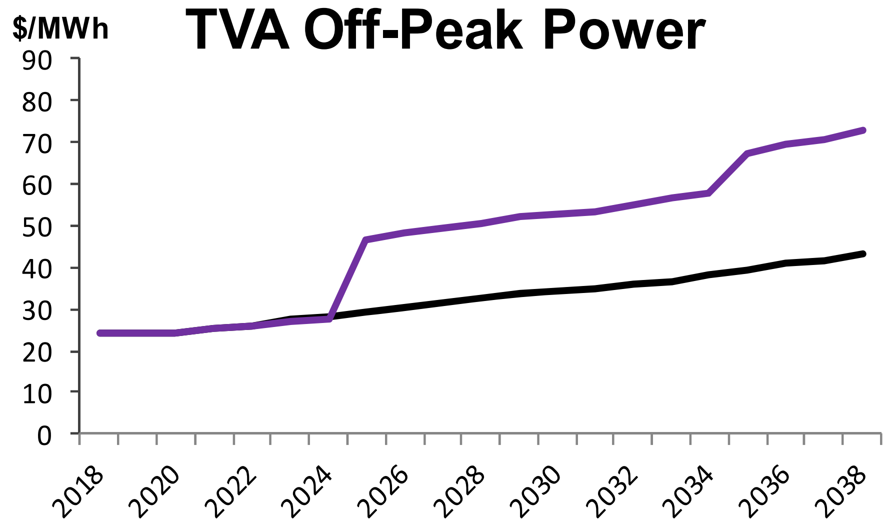
Even with increased natural gas prices, gas generation increases as the effect of CO2 costs on dispatch costs is half that of coal units.

Lower solar prices push solar capacity builds and generation.

4. Decarb: TVA Wholesale Power Prices

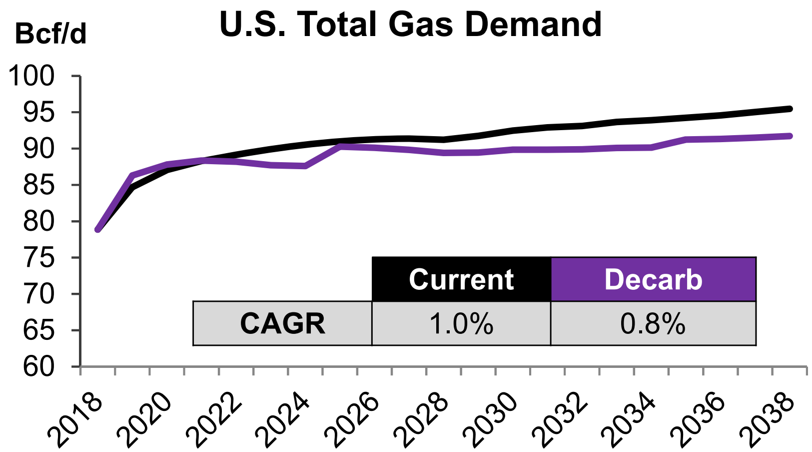


	Current	Decarb
CAGR	3.2%	5.7%

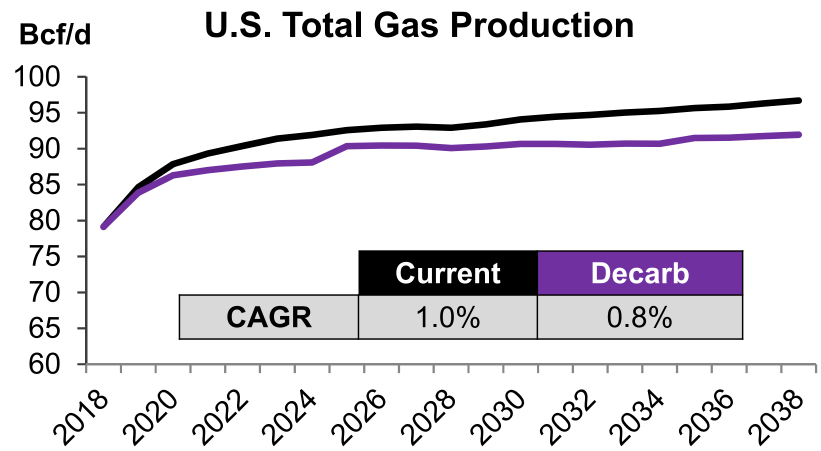


	Current	Decarb
CAGR	3.0%	5.7%

4. Decarb: Natural Gas Demand & Production



	Current	Decarb
CAGR	1.0%	0.8%



	Current	Decarb
CAGR	1.0%	0.8%

Lower gas demand due very high CO_2 cost

Lower gas production due to very high CO_2 cost & overall decarbonization

Rapid DER Adoption

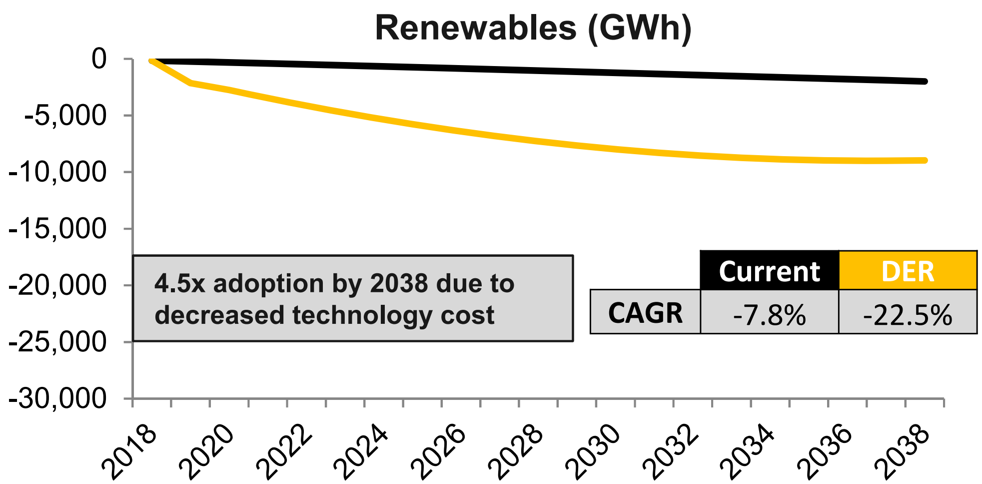
Rapid DER Adoption

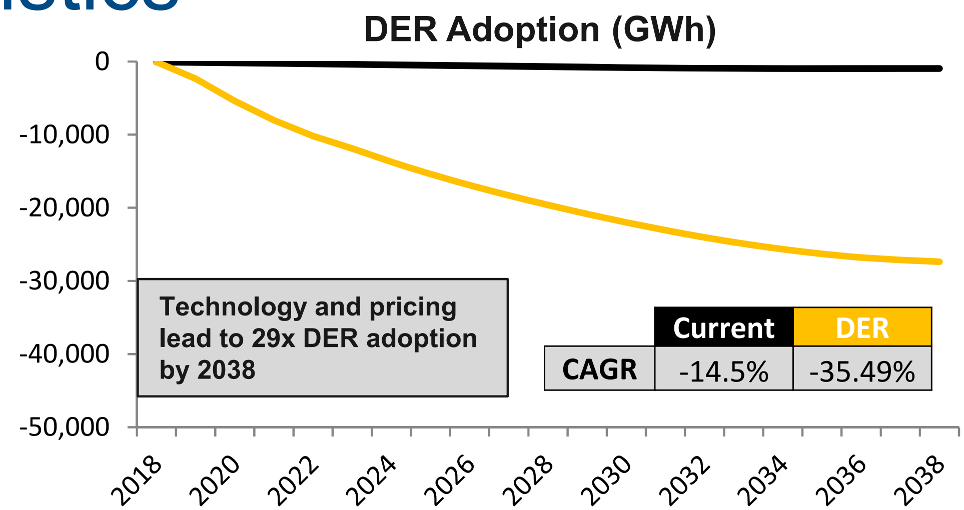
- Growing consumer awareness of and preference for energy choice, coupled with rapid advances in energy technologies, drive high penetration of distributed generation, storage, and energy management
- Utilities are no longer the sole source of generation and multiple options are available to consumers
- Market shift results in lower loads, decreased need for supply-side generation, but potential impacts to transmission and distribution planning and infrastructure

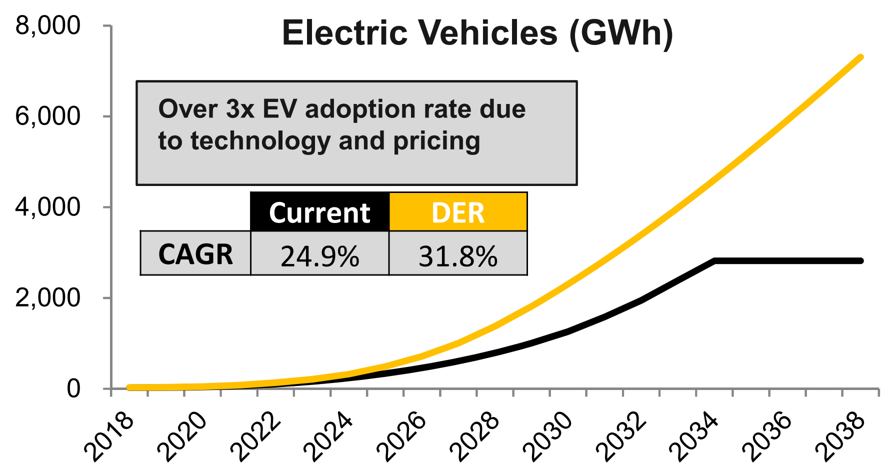
5. DER: Load Assumptions

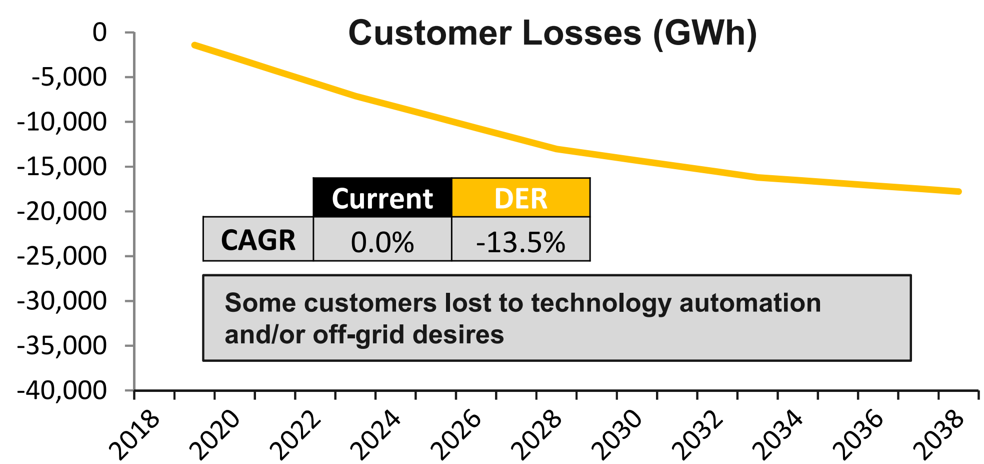
Driver	Description
Renewables (BTM)	• Increased behind-the-meter solar penetration due to decreasing technology costs for residential applications (9,000 GWh, 8% energy reduction in 2038)
Electric Vehicle Growth	• Increased EV penetration rates relative to base case due to increases in solar and storage adoption • EVs grow to 7,000 GWh by 2038 (1.5m EVs, 2.5x base case)
Distributed Energy Resources	• Increases in efficiencies reduces demand (12,000 GWh by 2038) • Increase in CHP adoption due to technology advancements and cost reduction (10,000 GWh by 2038) • Energy storage adoption (4,000 GWh by 2038)
Demand Drivers	• Fast adoption of distributed resources driven by rapidly declining technology costs • Increased EV adoption (from current outlook) due to storage plus solar adoption • Off-grid customers further decrease loads

5. DER: Load Characteristics



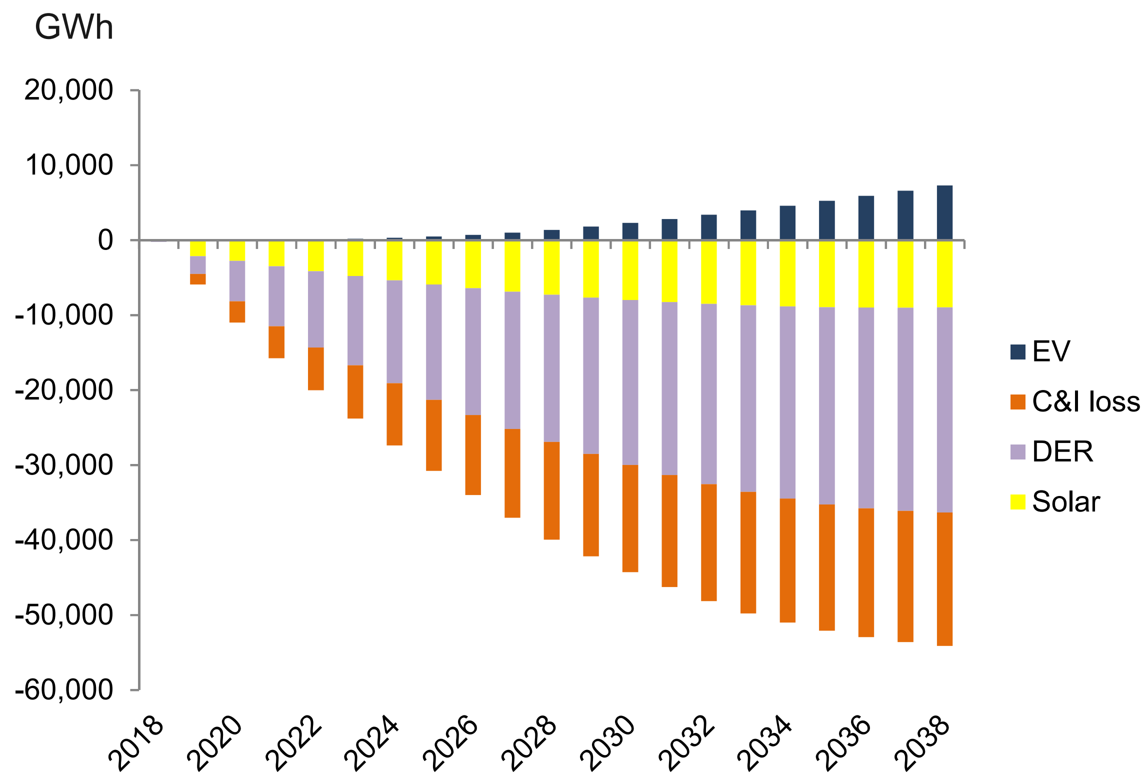




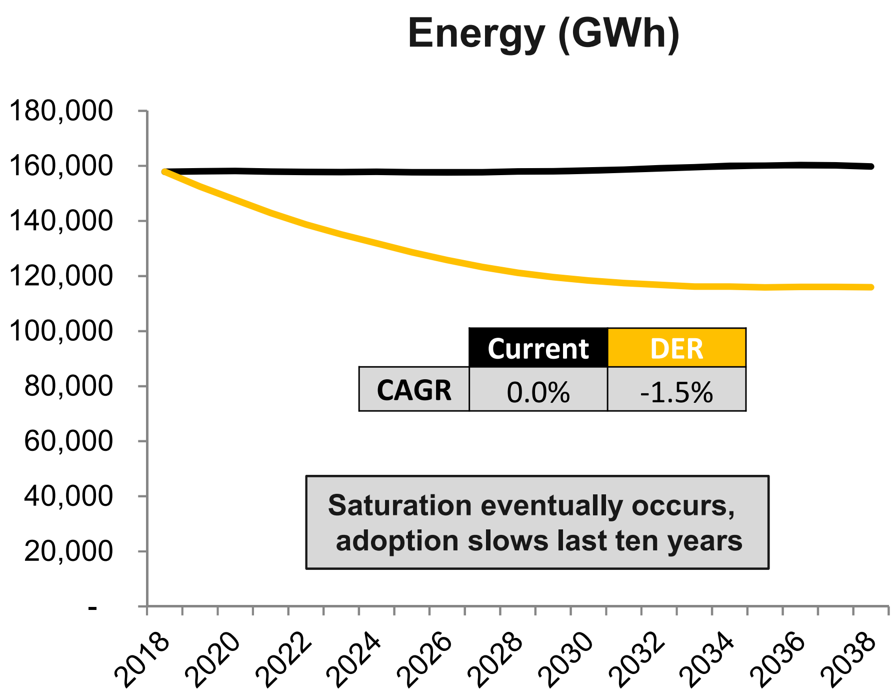


5. DER: Scenario Assumption Impacts

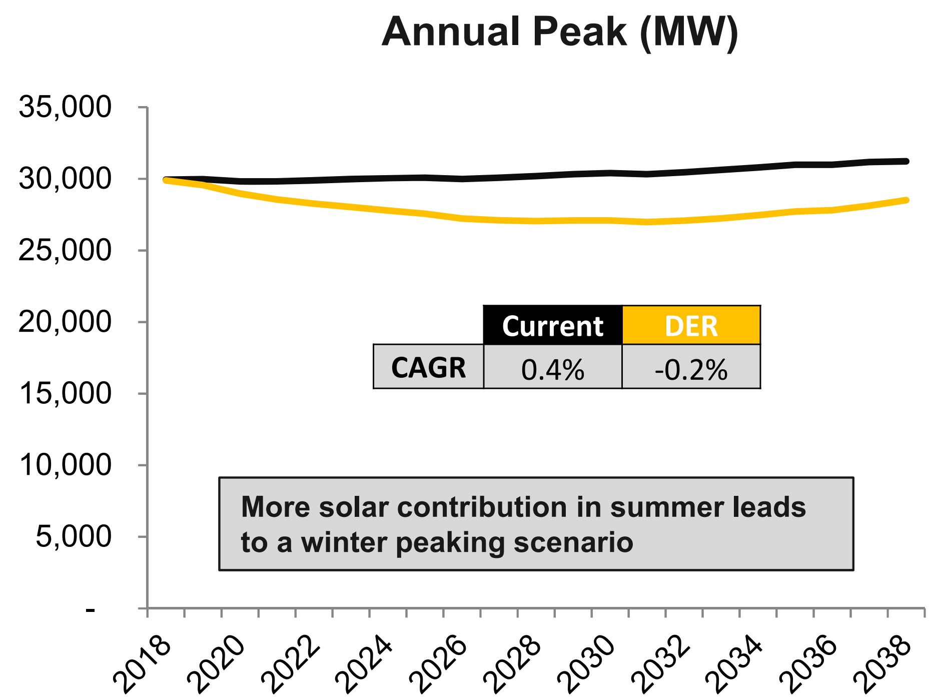
- Solar + Battery technology becomes economic by 2023
- EV adoption driven by increases in solar + battery adoption
- Customer losses in the C&I sector due to off-grid desire and/or technological advancements resulting in automation efficiencies



5. DER: Energy & Peak

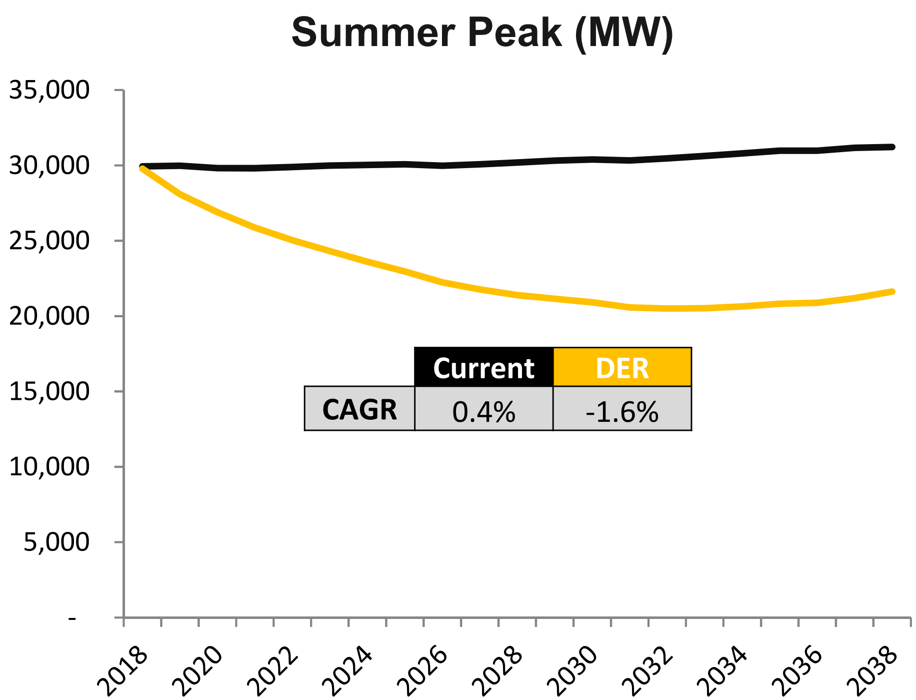


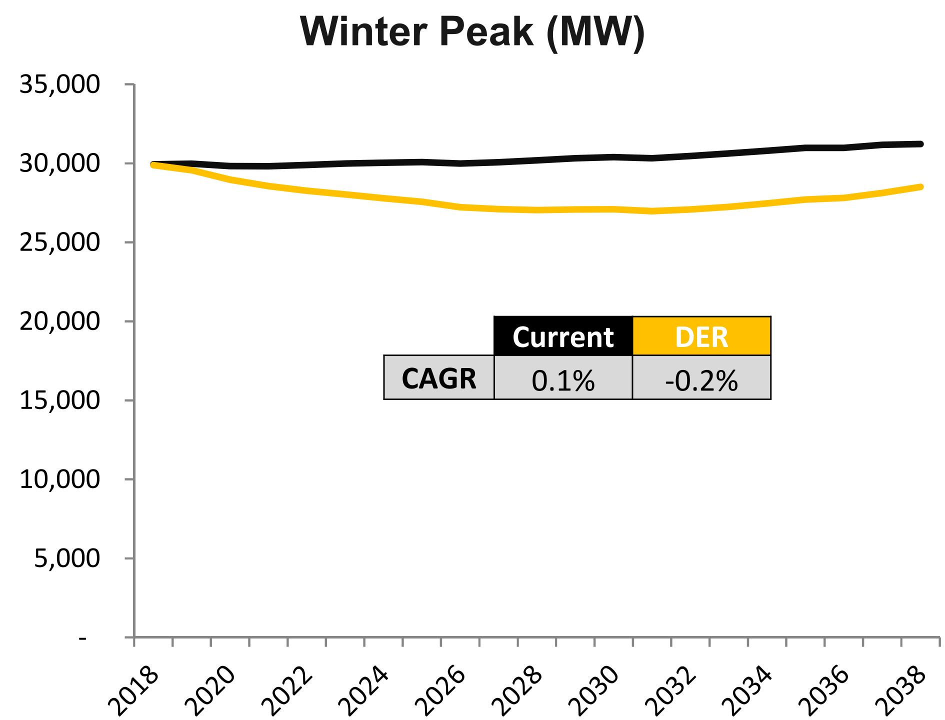
	Current	DER
CAGR	0.0%	-1.5%



	Current	DER
CAGR	0.4%	-0.2%

5. DER: Seasonal Peak

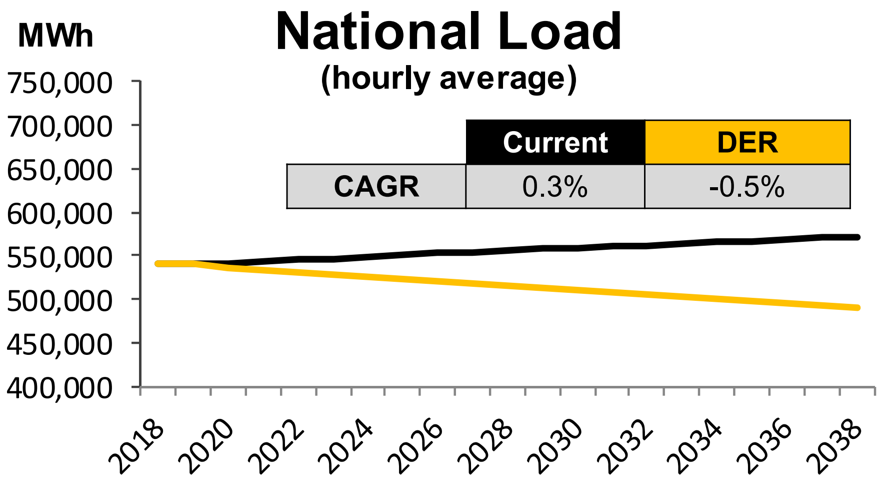




5. DER: Commodity Assumptions

Drivers	Description
National Demand Growth	• Strong decline in U.S. demand growth: from 0.3% to -0.5%
CO2 Regulations	• No change in CO2 cost assumptions ($0/ton)
Solar Prices	• Very low solar costs
Gas Prices	• Lower Henry Hub gas prices due to lower gas demand
Gas Exports	• Higher gas exports due to lower gas prices
Coal Prices	• Lower coal prices due to lower demand and lower natural gas prices
National Capacity Mix	• Strong increase in solar construction; coal capacity continues to decline at same pace; new natural gas capacity is flat as overall power demand is declining.

5. DER: National Impacts



	Current	DER
CAGR	0.3%	-0.5%

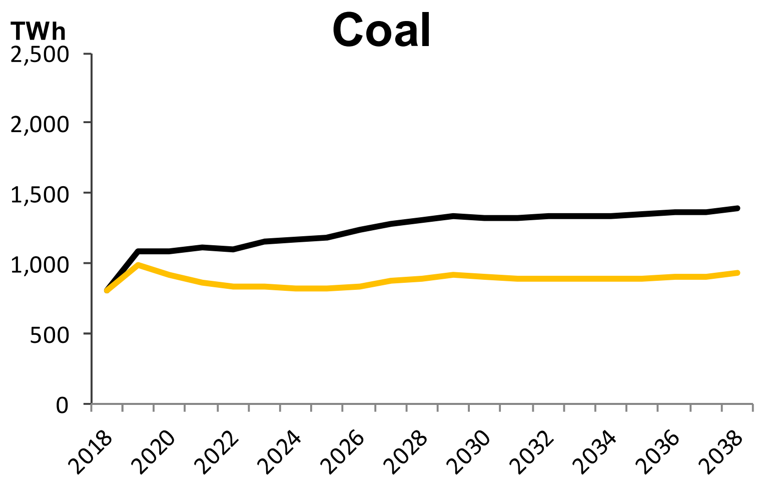
National Capacity Mix by 2038

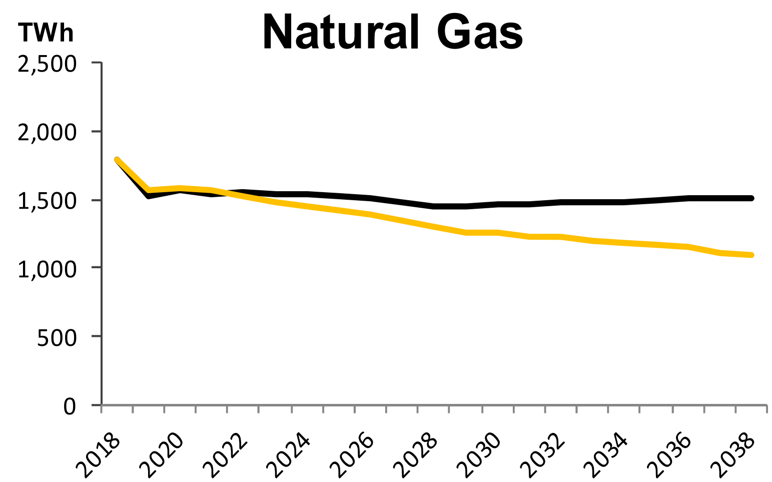
	Coal	NatGas	Nuclear	Hydro	Wind	FuelOil	Solar	Other
Current	20%	52%	7%	9%	7%	1%	3%	1%
DER	21%	44%	8%	9%	8%	1%	6%	1%

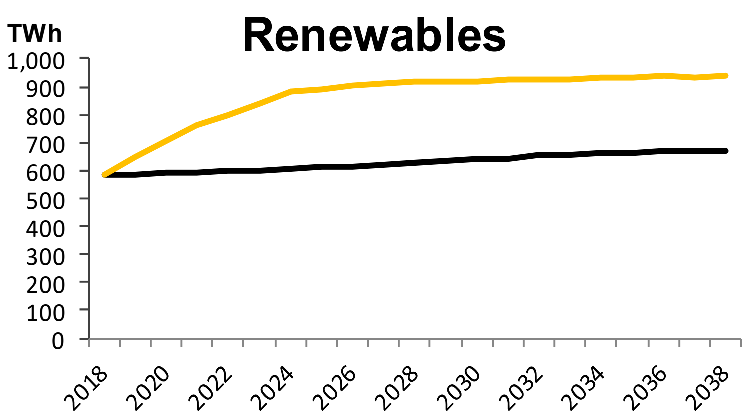
Very low solar build costs prices push solar capacity increases at the expense of natural gas units.

Large decline in national load growth depresses need for additional gas units.

5. DER: National Generation by Fuel



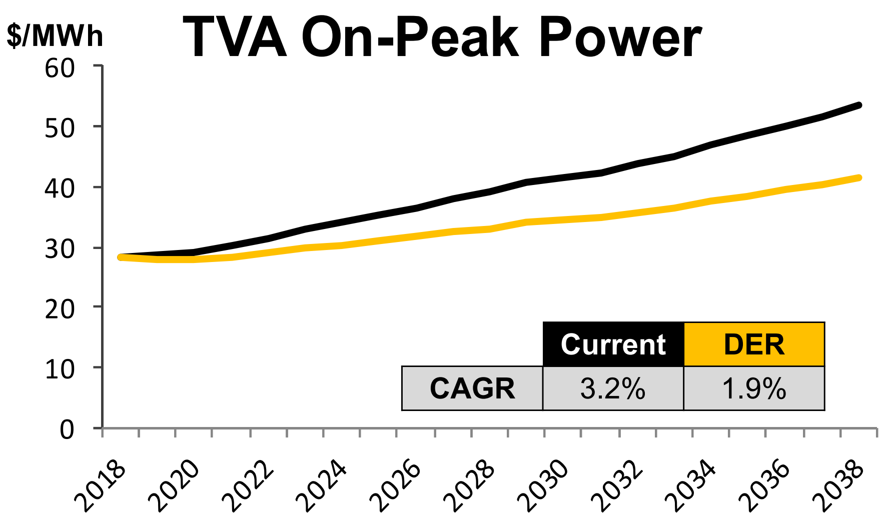


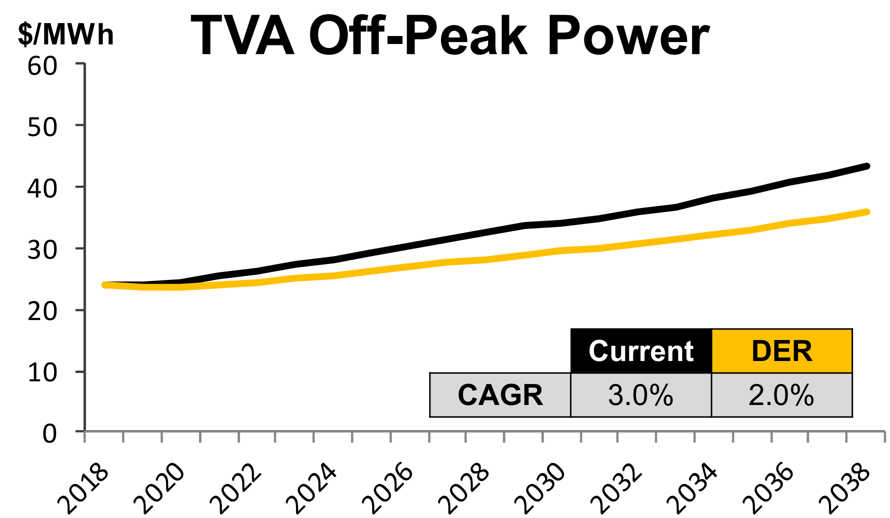


Very low solar prices push solar generation higher.

Despite lower coal and natural gas prices, fossil generation falls as overall national demand declines.

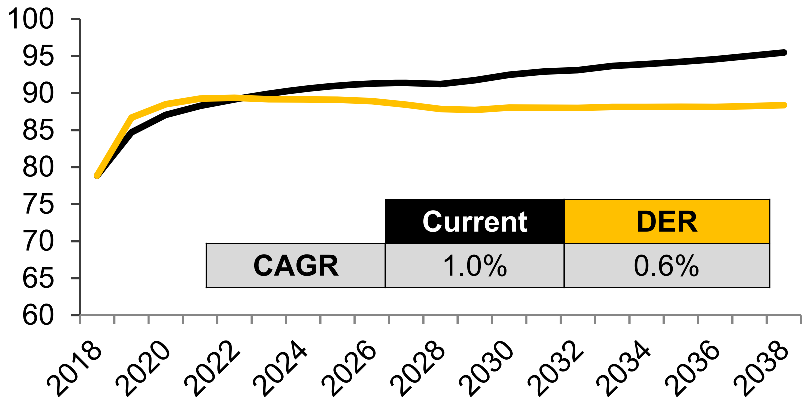
5. DER: TVA Wholesale Power Prices



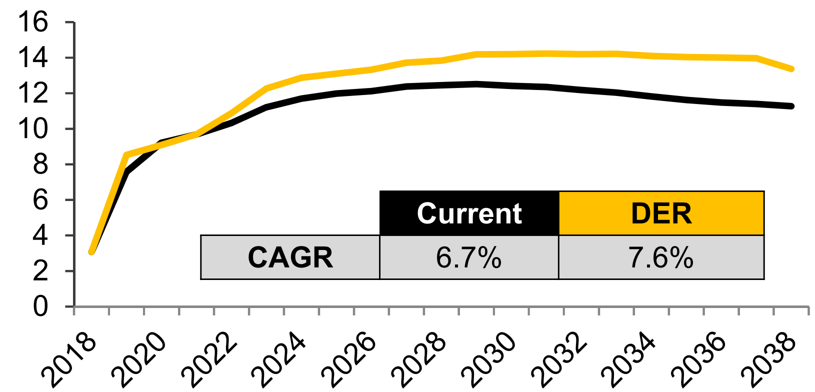


Lower coal and natural gas prices, coupled with lower demand drive the lower peak and off-peak power prices.

5. DER: Natural Gas Demand & Exports



	Current	DER
CAGR	1.0%	0.6%



	Current	DER
CAGR	6.7%	7.6%

Lower gas demand due very rapid DER adoption

Lower gas prices improve gas export economics, resulting in higher exports

No Nuclear Extensions

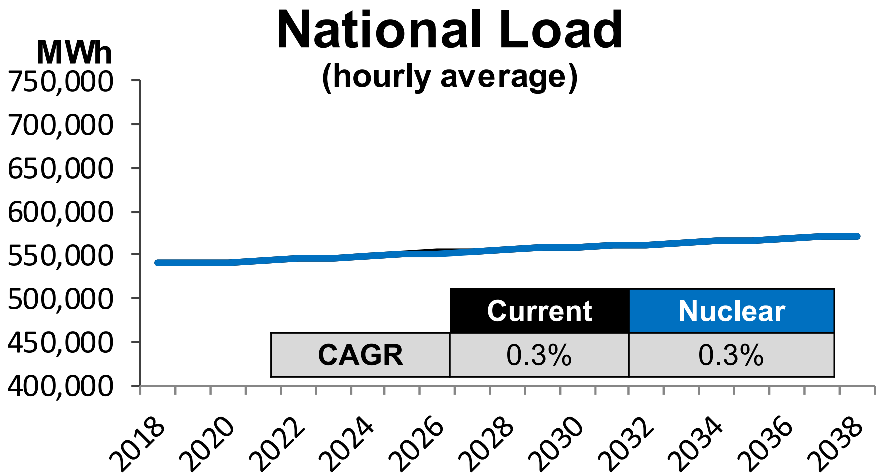
No Nuclear Extensions

- Driven by aging assets and desire for national energy security and resiliency, there is a regulatory challenge to relicensing of existing and construction of new, large scale nuclear. Both cease in favor of technologies that are more secure, modular, and flexible.
- National energy policy drives carbon regulation or legislation and promotes small modular reactor technology through subsidies to drive SMR technology breakthrough and improved economics.

6. Nuclear: Commodity Assumptions

Drivers	Description
National Demand Growth	• Same as current case: growth of 0.3%
CO2 Regulations	• No change in CO2 cost assumptions ($0/ton)
Solar Prices	• No change in from Current
Gas Prices	• No change in Henry Hub gas prices
Gas Exports	• No change in gas exports
Coal Prices	• No change in coal prices
National Capacity Mix	• Decreasing nuclear capacity after 2030. No changes in solar construction; coal capacity continues to decline at same pace; new natural gas capacity is slightly higher replacing the lost nuclear.

6. Nuclear: National Impacts



	Current	Nuclear
CAGR	0.3%	0.3%

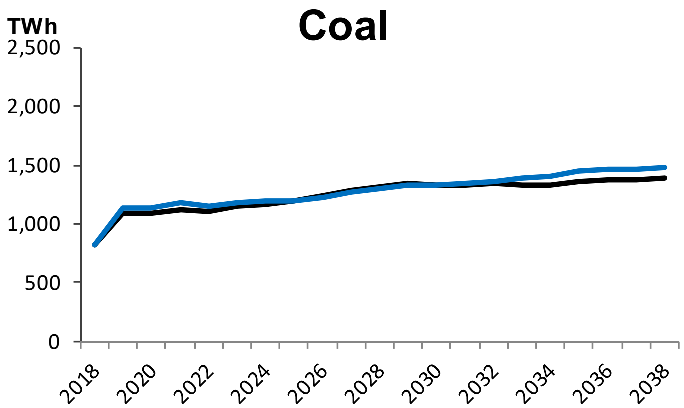
No change in national demand in this scenario.

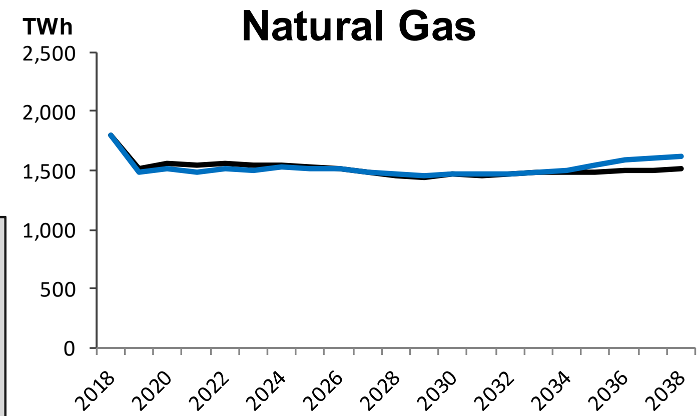
National Capacity Mix by 2038

	Coal	NatGas	Nuclear	Hydro	Wind	FuelOil	Solar	Other
Current	20%	52%	7%	9%	7%	1%	3%	1%
Nuclear	20%	53%	5%	9%	8%	1%	3%	1%

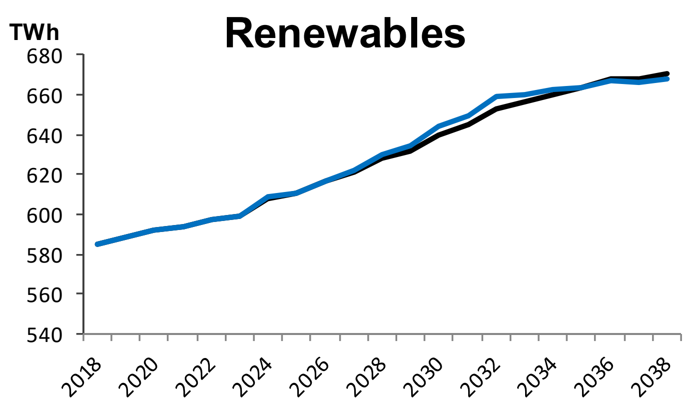
Nuclear retirements, due to units reaching their 60 year operational life, lowers nuclear capacity beyond 2030.

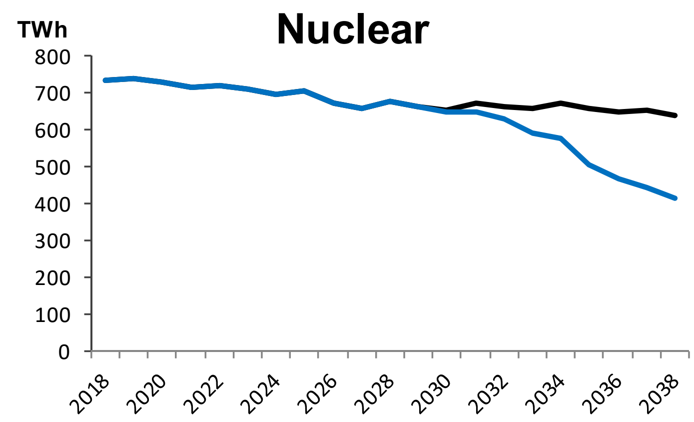
6. Nuclear: National Generation by Fuel



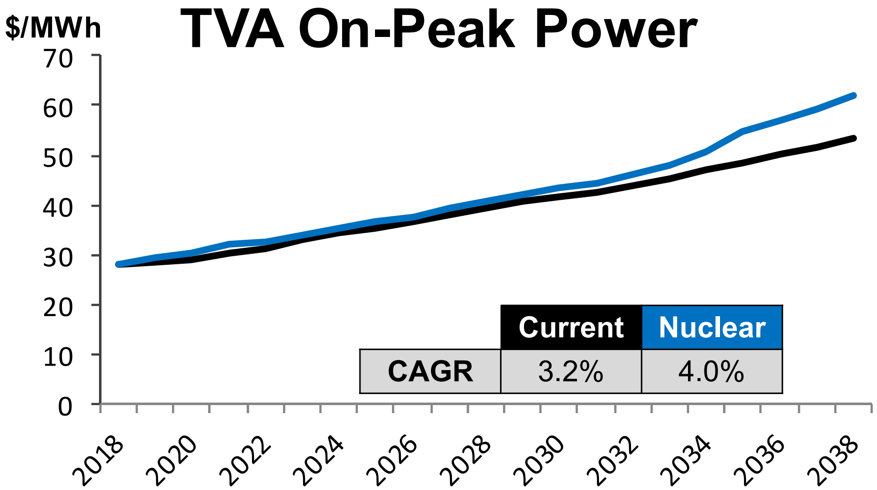


While nuclear generation is lower beyond 2030, gas and coal show a slight increase.

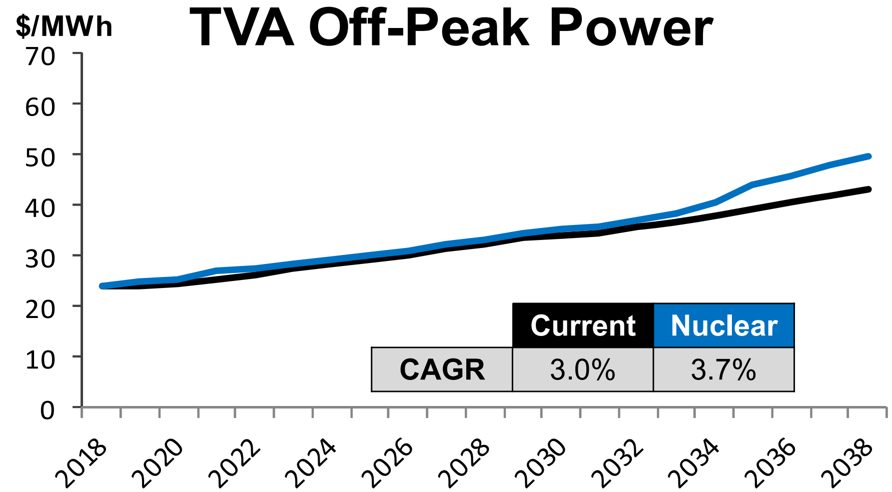




6. Nuclear: TVA Wholesale Power Prices



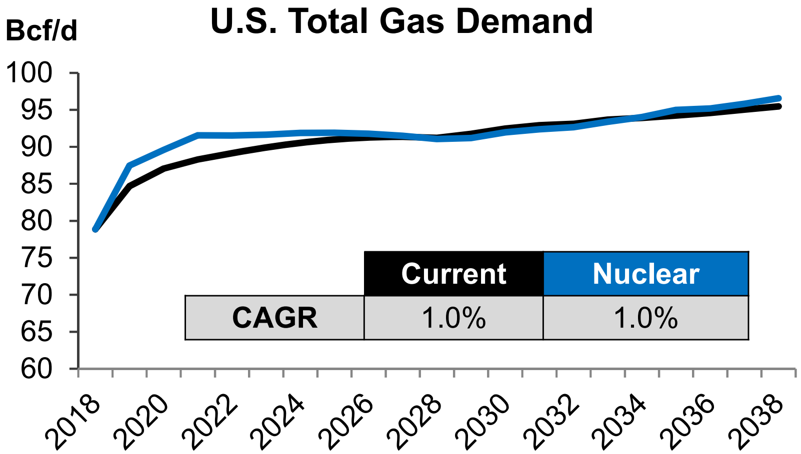
	Current	Nuclear
CAGR	3.2%	4.0%



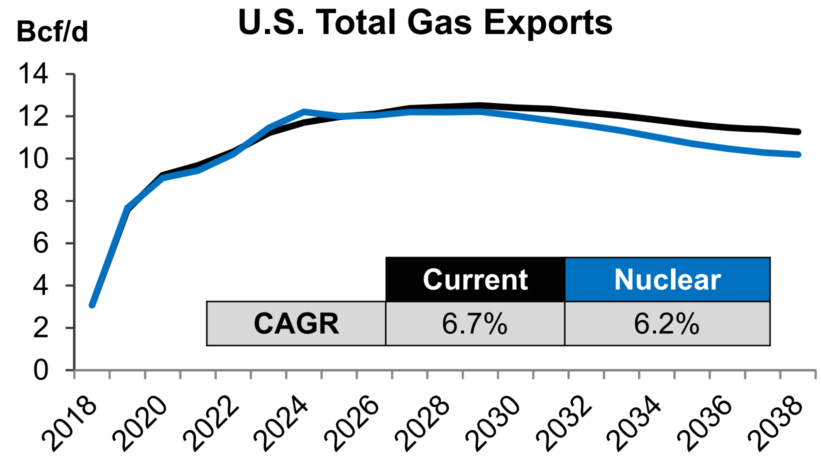
	Current	Nuclear
CAGR	3.0%	3.7%

Beyond 2030 the loss of national nuclear capacity pushes natural gas demand and prices higher and the power prices follow the upward trend.

6. Nuclear: Natural Gas Demand & Exports



	Current	Nuclear
CAGR	1.0%	1.0%



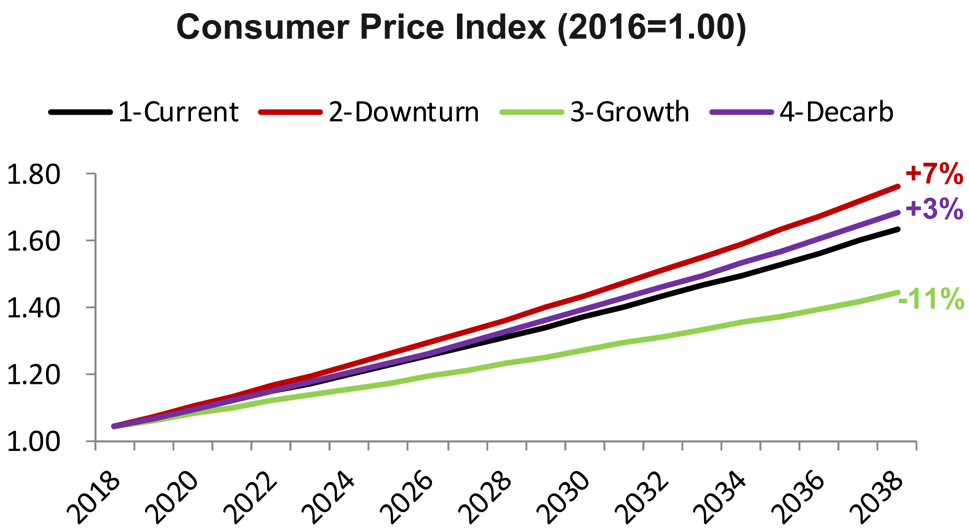
	Current	Nuclear
CAGR	6.7%	6.2%

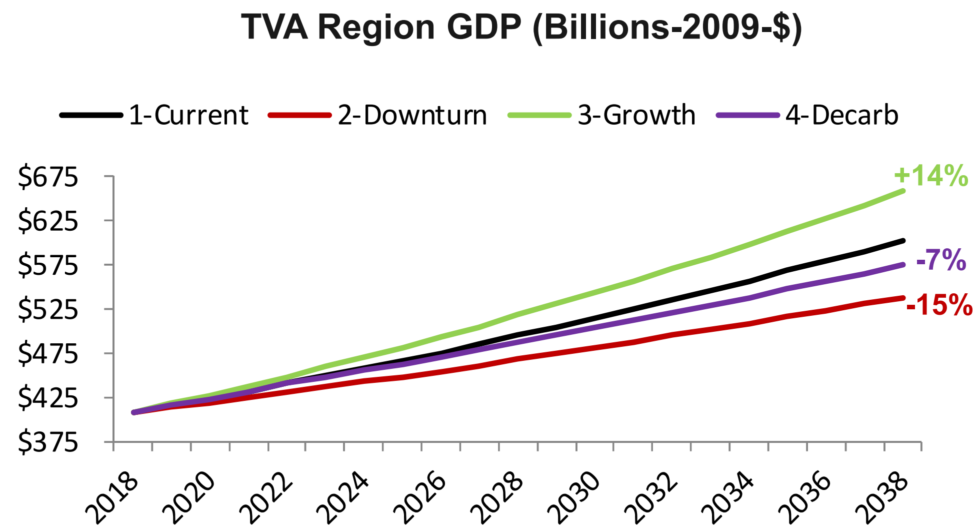
No Nuclear Extension assumption has very little impact on overall gas burn

No change in gas price or exports

Scenario Summary

U.S. Macro Forecasts by Scenario*



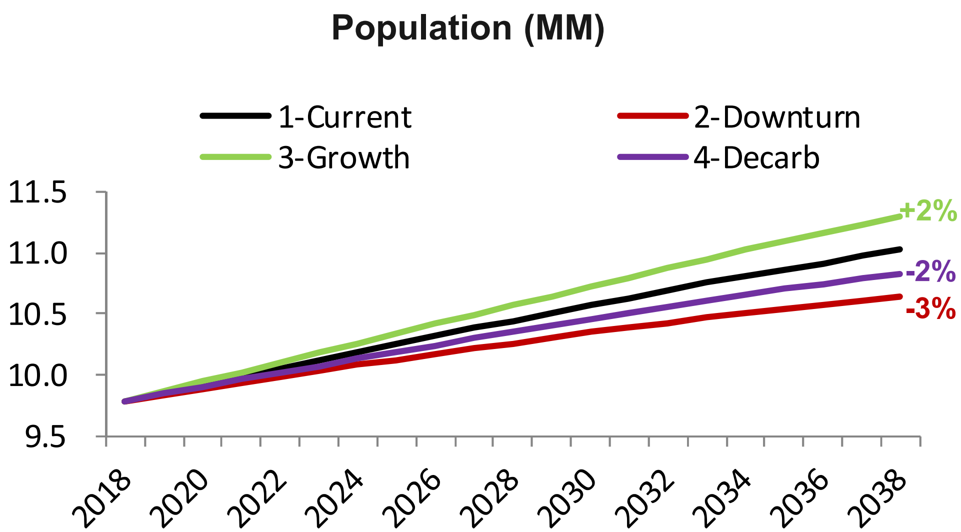


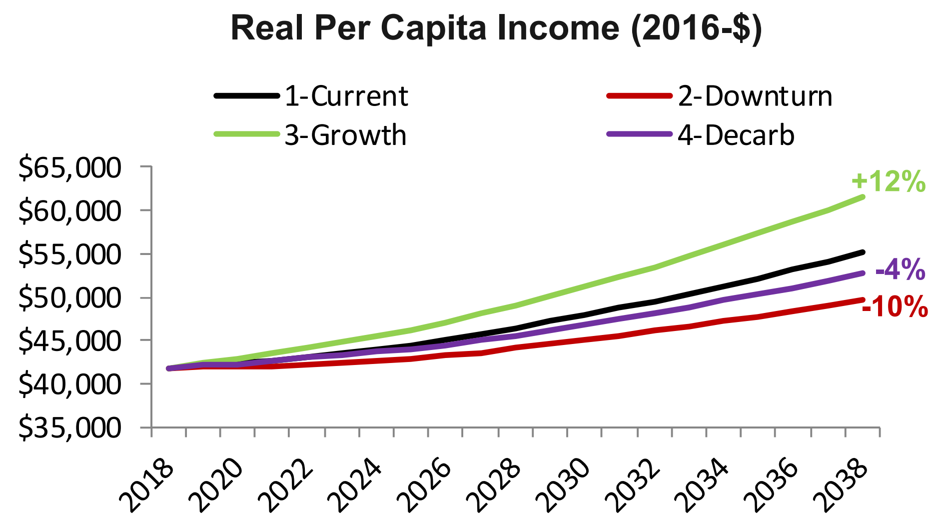
By 2038, CPI ranges from 17% lower to 12% higher than Current

By 2038, TVA GDP ranges from $108 BB lower to $99 BB higher than Current

*Note: Economic forecast for scenarios 5 DER and 6 Nuclear are the same as for 1 Current

TVA Region Forecasts by Scenario



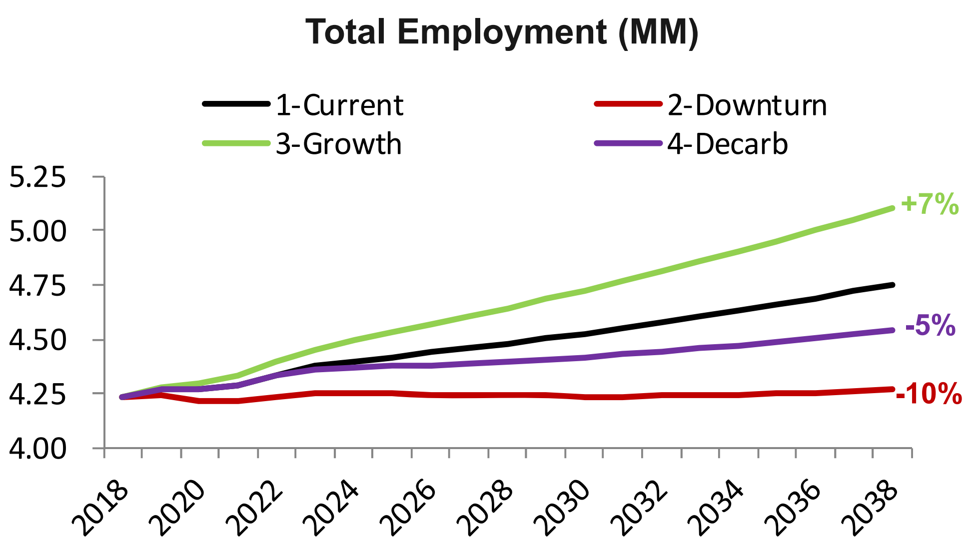


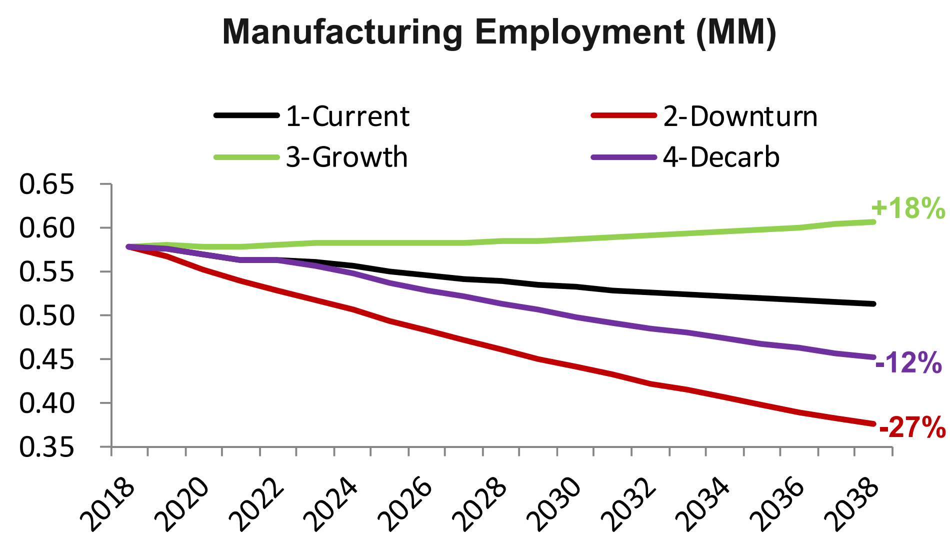
By 2038, TVA region population ranges from 383K lower to 271K higher than Current

By 2038, TVA region real PCI ranges from $5,475 lower to $6,342 higher than Current

*Note: Economic forecast for scenarios 5 DER and 6 Nuclear are the same as for 1 Current

TVA Region Forecasts by Scenario





By 2038, TVA region total employment ranges from 486K lower to 353K higher than Current

By 2038, TVA region MFG employment ranges from 138K lower to 93K higher than Current

*Note: Economic forecast for scenarios 5 DER and 6 Nuclear are the same as for 1 Current

Scenario Assumptions (2018 – 2038)

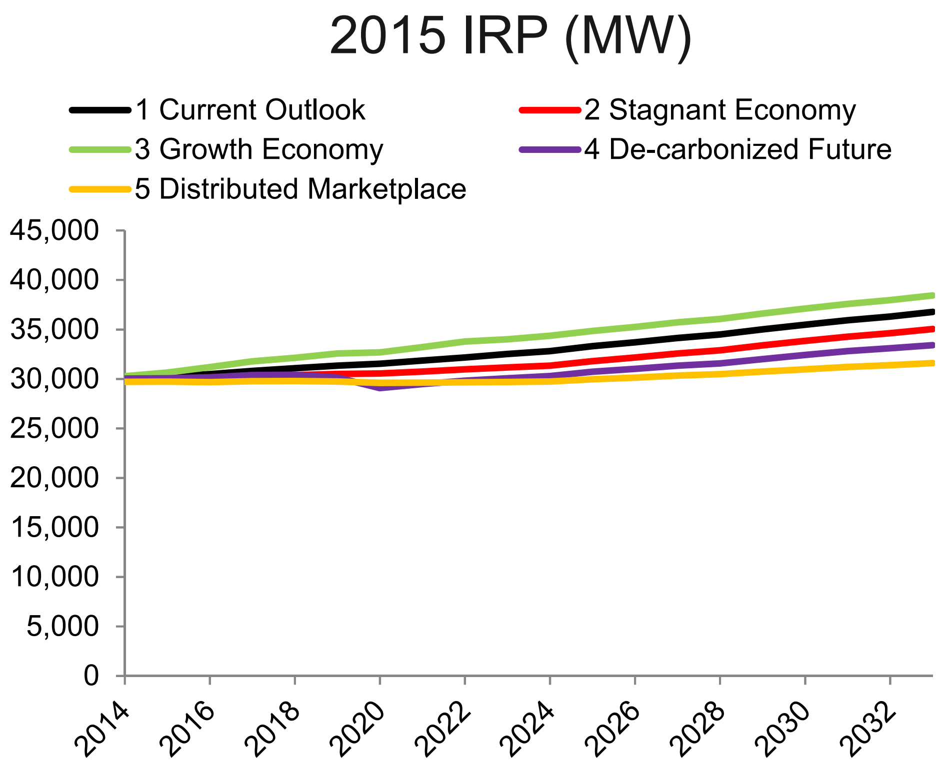
	Current Outlook	Economic Downturn	Valley Load Growth	Decarbonization	Rapid DER Adoption	Nuclear
U.S. GDP	2.0%	1.5%	2.2%	1.8%	2.0%	2.0%
U.S. Inflation	1.9%	2.2%	1.5%	2.0%	1.9%	1.9%
TVA Population	0.6%	0.4%	0.7%	0.5%	0.6%	0.6%
TVA Total Employment	0.6%	0.0%	0.9%	0.3%	0.6%	0.6%
TVA Manufacturing Employment	-0.6%	-2.1%	0.2%	-1.2%	-0.6%	-0.6%

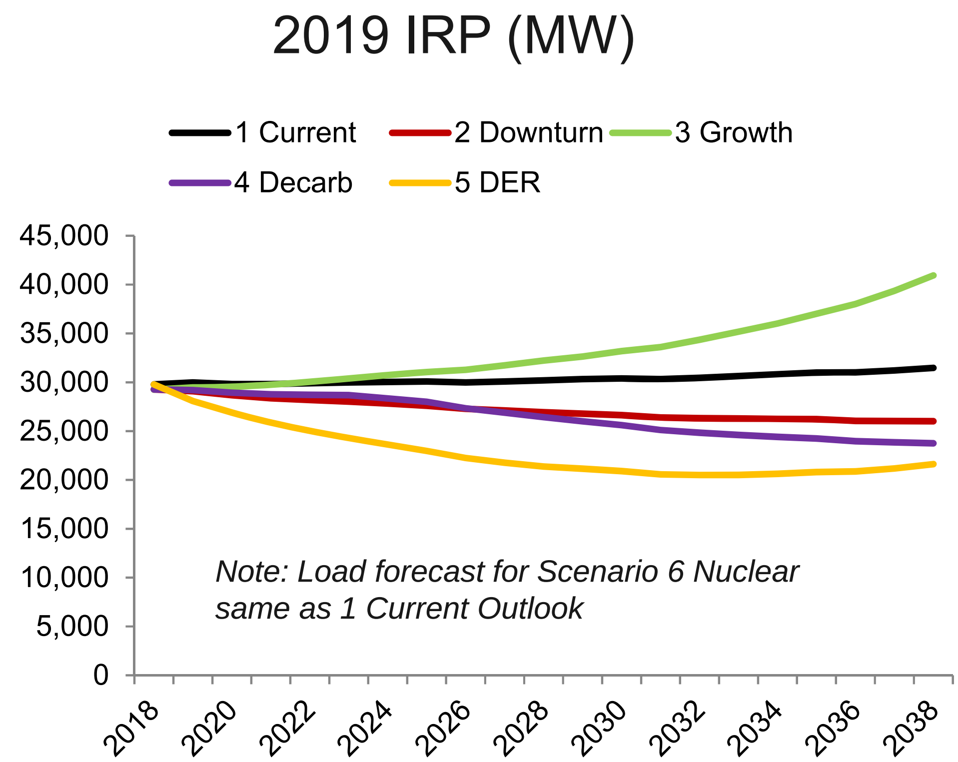
Scenario Assumptions (2018 – 2038)

20-year CAGR	Current Outlook	Economic Downturn	Valley Load Growth	Decarbonization	Rapid DER Adoption	Nuclear
National Demand	0.3%	0.0%	1.4%	-0.2%	-0.5%	0.3%
Henry Hub Gas Price	3.9%	3.4%	4.7%	4.8%	2.9%	4.1%
TVA Power Price	3.2%	2.7%	4.5%	5.7%	1.9%	4.0%
Coal	2.4%	2.5% *	2.0% **	2.5% *	2.2%	2.4%

Notes:
* Real coal prices are lower than Current case, but higher inflation causes nominal prices to be slightly higher.
** Real coal prices are the same as Current case, but lower inflation causes nominal prices to be lower.

IRP Comparison

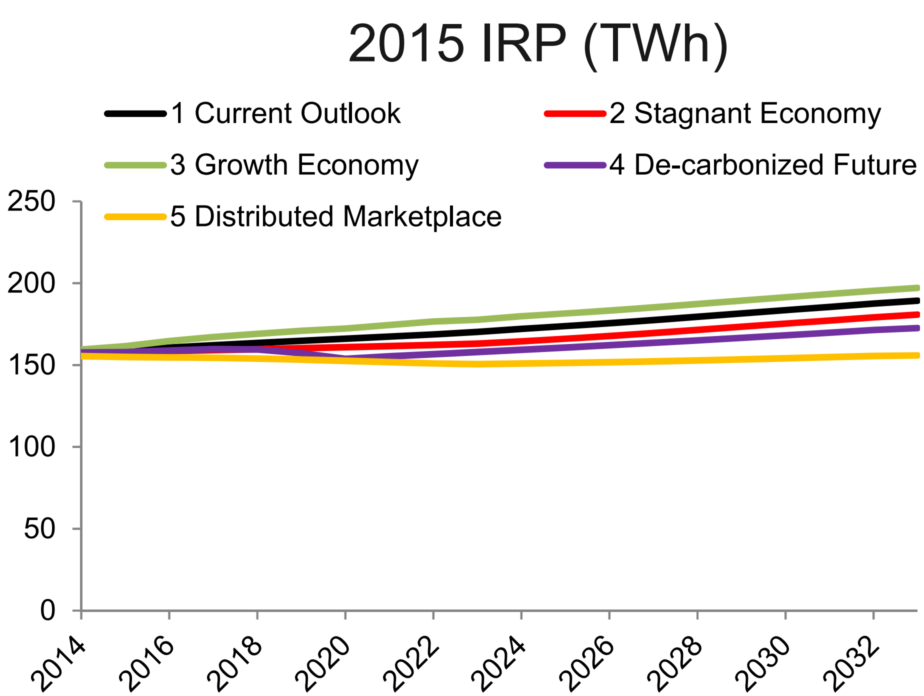




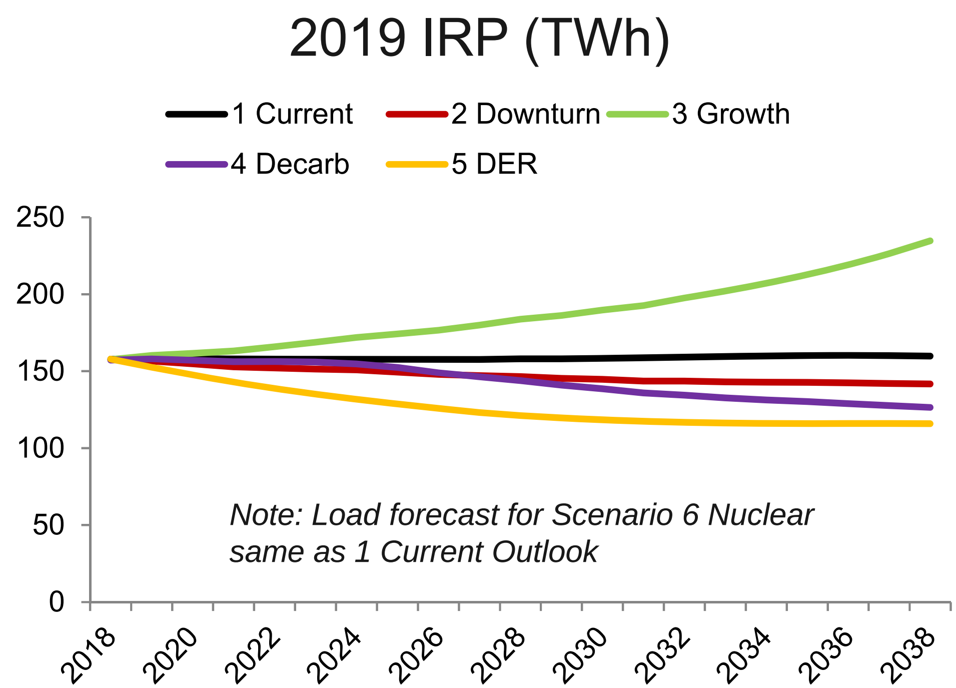
	Current	Stagnant	Growth	Decarb	Dist Mkt
CAGR	1.1%	0.8%	1.3%	0.6%	0.3%

	Current	Downturn	Growth	Decarb	DER	Nuclear
CAGR	0.3%	-0.5%	1.8%	-1.1%	-1.4%	0.3%

IRP Comparison

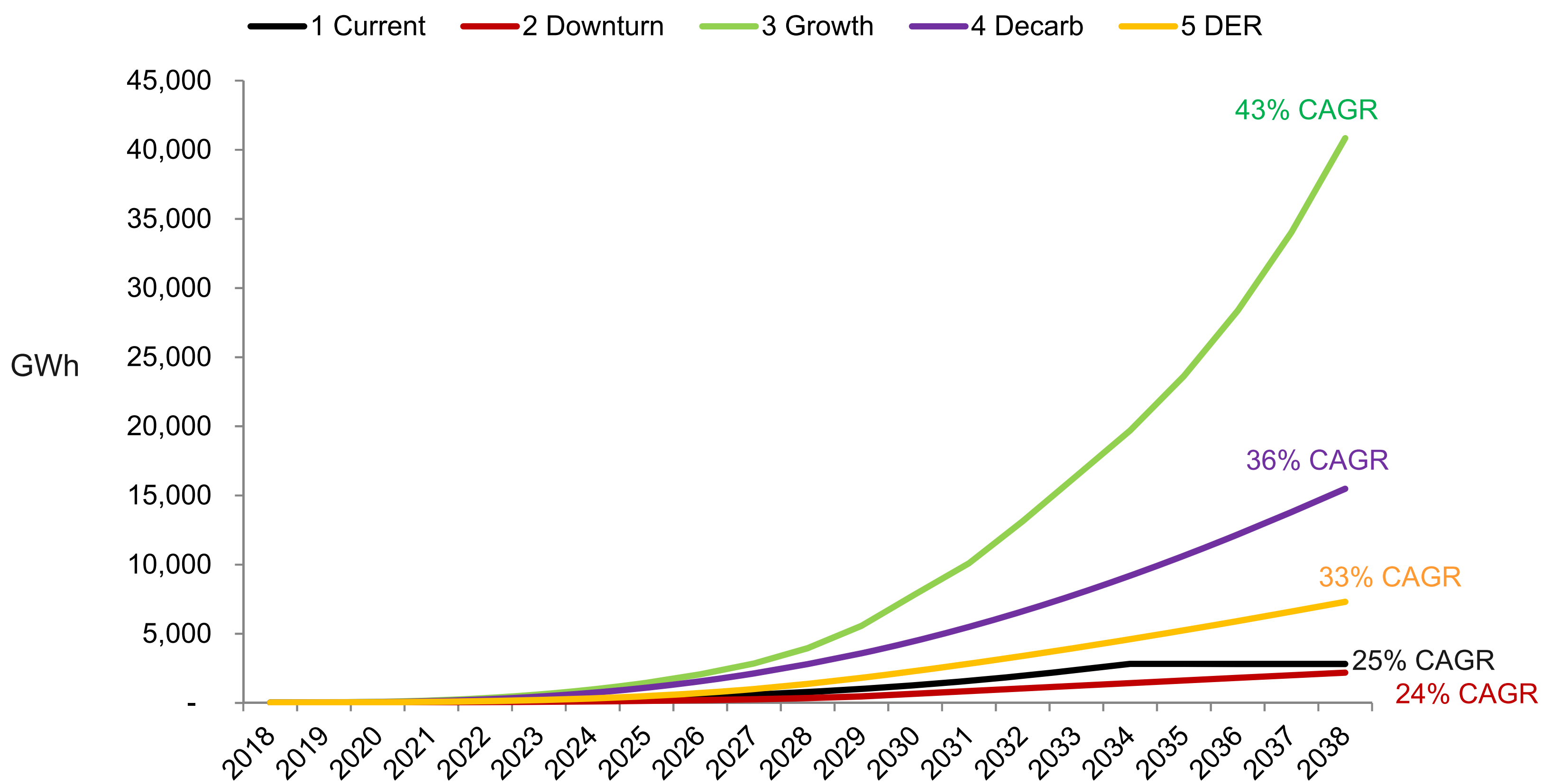


	Current	Stagnant	Growth	Decarb	Dist. Mkt
CAGR	0.9%	0.6%	1.1%	0.4%	-0.1%



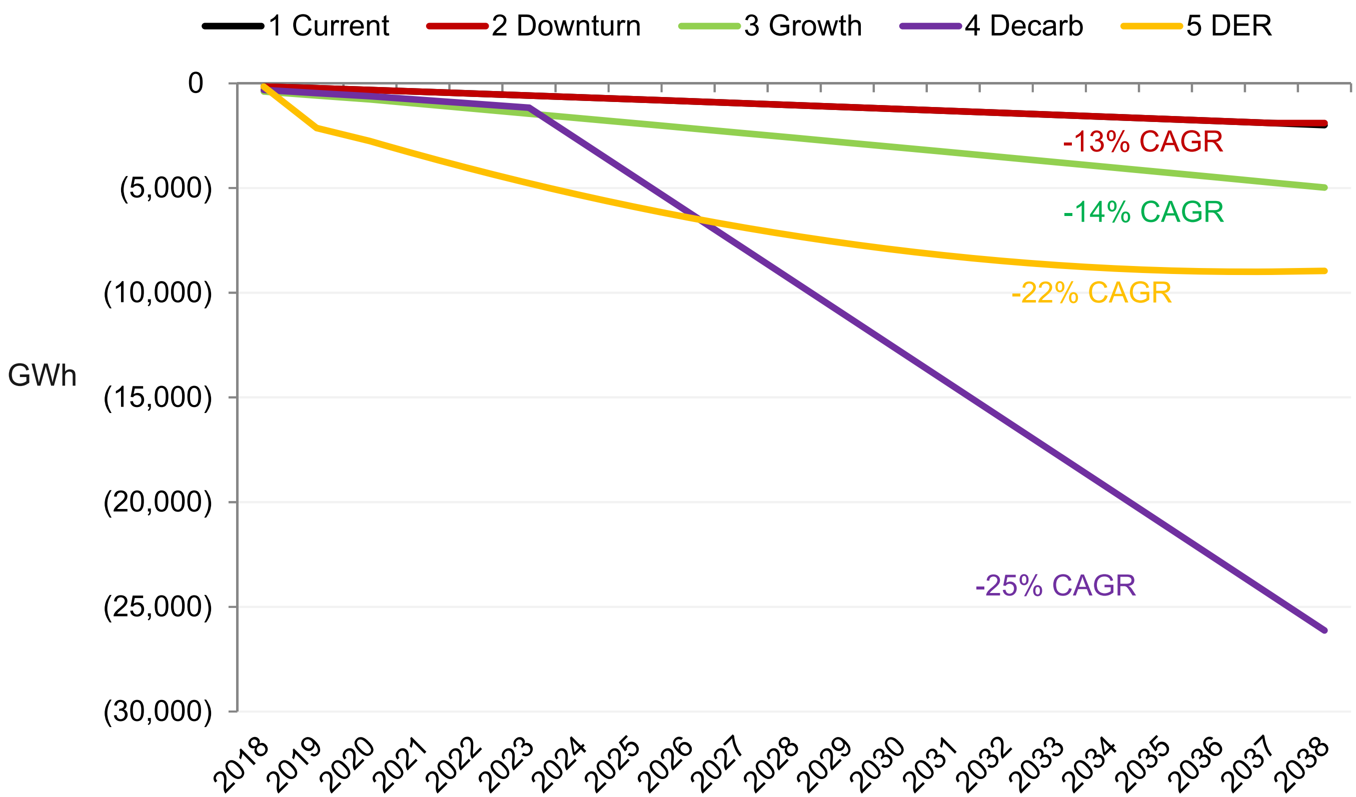
	Current	Downturn	Growth	Decarb	DER	Nuclear
CAGR	0.0%	-0.5%	2.0%	-1.1%	-1.5%	0.0%

Electric Vehicle Load Projections



Note: Forecast for Scenario 6 Nuclear same as 1 Current Outlook

Renewables Projections

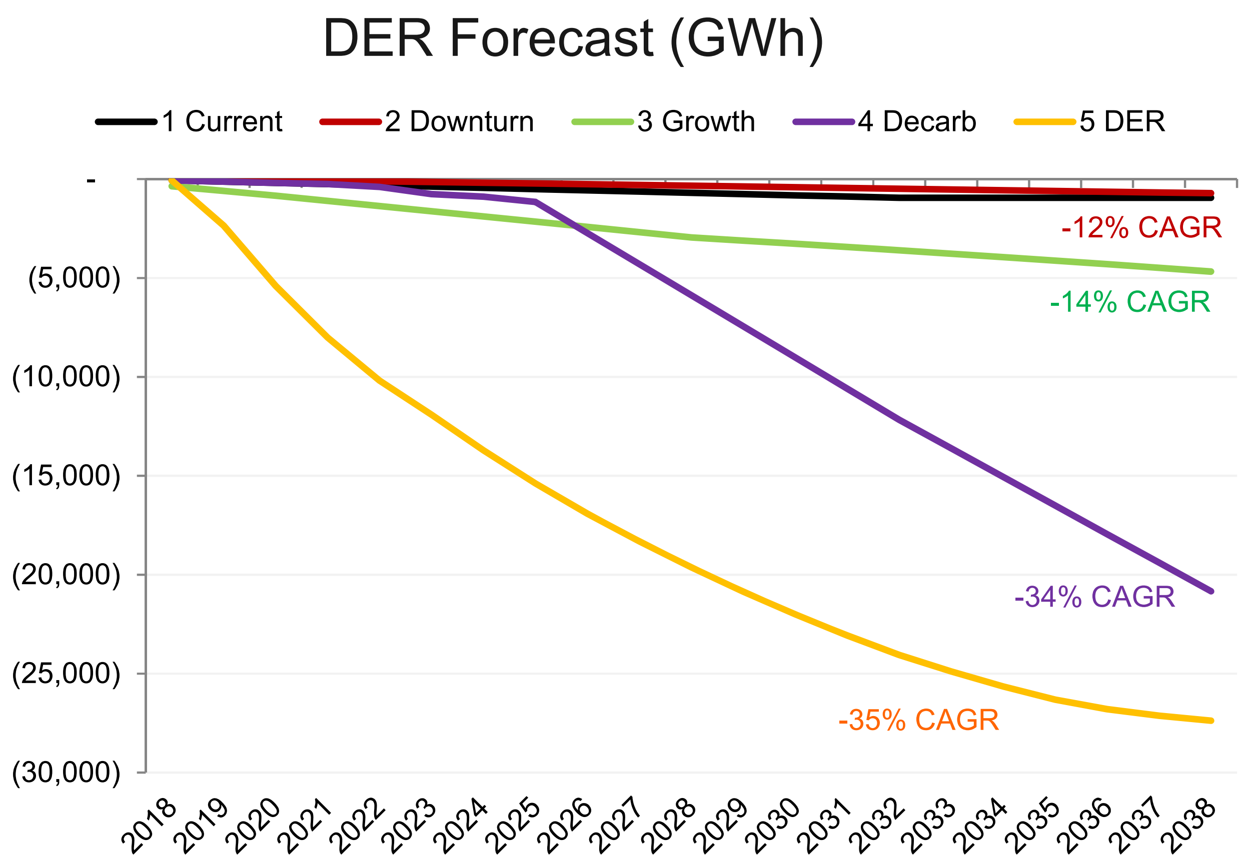


- Economic Downturn same as Current Outlook
- Decarbonization and Rapid DER see the highest renewable adoption
- In the rapid case, adoption faster in the first 10 years than in decarbonization case which sees rapid adoption after 2025

Note: Forecast for Scenario 6 Nuclear same as 1 Current Outlook

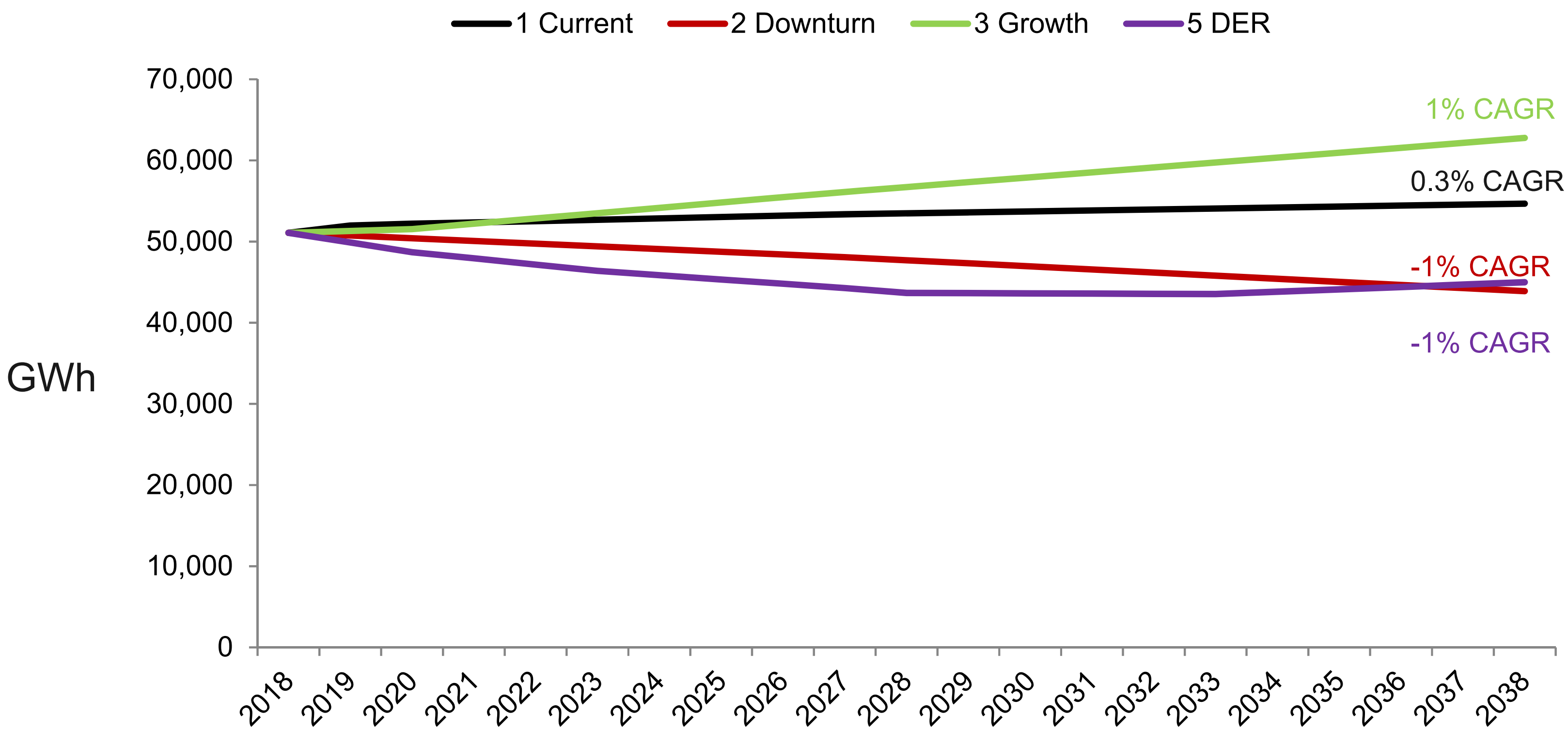
DER Projections

- DER Forecast includes Combined Heat and Power (CHP), increased EE (above outlook), and Energy Storage
- Largest DER adoption in Rapid DER case
- Decarbonization scenario DER adoption happens after 2025
- Low DER adoption in the downturn case due to depressed economy



Note: Forecast for Scenario 6 Nuclear same as 1 Current Outlook

Commercial & Industrial Customer Growth Projections



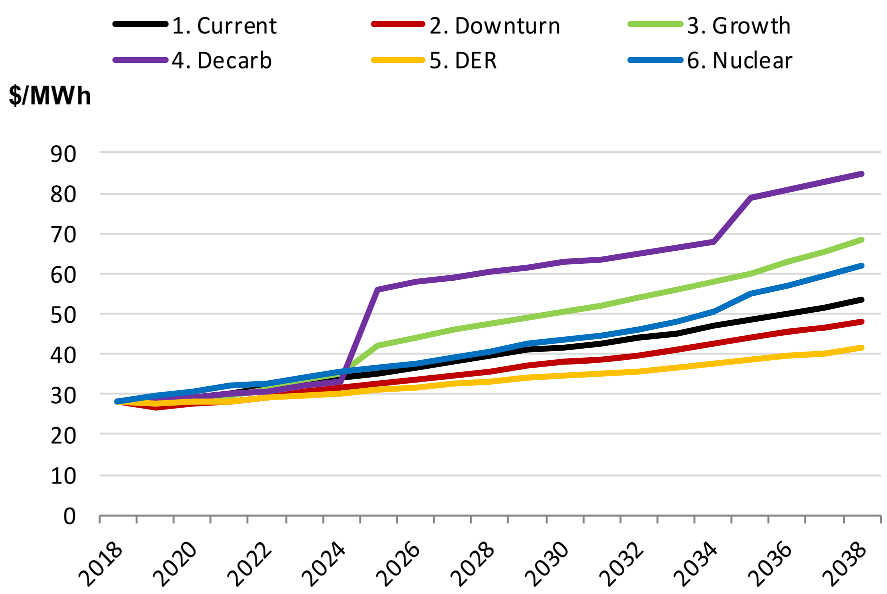
Note: Forecast for Scenarios 4 Decarb and 6 Nuclear same as 1 Current Outlook

Scenario Assumptions

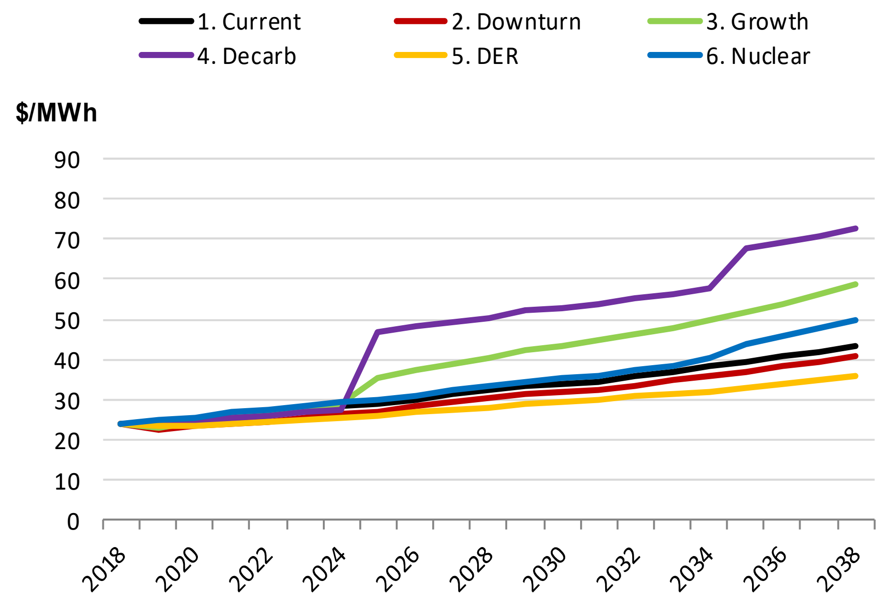
	Current	Downturn	Growth	Decarb	DER	Nuclear
Annual Energy CAGR (2018-2038)	**Flat (0.0%)**	**Low (-0.5%)**	**High (2.0 %)**	**Low (-1.1%)**	**Very Low (-1.5%)**	**Flat (0.0%)**
Summer Peak MW CAGR (2018-2038)	0.3%	-0.5%	1.8%	-1.1%	-1.4%	0.3%
ITC Tax Credit	Follows current ITC	Follows current ITC	Follows current ITC	ITC Extension and incentives to drive decarbonization	Follows current ITC	Follows current ITC
Renewable Impact (BTM)	13% CAGR	13% CAGR	14% CAGR	25% CAGR	22% CAGR	13% CAGR
Storage (BTM)	0%	0%	52% CAGR (Last 10 years)	63% CAGR (Last 10 years)	22% CAGR (Last 15 years)	0%
Other BTM DG impact (microgrid, CHP)	9% CAGR	9% CAGR	12% CAGR	12% CAGR	12% CAGR	9% CAGR
Electrification impact - EV	25% CAGR	24% CAGR	43% CAGR	36% CAGR	33% CAGR	25% CAGR
C&I Growth	0.3% CAGR	-1% CAGR	1% CAGR	0.3% CAGR	-1% CAGR	0.3% CAGR
Electrification impact - Cryptocurrency	0%	0%	22% CAGR	0%	0%	0%

TVA Wholesale Power Prices

On-Peak

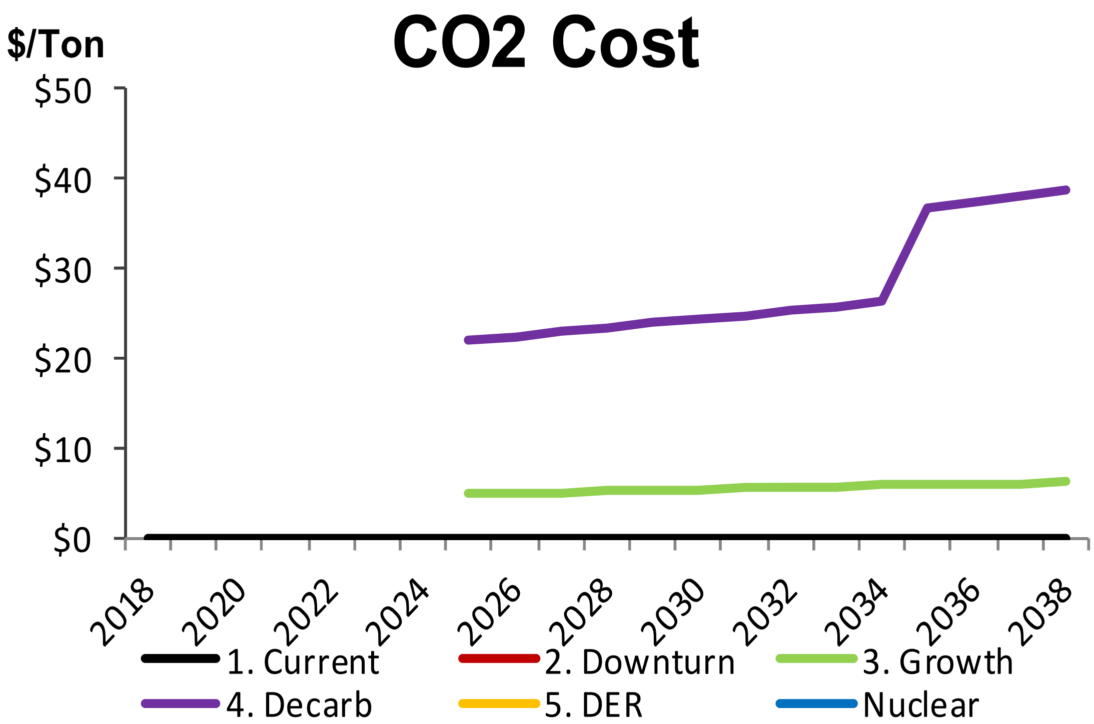


Off-Peak



The most significant driver of scenario differences is the addition of the CO2 costs in 2025. Otherwise, national load growth, or declines, influence natural gas prices and capacity additions.

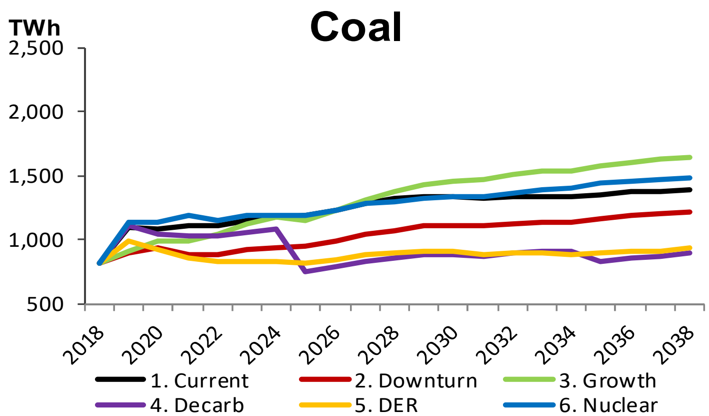
CO2 Costs

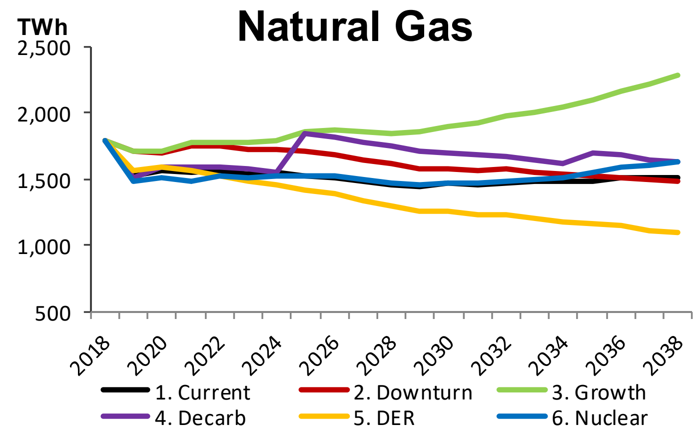


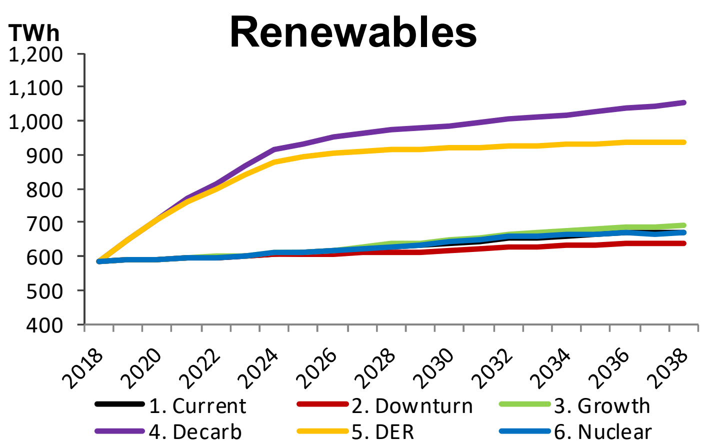
Decarb and Growth scenarios include CO2 costs starting in 2025.

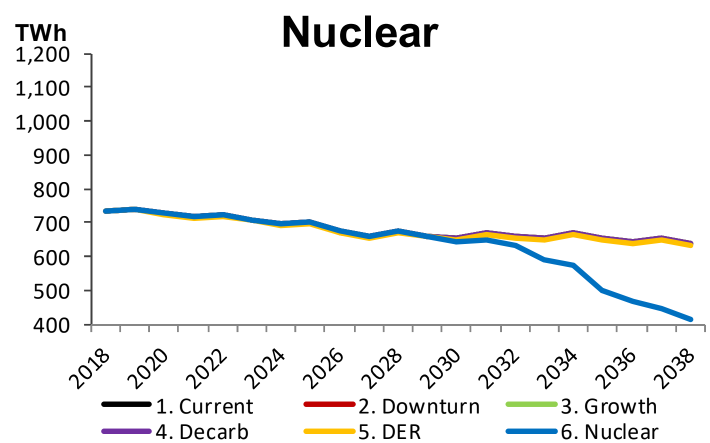
All other scenarios assume no carbon penalty.

National Generation by Fuel







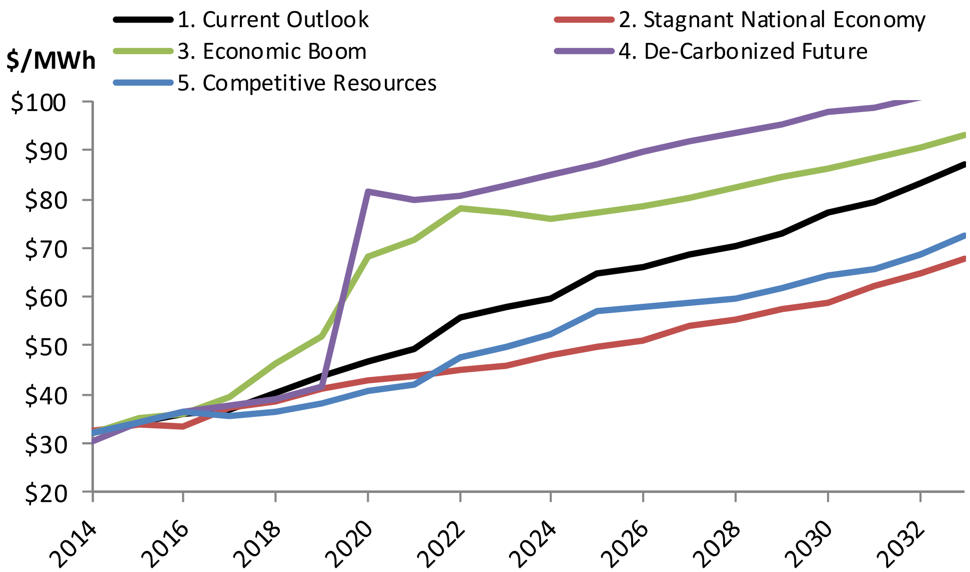


Most significant driver of scenario differences is CO2 costs in 2025. Otherwise, national load changes influence natural gas prices and capacity additions.

TVA Wholesale Power Prices

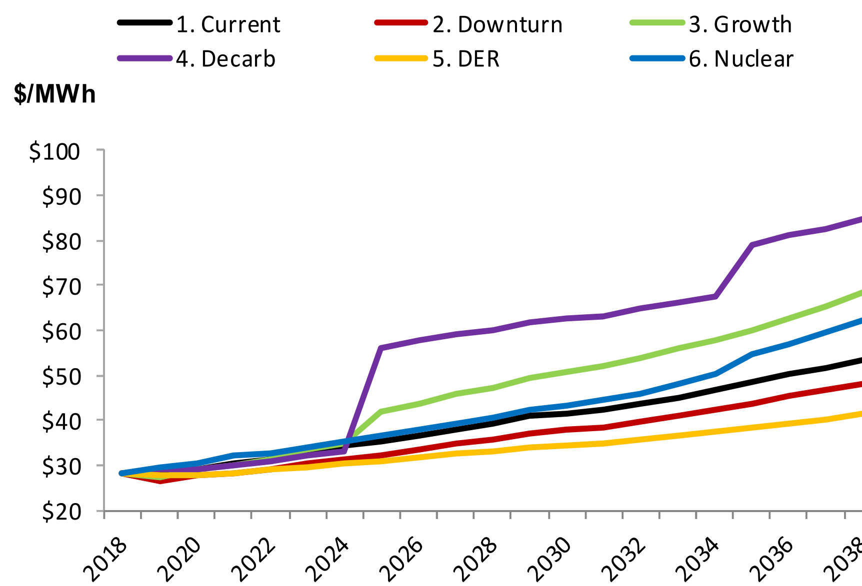
On-Peak

2015 IRP



In the 2015 IRP, all of the scenarios had increasing national demand escalation.

2019 IRP



Most significant driver of scenario differences is CO2 costs in 2025. Otherwise, national load changes influence natural gas prices & capacity additions.


BREAK

Scenario Design: Group Breakout

Jo Anne Lavender

Group Discussion Question:

What are your comments, thoughts or inputs for scenario design?

Group Report Out

2019 IRP Working Group

Meeting 5: July 24, 2018

Agenda – July 24

7:00	Breakfast	
8:00	Welcome & Overview	Jo Anne Lavender
8:15	Scenario Discussion & Responses	Hunter Hydas & Tim Sorrell
8:45	BREAK	
9:00	Resource Planning Framework	Jane Elliott
10:30	BREAK	
10:45	Current Resource Portfolio	Jane Elliott
11:30	LUNCH	
12:30	Intro to Resource Options	Jane Elliott
1:30	Group Discussion	
1:45	Closing Comments & Next Steps	Hunter Hydas & Jo Anne Lavender
2:00	Adjourn	

Scenario Discussion & Responses

Tim Sorrell


BREAK

Resource Planning Framework

Jane Elliott

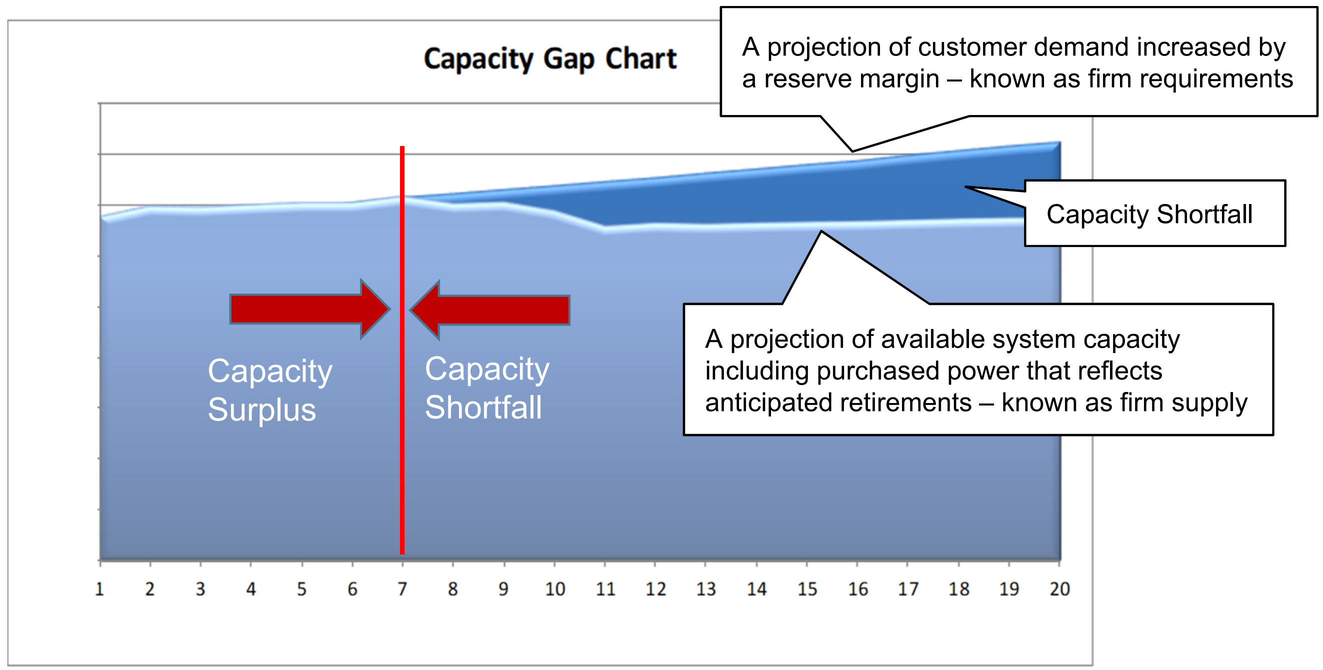
Goals for an Optimal Resource Plan

Low Cost	Risk Informed	Environmentally Responsible
Reliable	Diverse	Flexible

Resource Planning for Future Capacity Needs

Resource planning is about optimizing the mix of future capacity.

Projections of capacity needed are filled by the most cost-effective resource.



Recommended path provides a low cost, reliable, diverse and flexible system

Finding the Least Cost (Optimal) Resource Plan

- Using the reliability limit as a constraint, we optimize by minimizing the customer's delivered cost of power

Planning Objective Function:

Minimize Expected Present Value of Revenue Requirements

Components

- Optimization
- Time value of money
- Uncertainty

Constraints

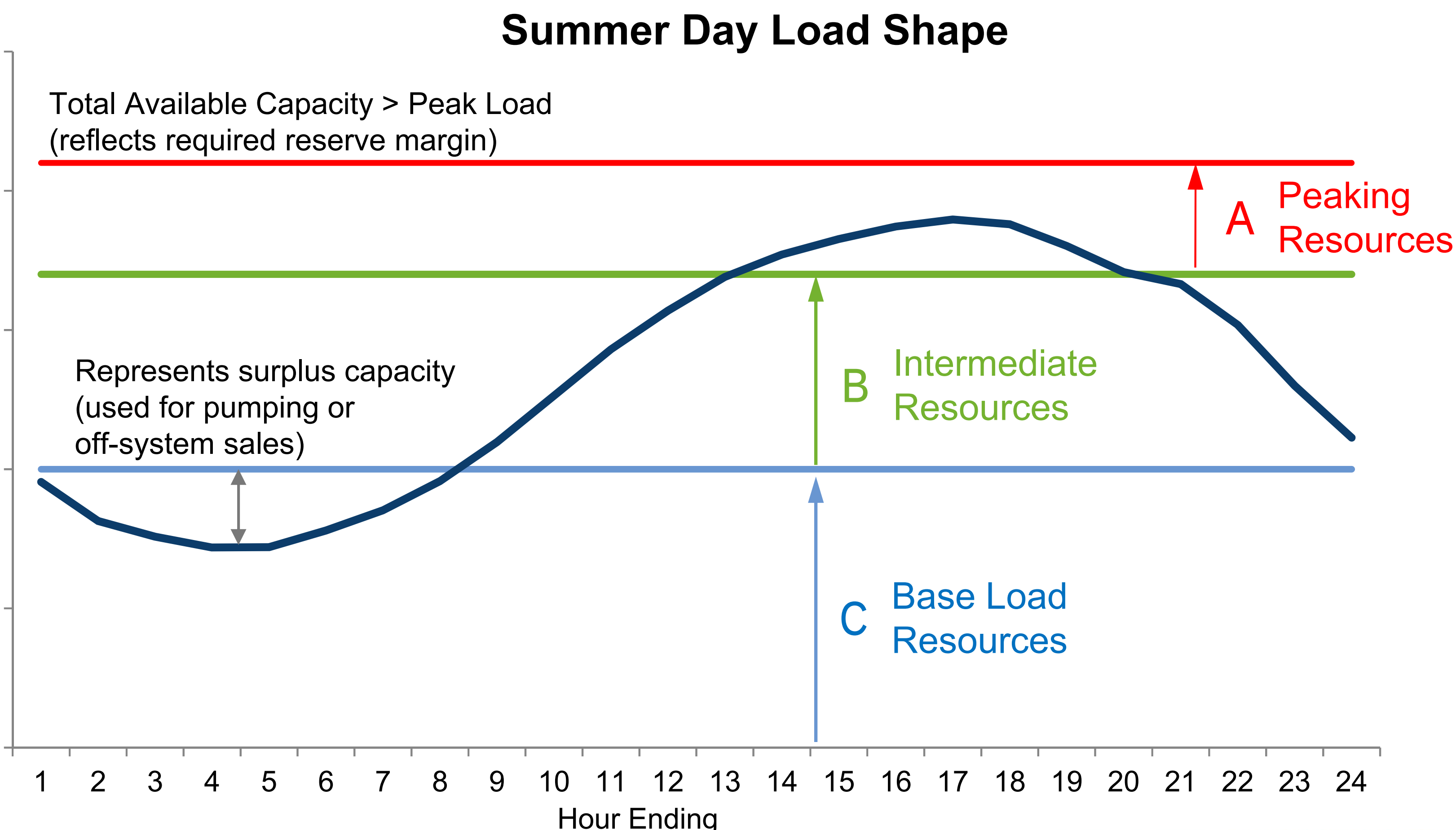
- **Planning reserve**

Revenue Requirements

- Operating expenses
- Return of and on capital

Objective is determining the resource mix that minimizes cost over the planning horizon

Understanding Resource Needs



Reserve Margin for Unplanned Events

Weather

Variability from normal
- Temperatures
- Thermal build up
- Hydrology

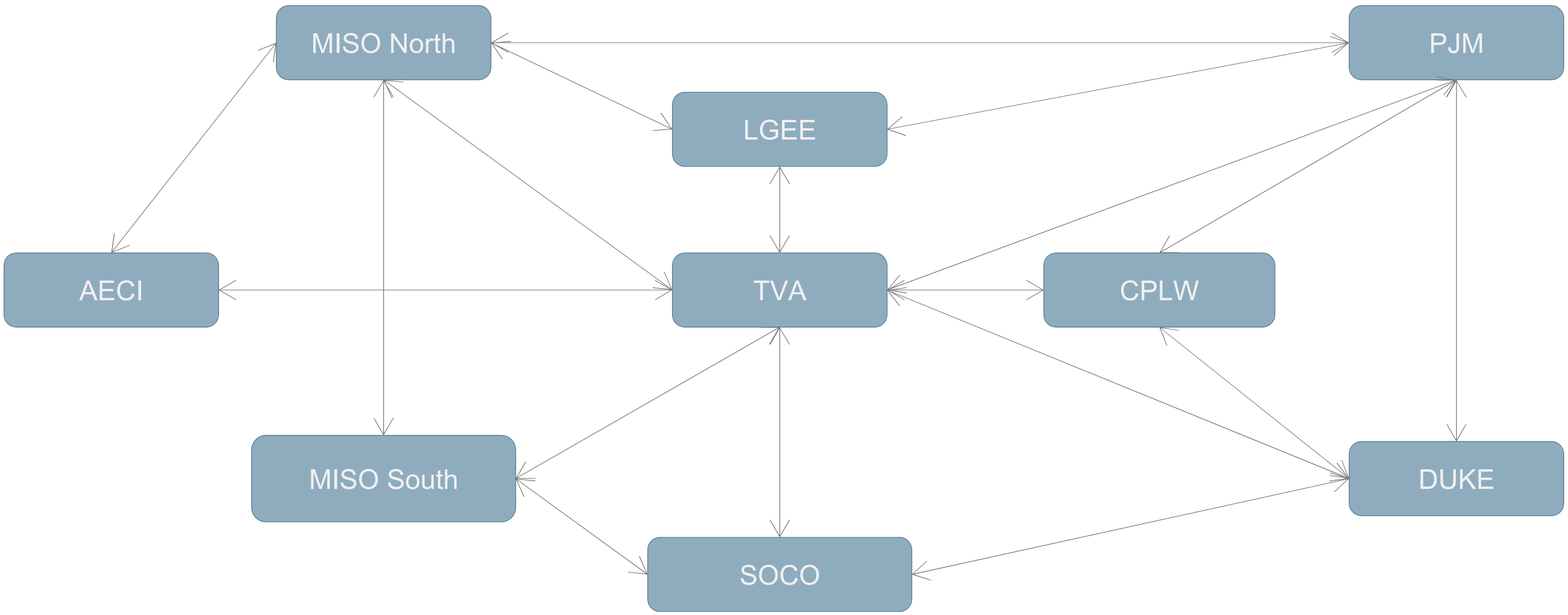
Forecast Error

Non-weather variability
- Economic cycles
- Consumer behavior

Outages

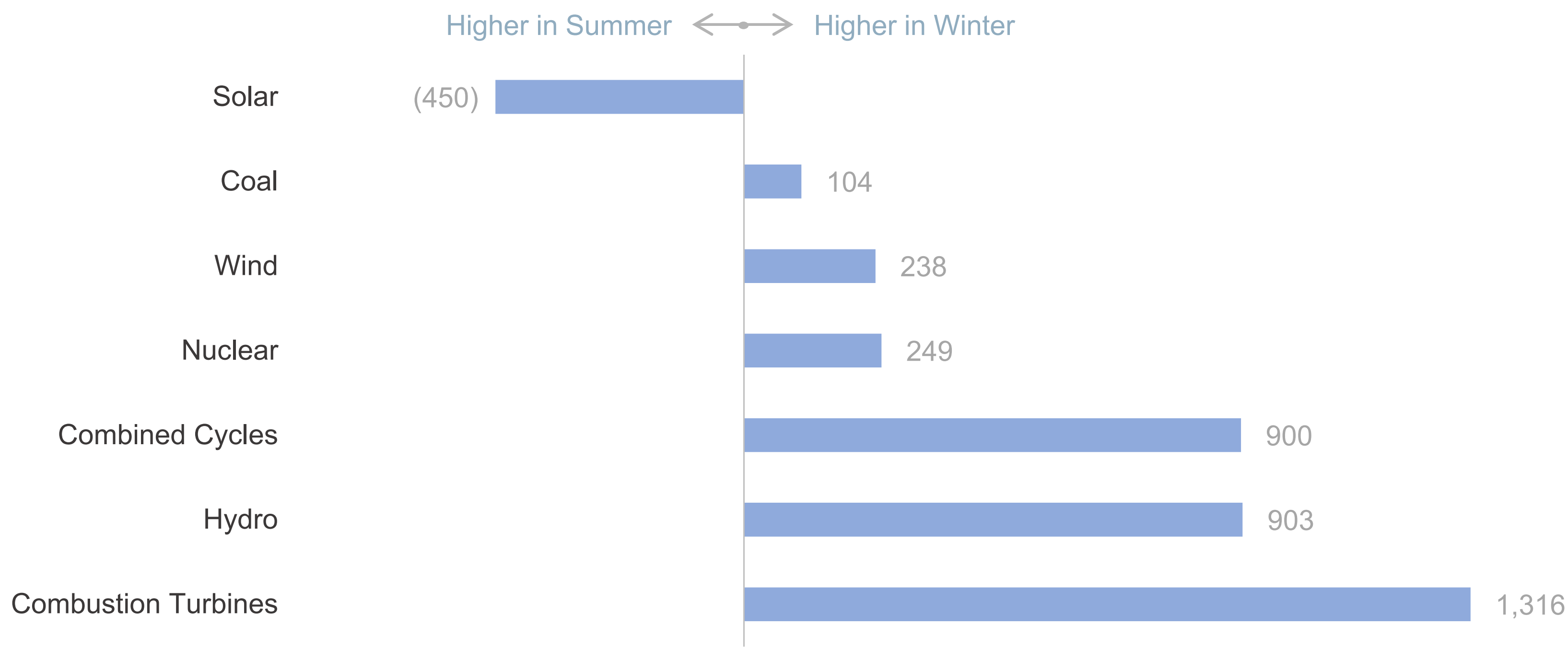
Unit performance
- Planned outages
- Forced outages
- Intermittent shapes

Study Topology



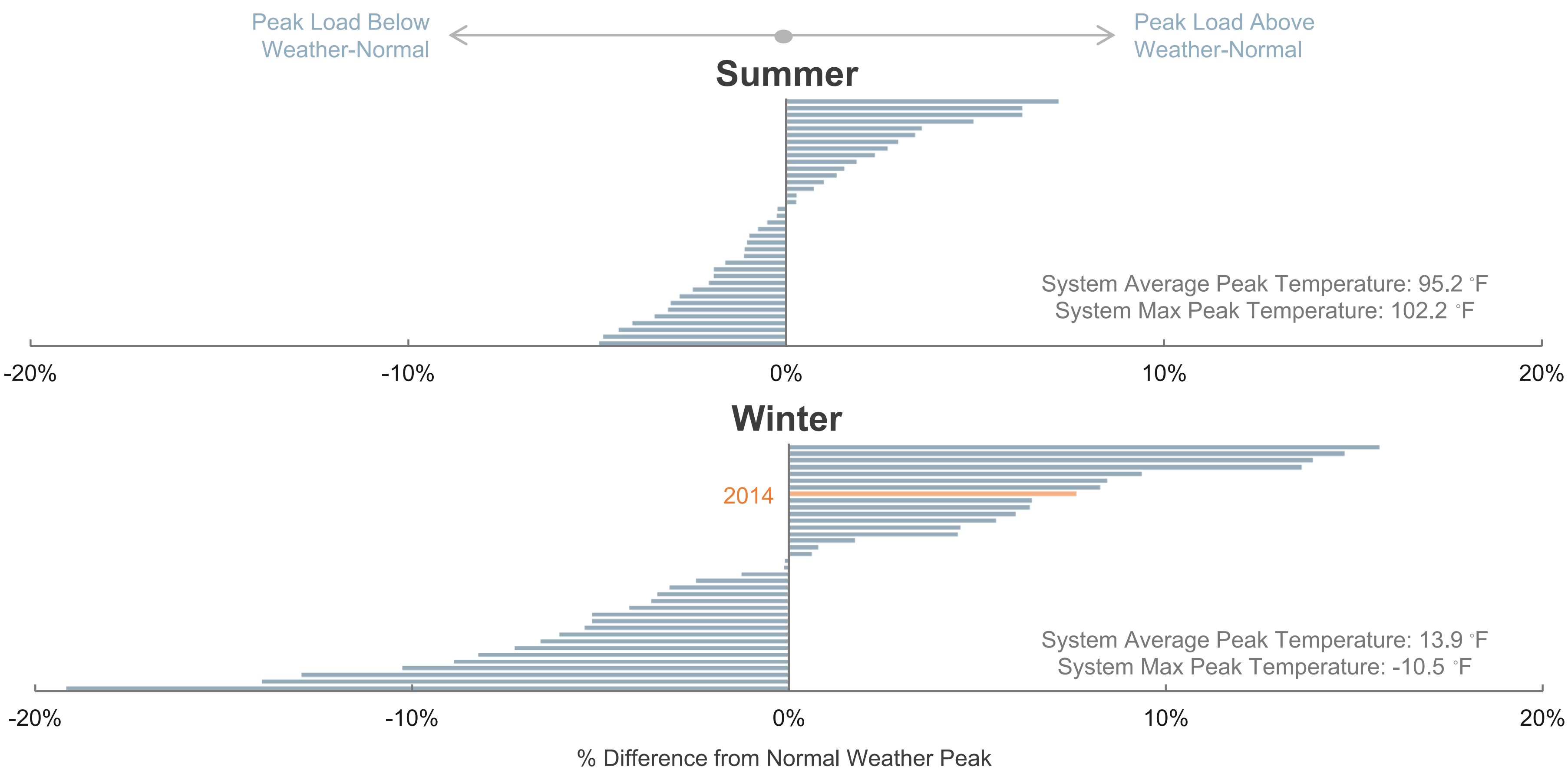
TVA has the ability to rely on neighbors during its peak, in part due to load diversity

Seasonal Capacity Differences

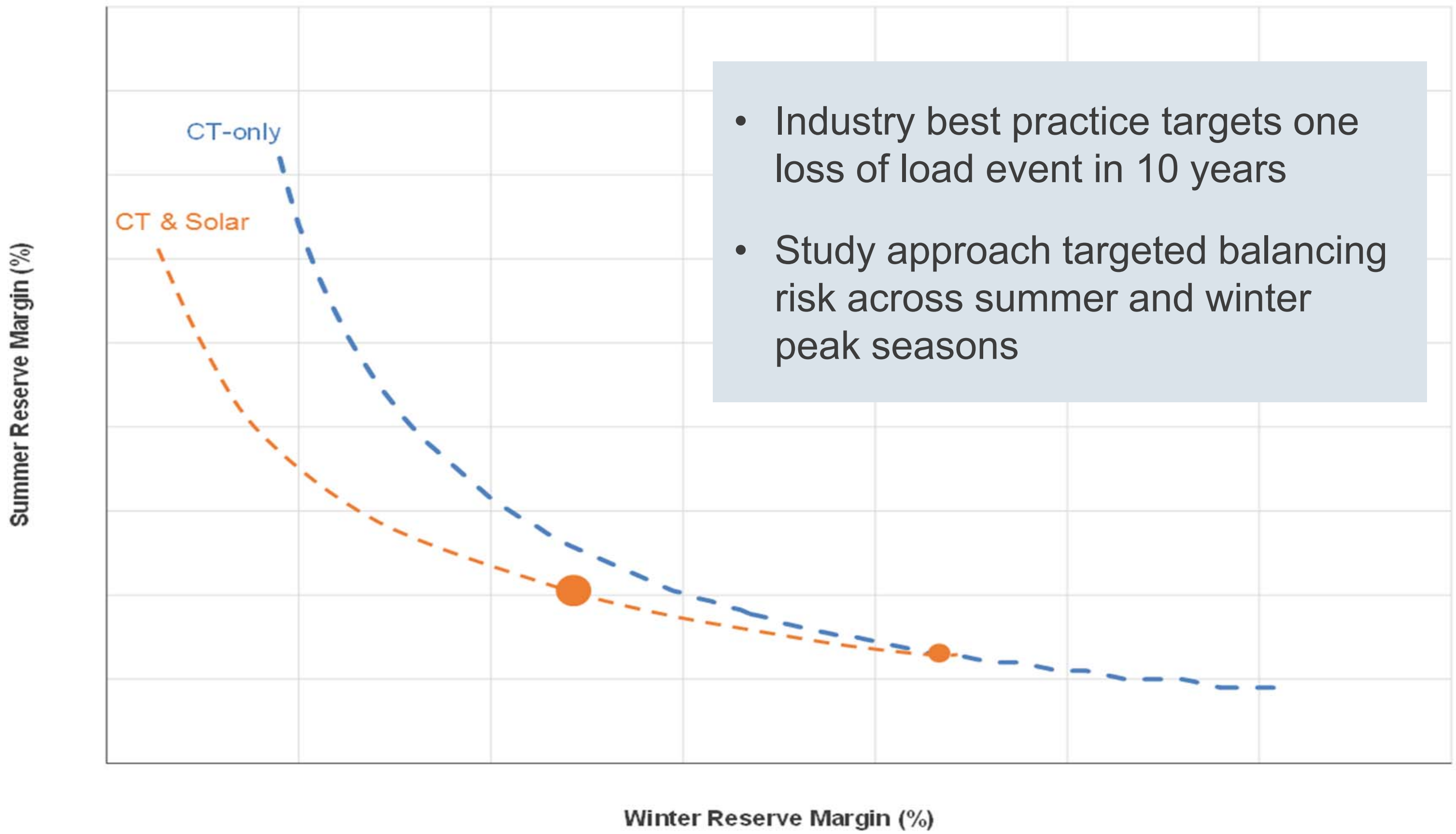


Solar has diminished capabilities in the winter, unlike the rest of the fleet

Seasonal Peak Weather Variability



Balancing Seasonal Risk for Evolving System



- Industry best practice targets one loss of load event in 10 years
- Study approach targeted balancing risk across summer and winter peak seasons

Generating Unit Operating Characteristics

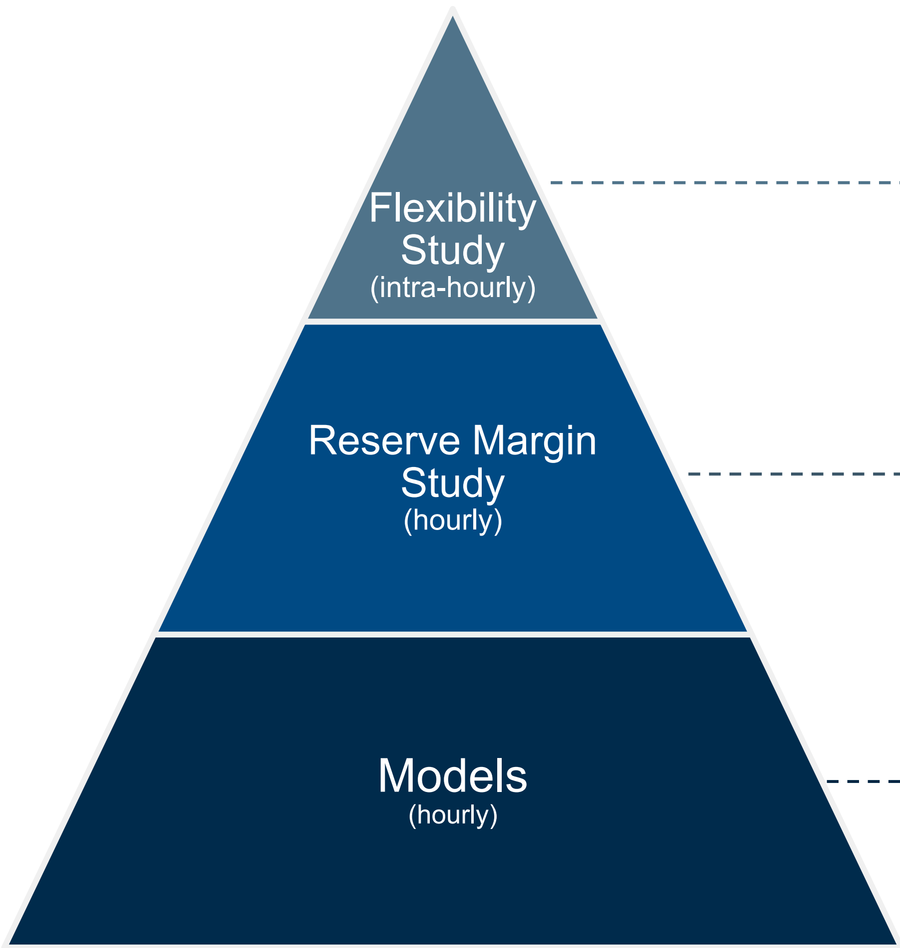
Physical

Item	Measure
Output (capacity)	MW (max dependable)
	MW (minimum)
Availability	Outage Rates
Flexibility	Ramp rate
Duty Cycle	Base, peaking
Control	Dispatchable, non-dispatchable
Fuel	Types of fuel, limits
Emissions	lbs per kWh
Other	Regulations & Constraints

Economic

Item	Measure
Capital Cost	$ - Installed cost
Efficiency	Heat rate (Btu/kWh)
Operating Cost	Fixed ($)
	Variable ($/kWh)
Fuel Cost	$/Btu
Emissions Cost	$/lb – as applicable

Capturing Flexibility

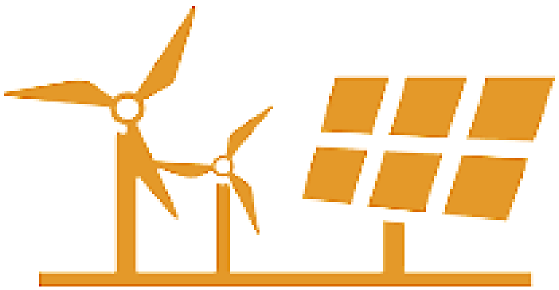


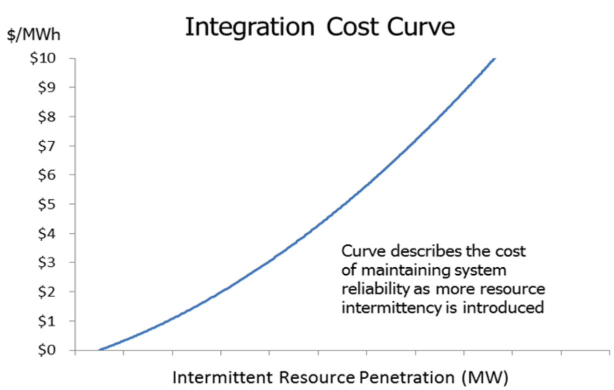
- Flexibility cost / discount for:
  - Solar and wind
  - Aeroderivatives / reciprocating engines
  - Batteries
- Historical wind and solar (intra-hour)
- Island case

- Historical experience
  - Load forecast error
  - Temperature-capacity curves
  - Forced outages
  - Neighbor capabilities

- Unit characteristics
  - Seasonal capacity
  - Outage rates
  - Ramping capabilities
- Solar & wind energy patterns
- Weather-normal loads

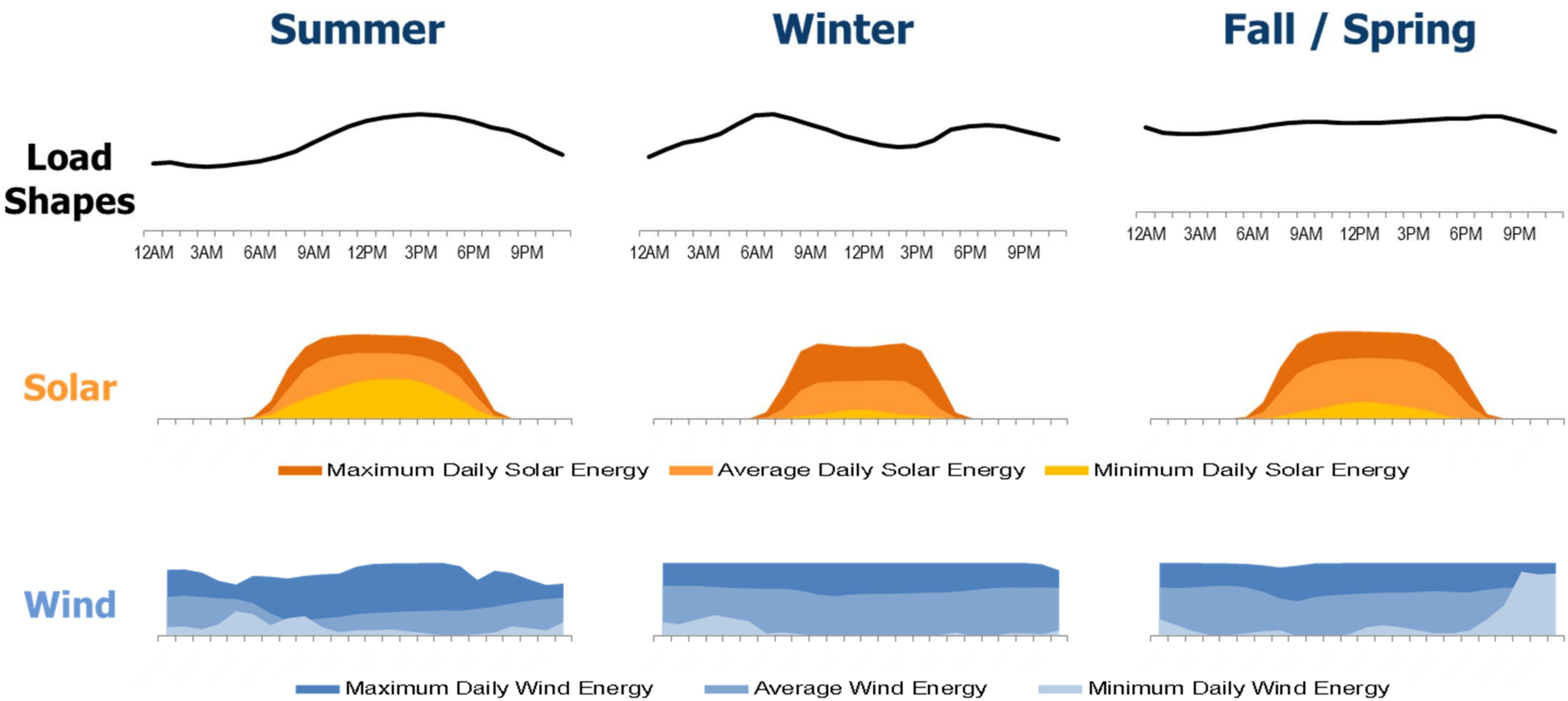
Integration Cost for Intermittent Resources





- Because wind & solar generation is intermittent, there are additional challenges to the system beyond those with traditional generation
- The cost of these challenges make up the integration cost
- This cost is used when valuating capacity expansion options and energy proposals

Seasonal Solar & Wind Shapes



Solar & Wind Dependable Capacity & Integration Cost

- Solar and wind are non-dispatchable resources which have unique operating characteristics that are different from thermal and other more traditional resources
- Net Dependable Capacity (NDC) is represented by availability at the peaks, which can vary depending on penetration of the resource
- Intermittent resources require the balance of the system to respond to their variability, driving an integration cost

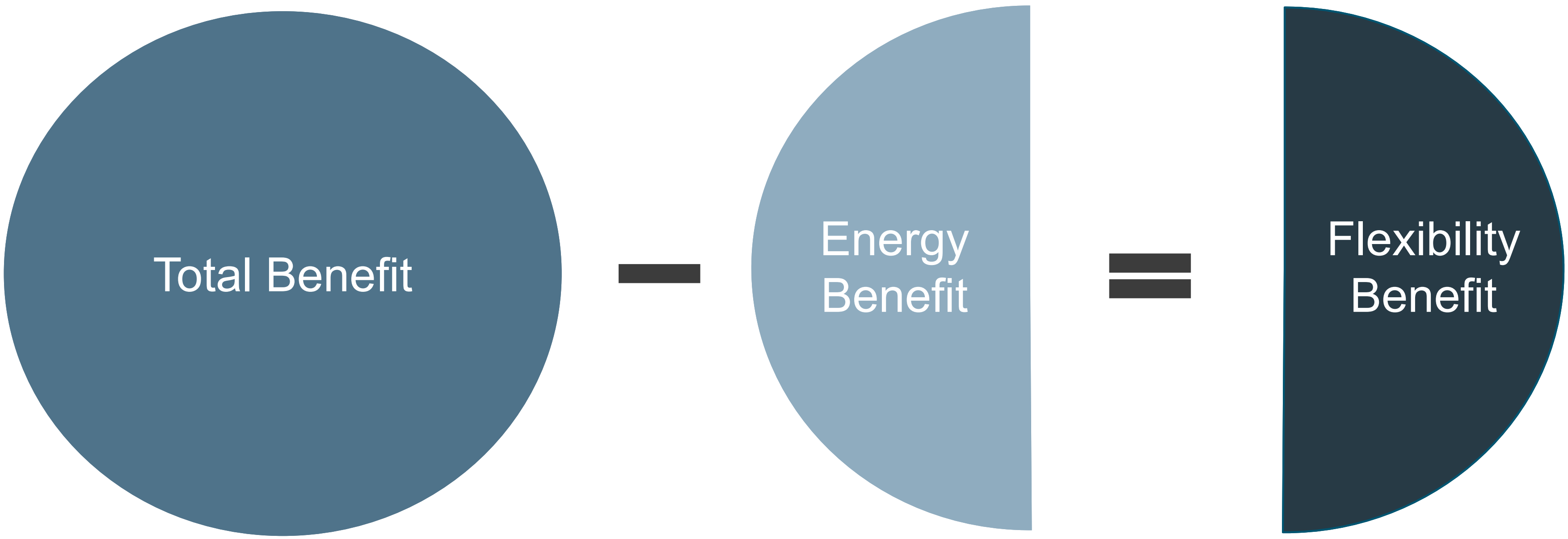
SOLAR

NDC
Integration Cost

WIND

NDC
Integration Cost

Integration Benefit for Flexible Resources



Calculate total benefit of aero/battery versus a CT **using intra-hourly dispatch with uncertainty**

Calculate energy benefit of aero/battery versus a CT **using hourly dispatch with uncertainty**

Cost difference results in flexibility benefit without any overlap

Size & Portfolio Affect Flexibility Value

Flexibility value **increases** with solar penetration

$/kW-mo	No Solar	2,500 MW Solar	5,500 MW Solar
200 MW			
500 MW			
1,000 MW			

Flexibility value **decreases** with penetration

Aero

Flexibility Benefit
$/kW

Battery

Flexibility Benefit
$/kW

Resource Planning Framework – Key Takeaways

- Planning reserve margin provides appropriate power supply to respond to unplanned events and reliably serve electricity demand
- Integration cost recognizes costs driven by integrating intermittent resources onto the system
- Flexibility benefit recognizes benefits driven by integrating flexible resources onto the system


BREAK

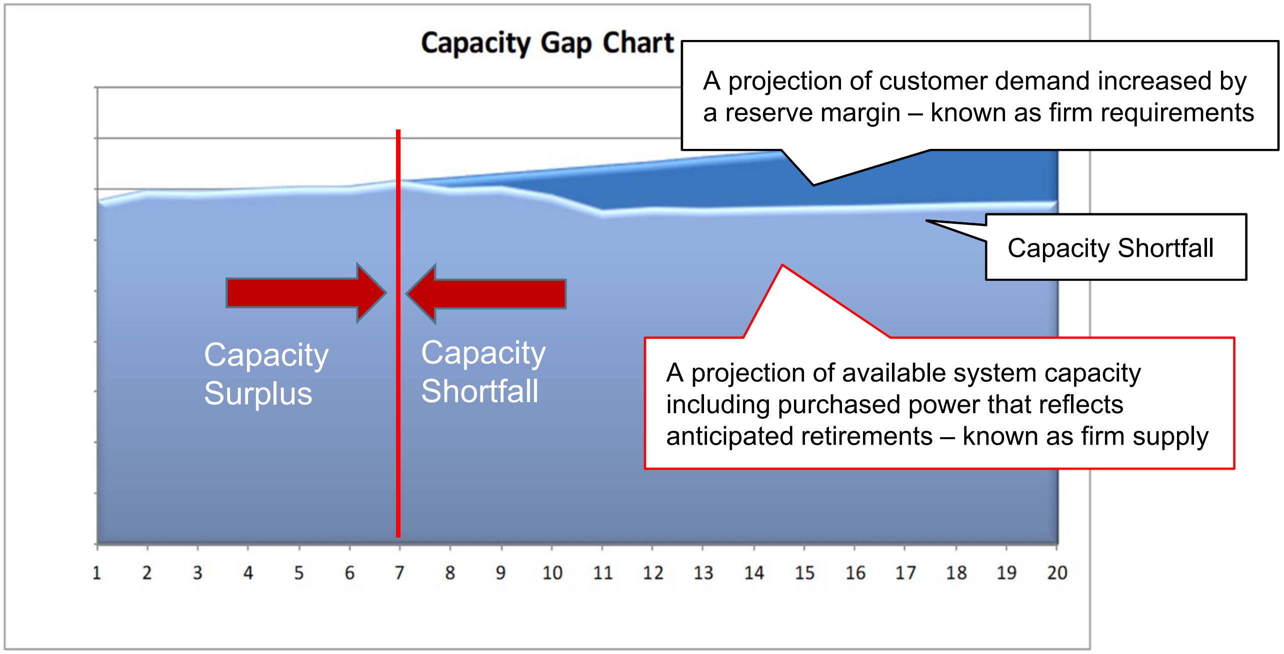
Current Resource Portfolio

Jane Elliott

Resource Planning for Future Capacity Needs

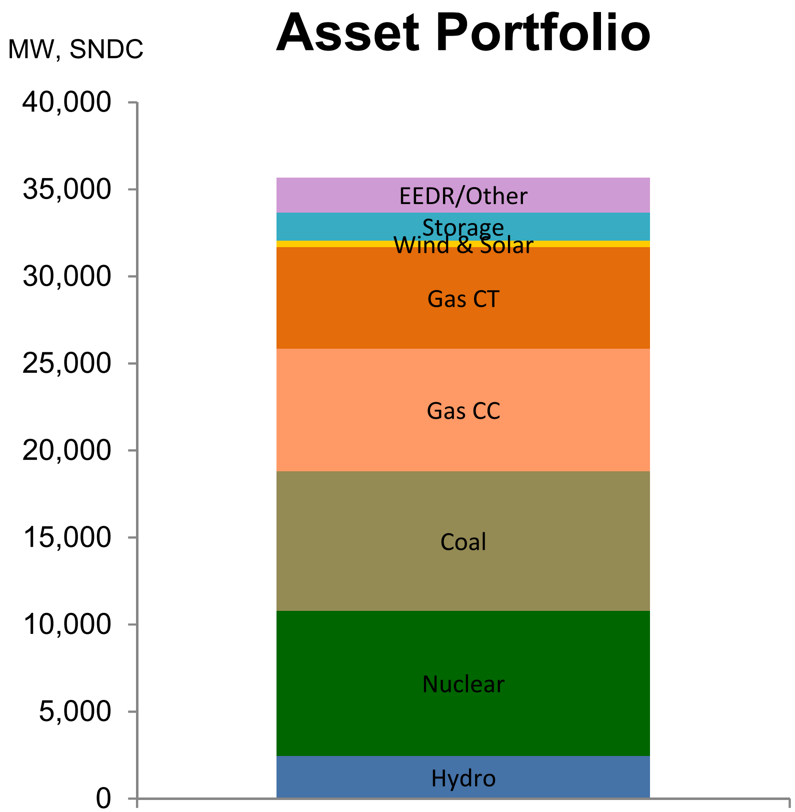
Resource planning is about optimizing the mix of future capacity.

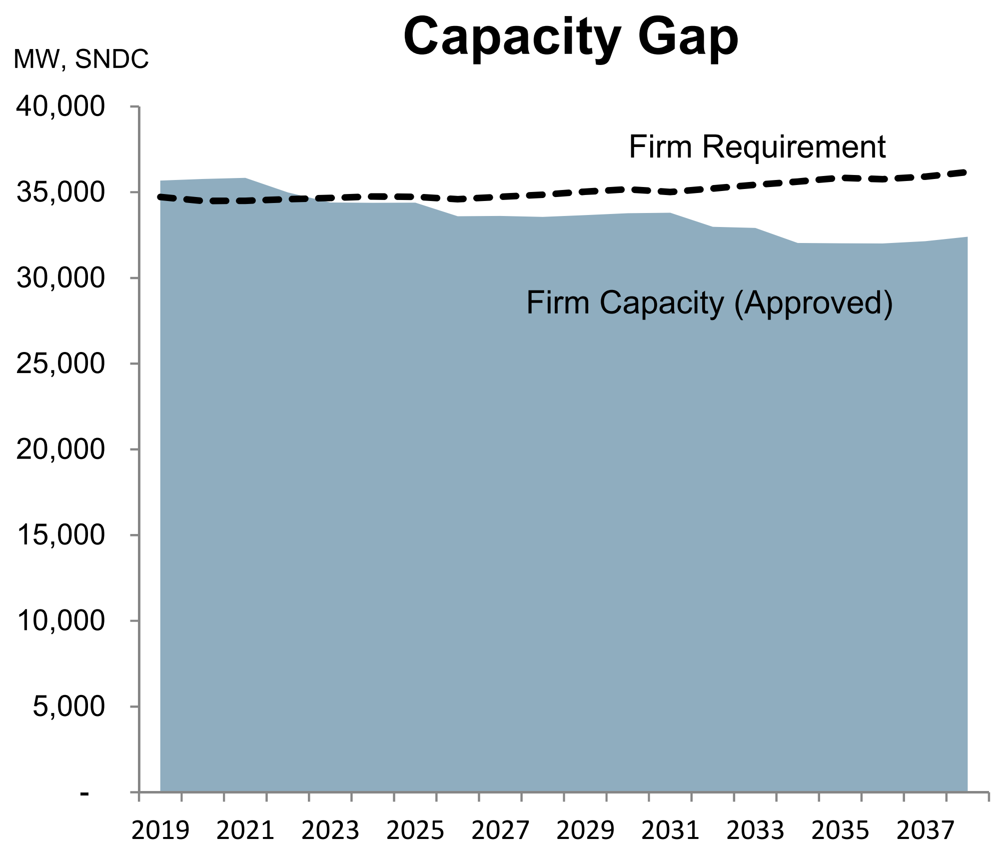
Projections of capacity needed are filled by the most cost-effective resource.



Recommended path provides low cost, reliability, diversity and flexibility

Current Portfolio and Projected Gap (Base Case)

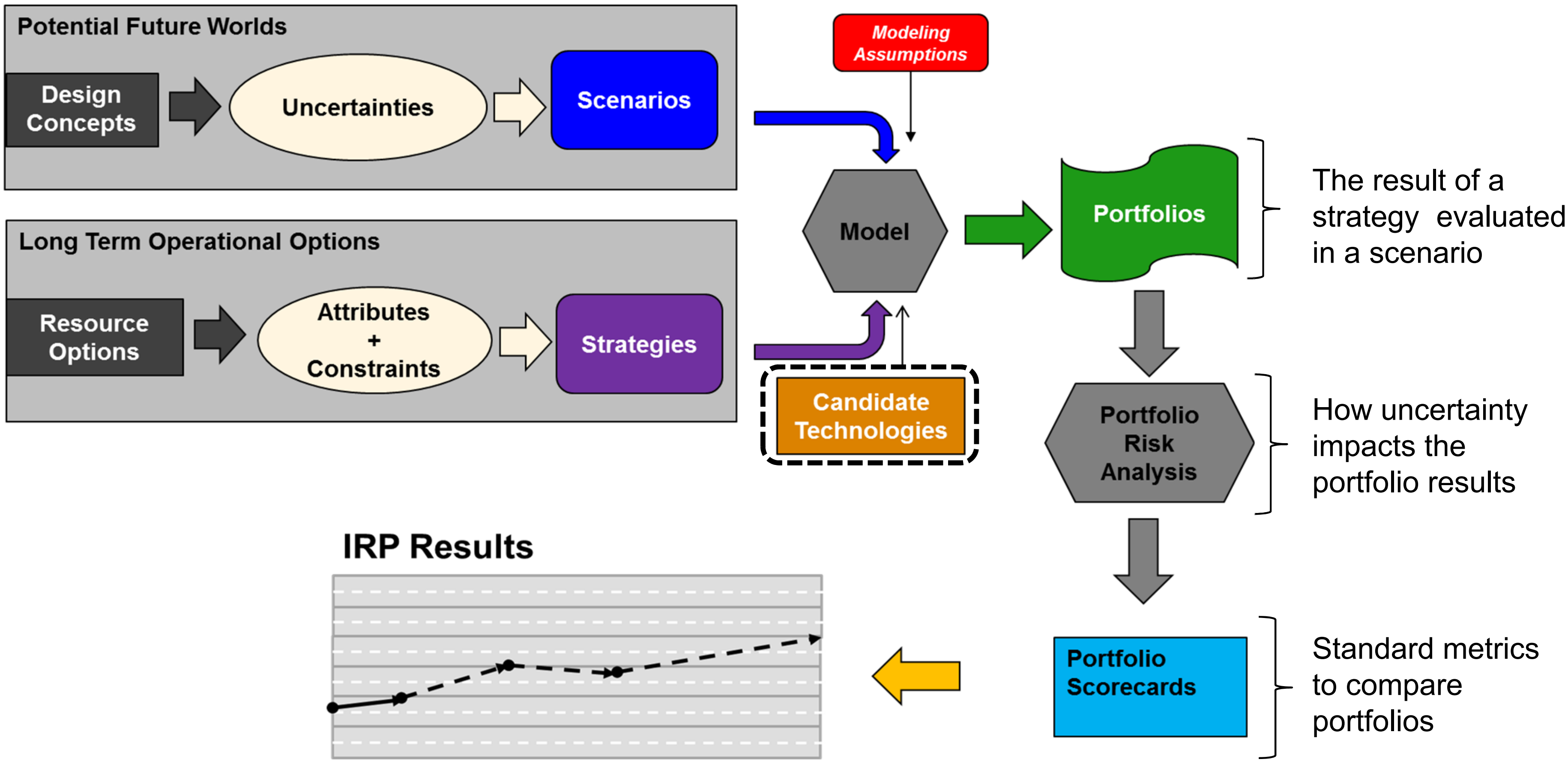




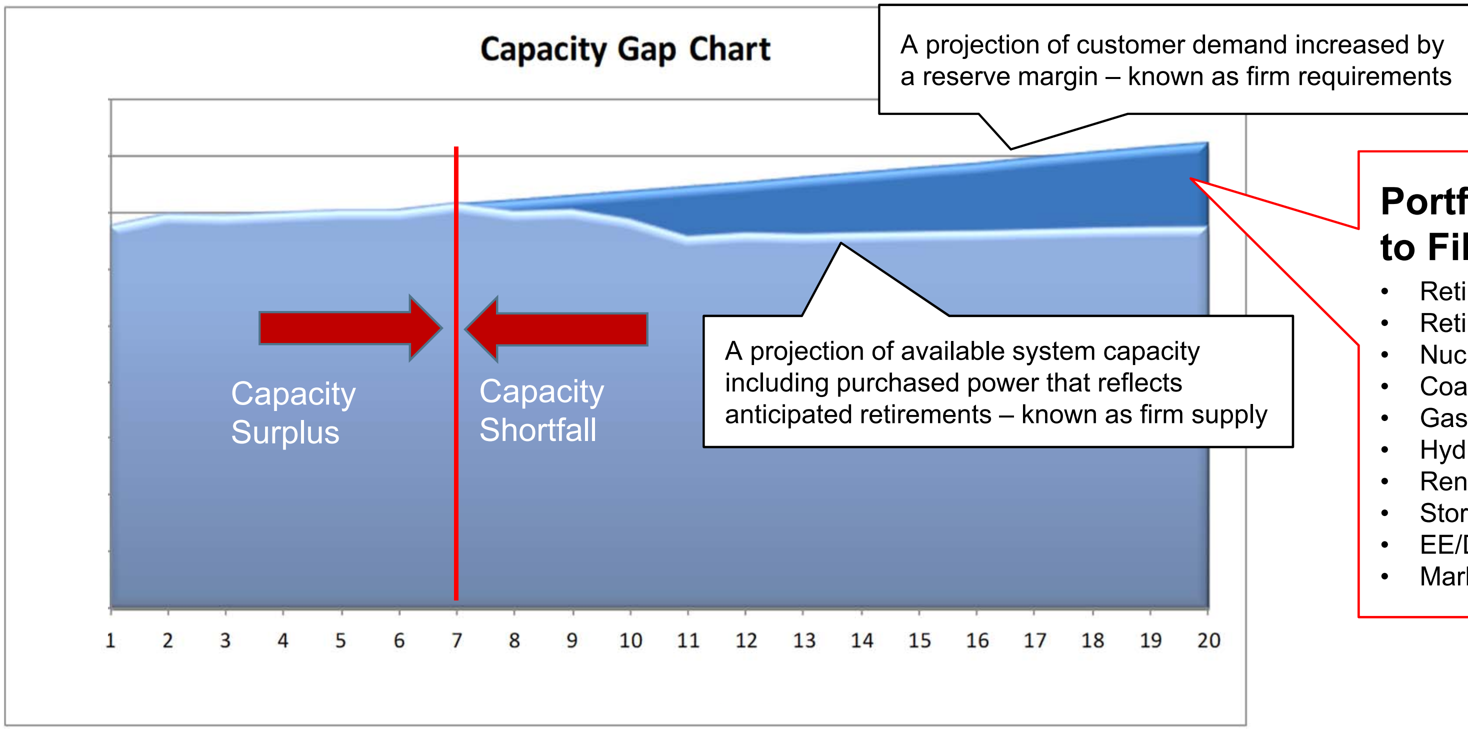
Introduction to Resource Technologies

Jane Elliott

Integrated Resource Planning Process



Resource Planning for Future Capacity Needs

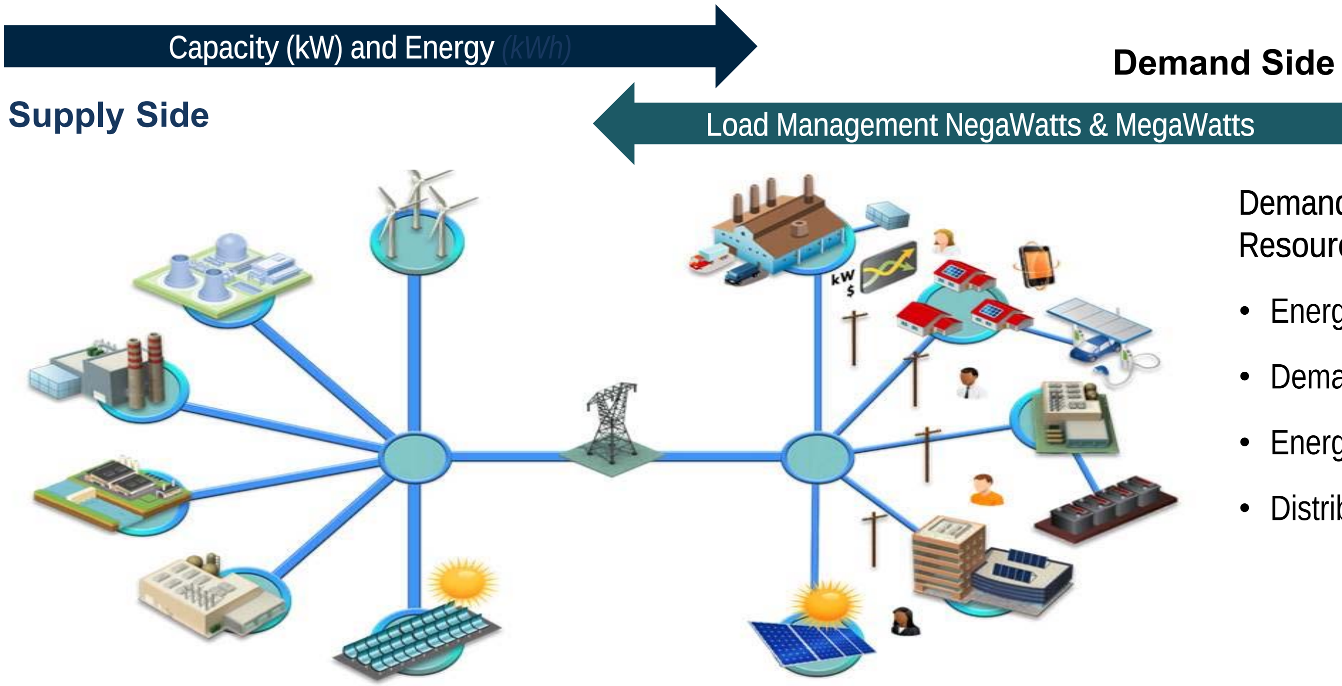


Portfolio Options to Fill the Gap

- Retired Coal
- Retired Nuclear
- Nuclear
- Coal
- Gas
- Hydro
- Renewables
- Storage
- EE/DR
- Market

Recommended path provides a low cost, reliable, diverse and flexible system

TVA Operates in Multidirectional Environment



Supply Side Resources

- Nuclear
- Coal
- Gas
- Purchased Power
- Renewables
- Hydro
- Other Assets

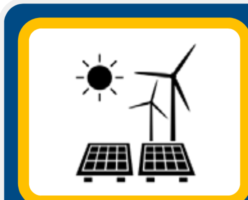
Demand Side Resources

- Energy Efficiency
- Demand Response
- Energy Services
- Distributed Generation

Wide Variety of Resource Options to Consider

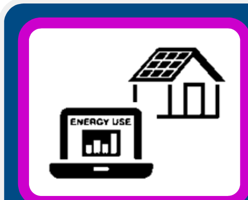
Conventional Power Plants

- Nuclear, coal and gas
- Screened based on feasibility, technology maturity, and levelized cost by type and duty cycle



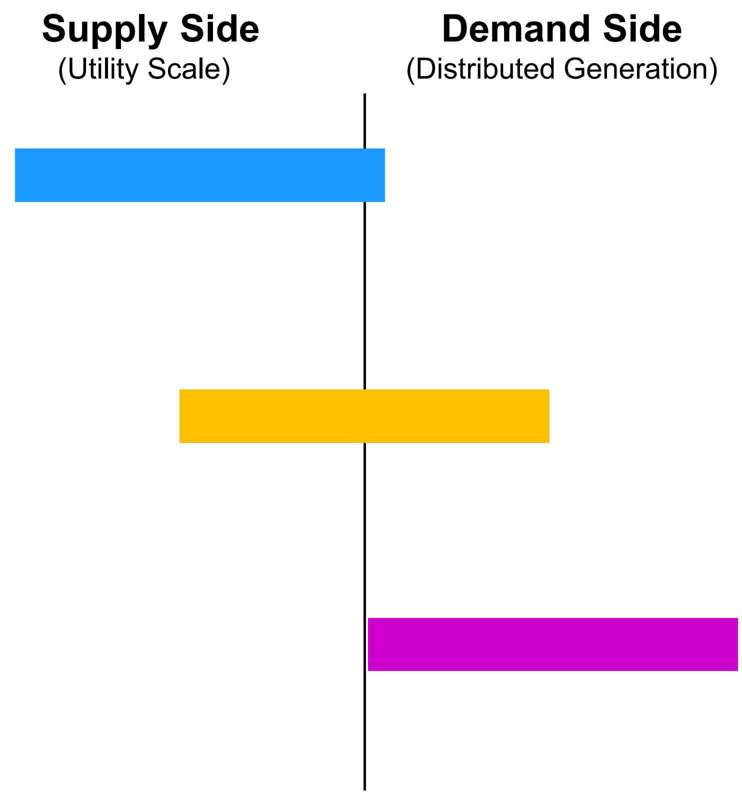
Renewable Resources

- Hydro, wind, solar, biomass and storage resources
- Screened based on feasibility, technology, maturity, and levelized cost by type and duty cycle



Distributed Energy Resources

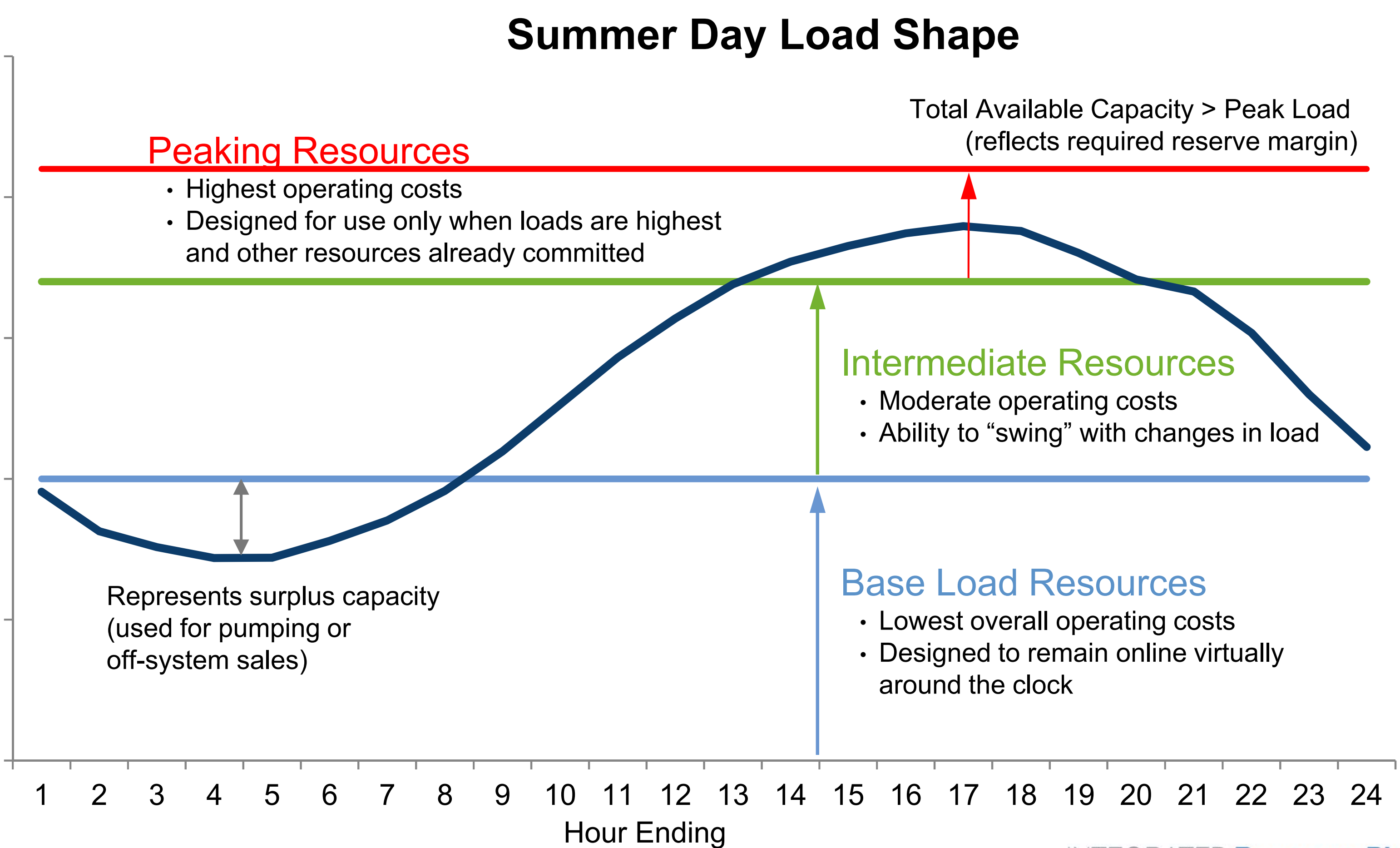
- Energy efficiency programs
- Demand response programs
- Distributed generation (e.g. solar, combined heat & power)



Resource options are screened based on multiple criteria:

- Technological viability and maturity
- Economic (based on levelized cost)

Resources Have Different Characteristics



Current Portfolio Mix to Meet Operational Needs





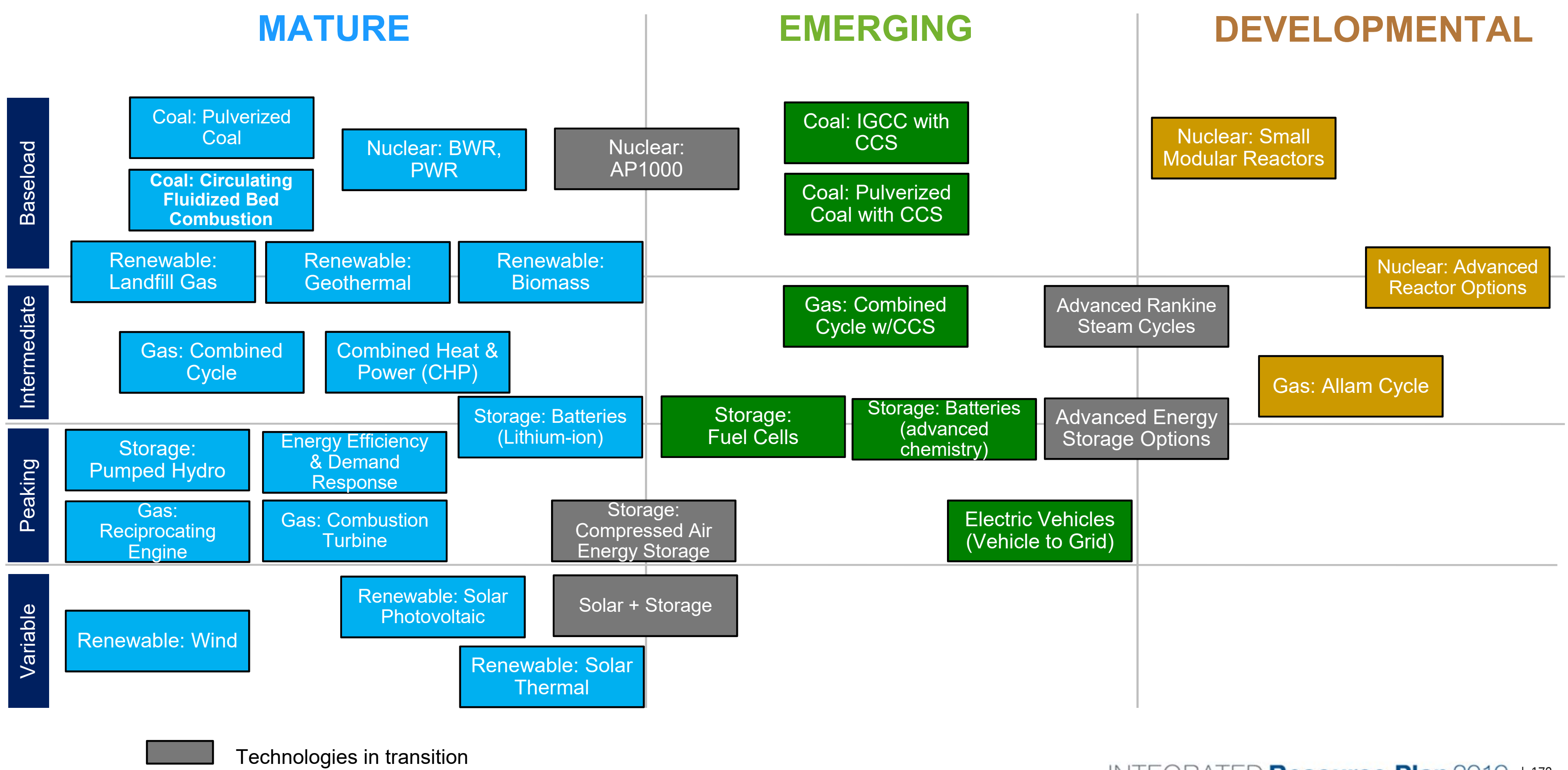

Hydro	Nuclear	Renewables	EEDR	Gas	Coal
4,200 MW conventional 1,600 MW pumped storage	7,800 MW	1,200 MW wind 130 MW utility-scale solar 250 MW programmatic solar/biomass	1,300 MW avoided capacity	5,800 MW CT and diesels 8,100 MW CC	8,400 MW

Approximately 42 percent of TVA's capacity is emission-free

Capacity values in this table are consistent with the 2017 10-k report (rounded to nearest 100 MW)

Evaluating Resource Maturity

<u>Preliminary tabulation of resources by duty cycle and maturity</u>



Preliminary List of 2019 IRP Resource Options

Conventional	Renewables / Storage	Distributed Resources	PPA

Coal
• Supercritical Pulverized Coal 800/1600 MW
• Supercritical Pulverized Coal with CCS 600/1200 MW
• IGCC 500 MW
• IGCC with CCS 469 MW
 	
Nuclear
• Nuclear AP1000 1117 MW
• Small Modular Reactors 600 MW
 	
Gas
• Reciprocating Engine (2x) 36MW
• Reciprocating Engine (6x) 113 MW
• Reciprocating Engine (12x) 226 MW
• Aeroderivative CT(2x) 192 MW
• Aeroderivative CT(4x) 384 MW
• Aeroderivative CT(6x) 576 MW
• Frame CT (3x) 703 MW
• Frame CT (4x) 934 MW
• Combined Cycle (1 on 1) 591 MW
• Combined Cycle (2 on 1) 1182 MW
• Combined Cycle (3 on 1) 1152 MW
	Storage
	• Pumped Storage 850 MW
	• Battery 15 MW (lithium-ion)
	• Compressed Air Energy Storage 330 MW
	• Battery (advanced chemistry)
	• Fuel cells
	
	Solar PV Options
	• Large 1-axis tracking 25 MW
	• Small fixed tilt 25 MW
	• Large Commercial Rooftop 25MW
	
	Wind Options
	• MISO/SPP 200 MW
	• In-Valley 120 MW
	• HVDC wind 250 MW
	
	Biomass Options
	• Direct Combustion 115MW
	• Repowering 75MW
	
	Hydro Options
	• Split Addition 40 MW
	• Space Addition 30MW
	• Run-of-River 25MW
		Energy Efficiency
		• Blocks by market segment; variable block size & duration
		
		Demand Response
		• Third-party and TVA programs
		
		Distributed Generation
		• Distributed Solar
		• Distributed Storage
		• Distributed Solar + Storage
		• Combined Heat and Power
		• Electric Vehicles (Vehicle to Grid)
			• Options are based on proposals submitted to TVA from resources inside and outside the Valley and are usually tied to a specific project for a defined term at a negotiated price
			
			• Transmission costs and import limitations are included in the PPA characteristics, if applicable
			
			• PPAs are not screened
			  o They are included in the database as proposed
			  o The model treats these PPAs as a fixed transaction that can only be selected based on terms defined in the offer
			  o PPAs cannot be rescheduled or selected in amounts that do not conform to the proposal

Fixed or Scheduled Assets			
• Existing Coal – some units will be evaluated • Existing Nuclear – some units will be evaluated • Existing Gas	• Existing hydro • Existing pumped storage • Existing Renewable PPAs (Solar, Wind, Biogas, SEPA Hydro, etc.) • End use generation programs • Existing solar	• Existing EEDR programs • Interruptible programs • In–house interruptible programs	• Existing non-renewable PPAs (Red Hills, DEC, diesels, etc.)

Resource Technologies – Next Steps

- Complete third-party review of resource planning assumptions (Navigant)
- Incorporate review feedback into planning assumptions
- Review recommended planning assumptions at next IRPWG meeting

Are we offering the right breadth of mature and emerging resources for selection?

TVA

Review of IRP Process and Discussion

Jo Anne Lavender

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)

<u>Key Tasks/Milestones in this study timeline include:</u>

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

IRP Working Group Meeting Objectives

June 6th-7th	July 23rd-24th	August 29th-30th	September 26th-27th
• Finalize scenarios • Review attributes and brainstorm/review strategies • Discuss proposed strategies and develop short list • Introduce resource options	• Finalize strategies • Scenario design preview • Resource options (draft) • Modeling framework	• Scenario design (final) • Strategy design preview • Resource options (final) after 3rd party review • Scorecard development	• Strategy design (final) • Scorecard design • EIS outline

Vote on scenarios

Vote on strategies

Considering all you have heard, what are your thoughts about the process to date?

Next Steps