2019 TAG Meeting #8:

Overview of gas modeling process, scenario electric power price forecast, overview of electric modeling process

PUGET SOUND ENERGY

Welcome

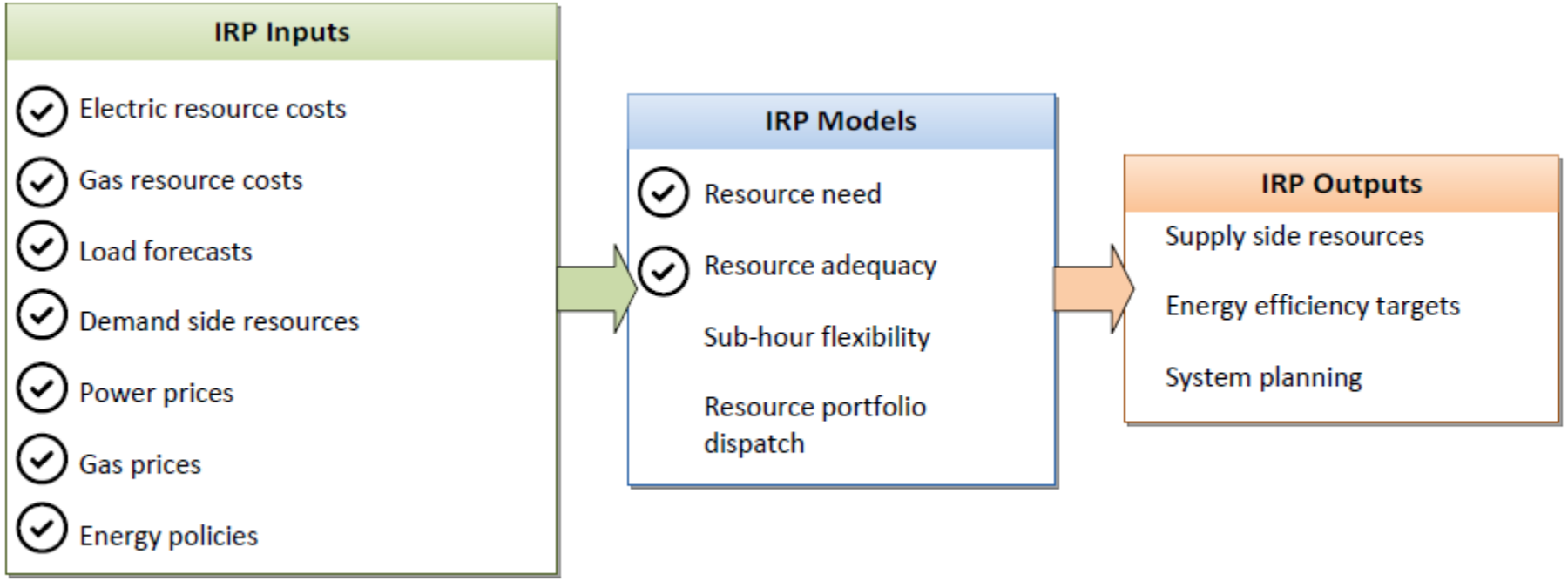
- Safety message
- Introductions
- Opening remarks

Meeting objectives

- PSE presents an overview of the gas modeling process
- PSE presents electric power price scenario results
- PSE presents an overview of the electric modeling process

IRP analytical process overview

- PSE has established an analytical framework to develop its **20-year forecast of demand side resources and supply side resources** that appear to be cost effective to meet the growing needs of our customers.



Includes Clean Energy Transformation Act

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Action items from prior IRPAG and TAG meetings

September 19, 2019 TAG #8

Open action items from previous IRPAG and TAG meetings

Action item #	Description (and meeting reference)	PSE action	Status
1	Identify contact for PSE's carbon reduction goals. (IRPAG #1, May 30, 2018)	PSE will include a listening session at the May 22, 2019 IRPAG meeting #3.	Complete
2	Consider methodology for posting TAG questions and answers publicly. (TAG #4, January 9, 2019)	PSE posted all relevant questions and answers. Online public input form developed and available. Reports posted monthly.	Complete
3	Host a presentation on the Energize Eastside project and invite TAG members. (TAG #4, January 9, 2019)	The presentation has been added to the agenda to TAG #7 on August 6, 2019 (cancelled due to appeals).	Cancelled

Items that will be included in the draft and final IRP can be found in the action item tracking for the book (at the end of the slide deck)

Open action items from previous IRPAG and TAG meetings

Action item #	Description (and meeting reference)	PSE action	Status
4	Consider providing an energy efficiency dialogue around policy and implementation of energy efficiency. (TAG #4, January 9, 2019)	This dialogue has been added to the agenda to TAG #7 on August 6, 2019 but meeting was cancelled. PSE is developing a new plan.	In progress
5	Finalize meeting notes from TAG #6. (TAG #6, May 29, 2019)	PSE distributed meeting notes on June 12; stakeholders provided feedback by June 19; PSE posted the final meeting notes to www.pse.com/irp on June 26.	Complete

Overview of gas portfolio modeling process

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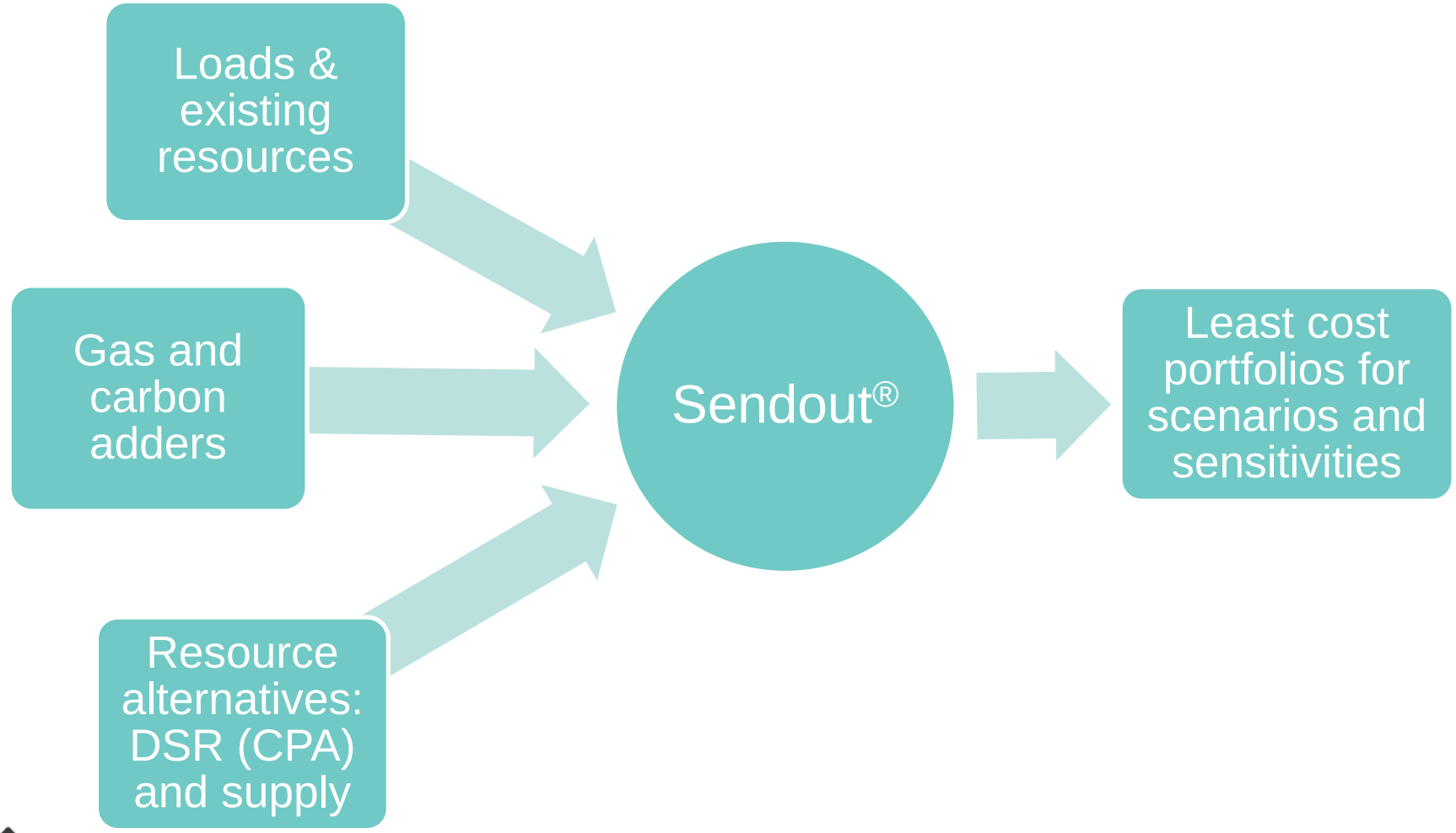
Gas portfolio modeling - SENDOUT



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Gas portfolio modeling - scenarios

	Scenario Name	Demand	Gas Price	CO_2 Price
1	Base	Mid[1]	Mid	Social cost of carbon included in Washington state[2], plus upstream natural gas GHG emissions (US and Canadian).
2	Low Growth	Low	Low	Social cost of carbon included in Washington state[2], plus upstream natural gas GHG emissions (US and Canadian).
3	High Growth	High	High	Social cost of carbon included in Washington state[2], plus upstream natural gas GHG emissions (US and Canadian).

Notes:

1. *Mid demand refers to the 2019 IRP Base Demand Forecast.*
2. *Interagency Working Group on Social Cost of Greenhouse Gasses, Technical Support Document, August 2016 update. It projects a 2.5 percent discount rate, starting with $62 per metric ton (2007$) in 2020.*

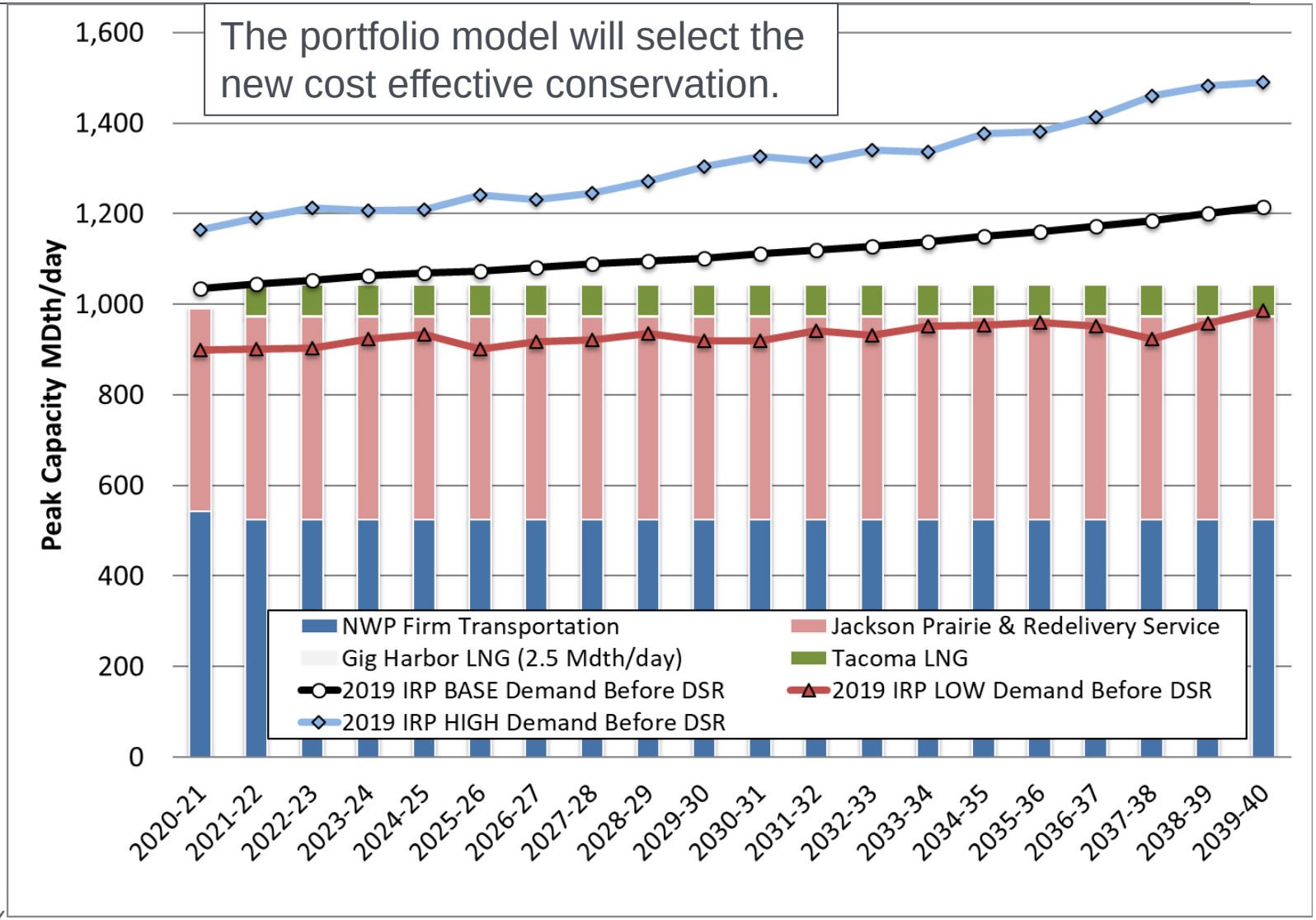
Gas portfolio modeling - sensitivities

NATURAL GAS ANALYSIS		
No.	**Sensitivities**	**Alternatives Analyzed**
A	Tacoma LNG	Tacoma LNG does not go into service
B	Extended DSR Potential	Future DSR measures extend benefits through second half of the study period
C	Alternative DSR discount Rate	Alternate discount rate of 6.5% for residential energy efficiency
D	Base + CO2 Tax	Social cost of carbon included in WA state, plus upstream natural gas GHG emissions, plus a carbon tax of $15/ton

$15/ton from proposed SB 5971

Gas portfolio modeling – load resource balance

The portfolio model will select the new cost effective conservation.



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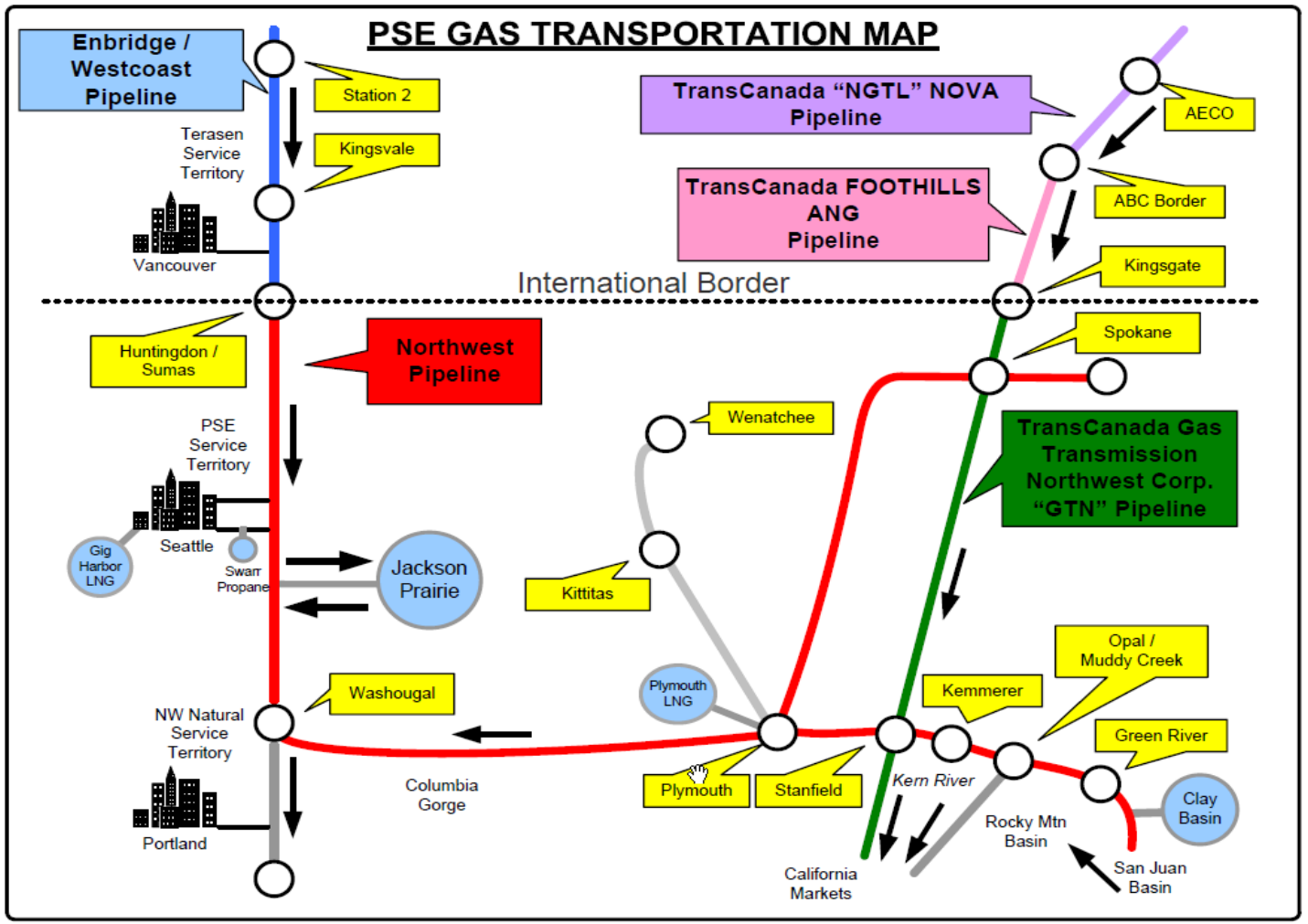
Gas portfolio modeling – supply side resources



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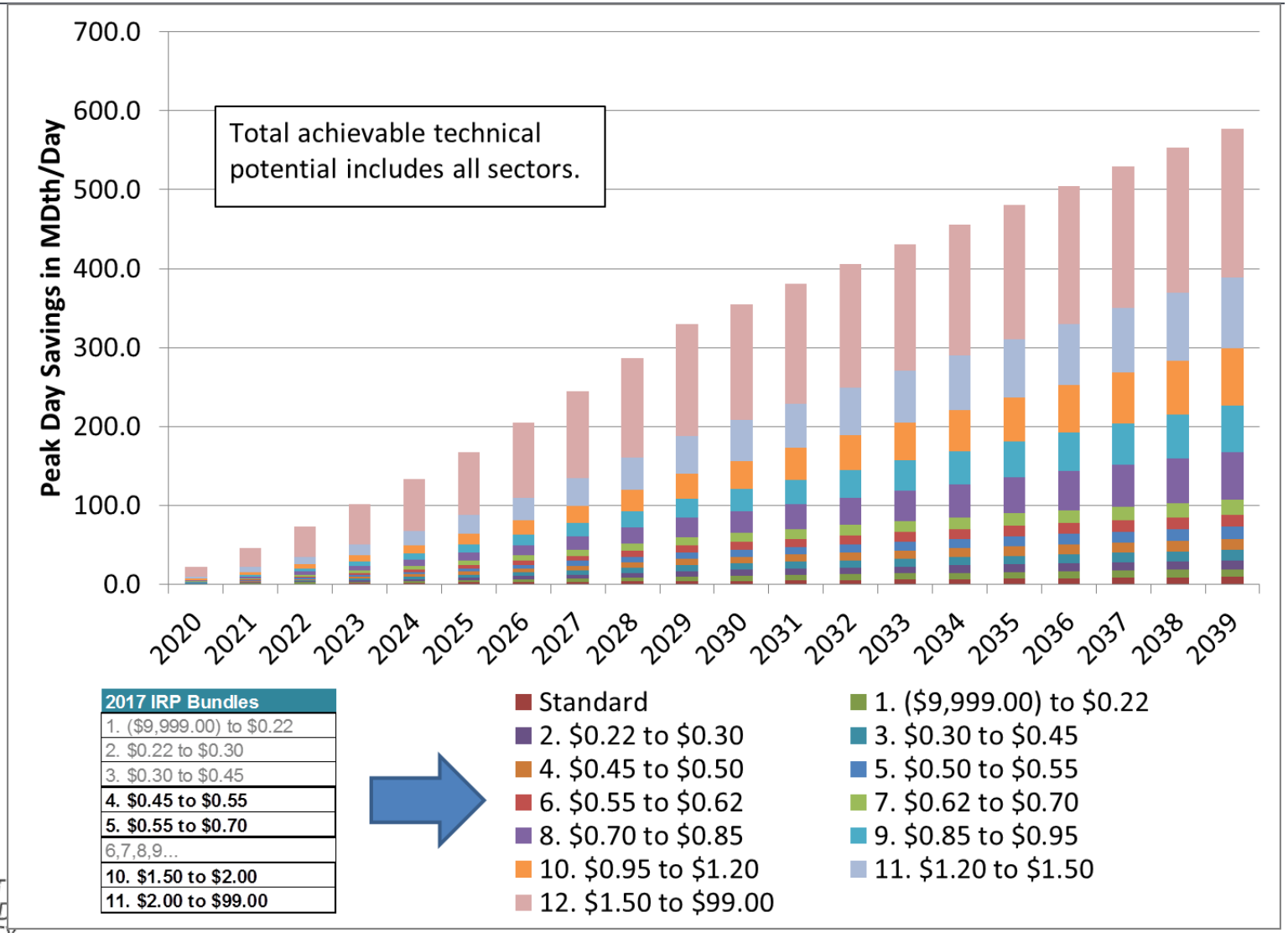
Gas portfolio modeling – DSR bundles



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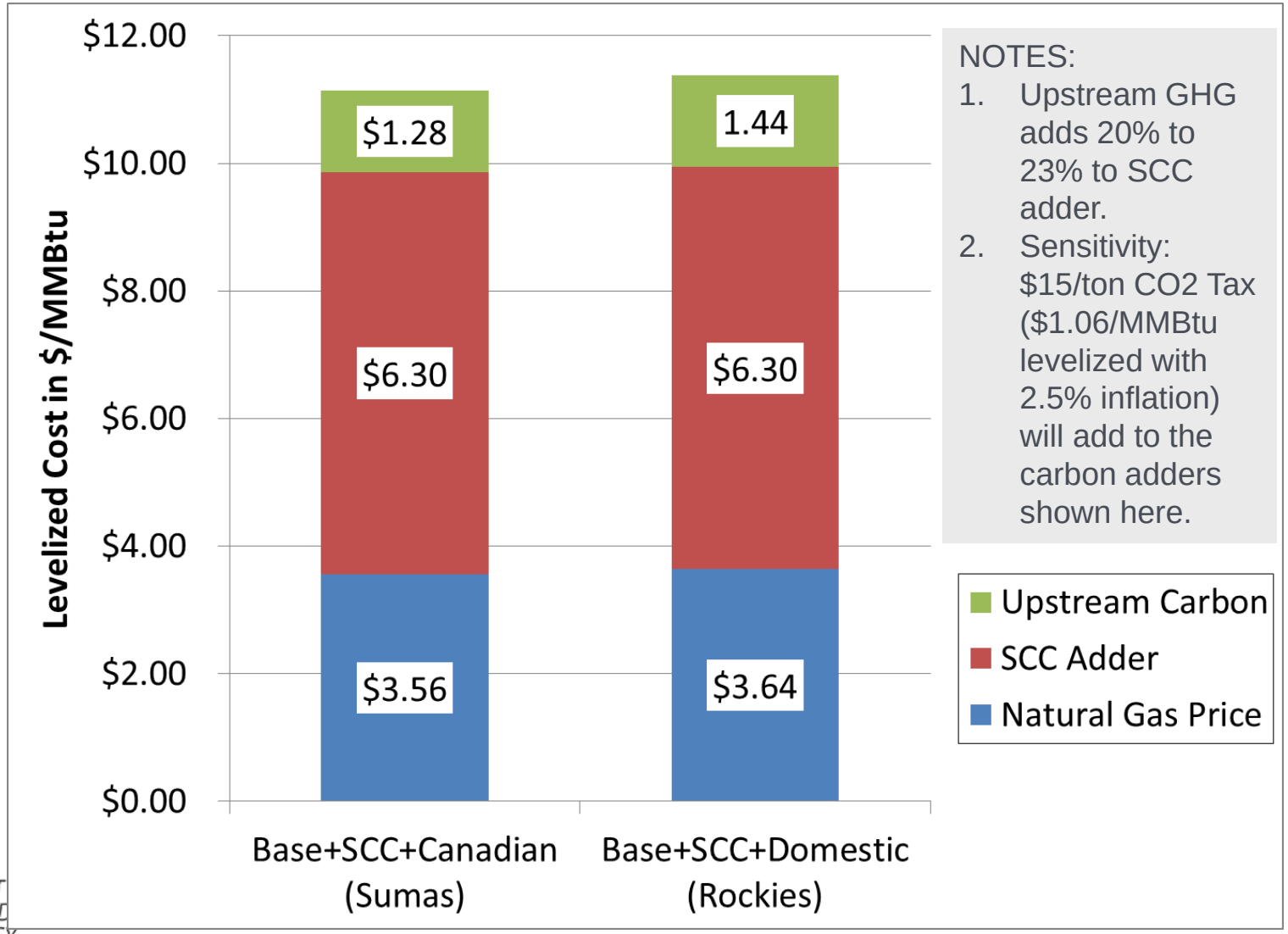
Cost of gas: commodity + SCC adder



NOTES:

1. Upstream GHG adds 20% to 23% to SCC adder.
2. Sensitivity: $15/ton CO2 Tax ($1.06/MMBtu levelized with 2.5% inflation) will add to the carbon adders shown here.

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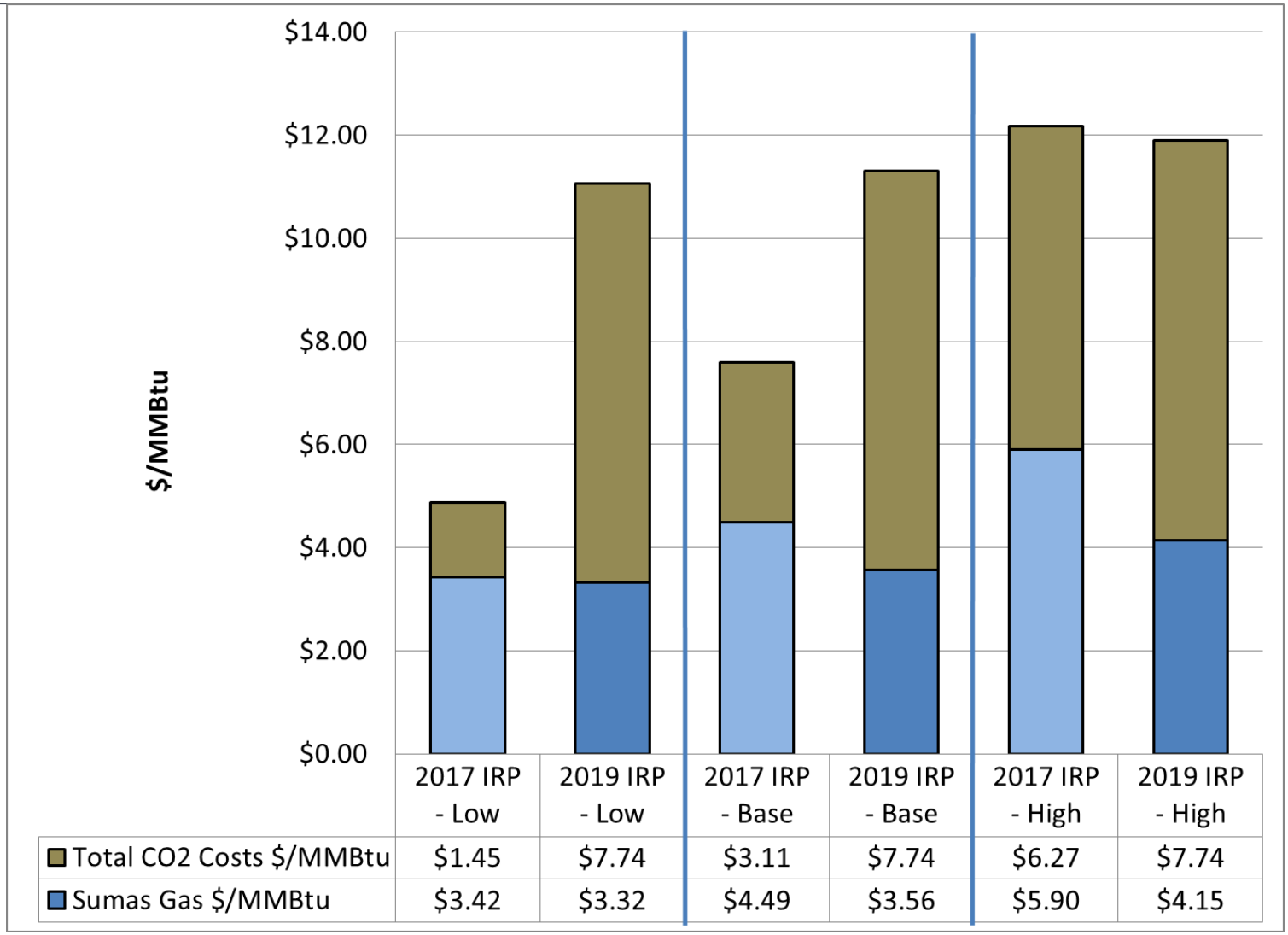
2017 IRP vs 2019 IRP cost of gas comparison



	2017 IRP - Low	2019 IRP - Low	2017 IRP - Base	2019 IRP - Base	2017 IRP - High	2019 IRP - High
Total CO2 Costs $/MMBtu	$1.45	$7.74	$3.11	$7.74	$6.27	$7.74
Sumas Gas $/MMBtu	$3.42	$3.32	$4.49	$3.56	$5.90	$4.15

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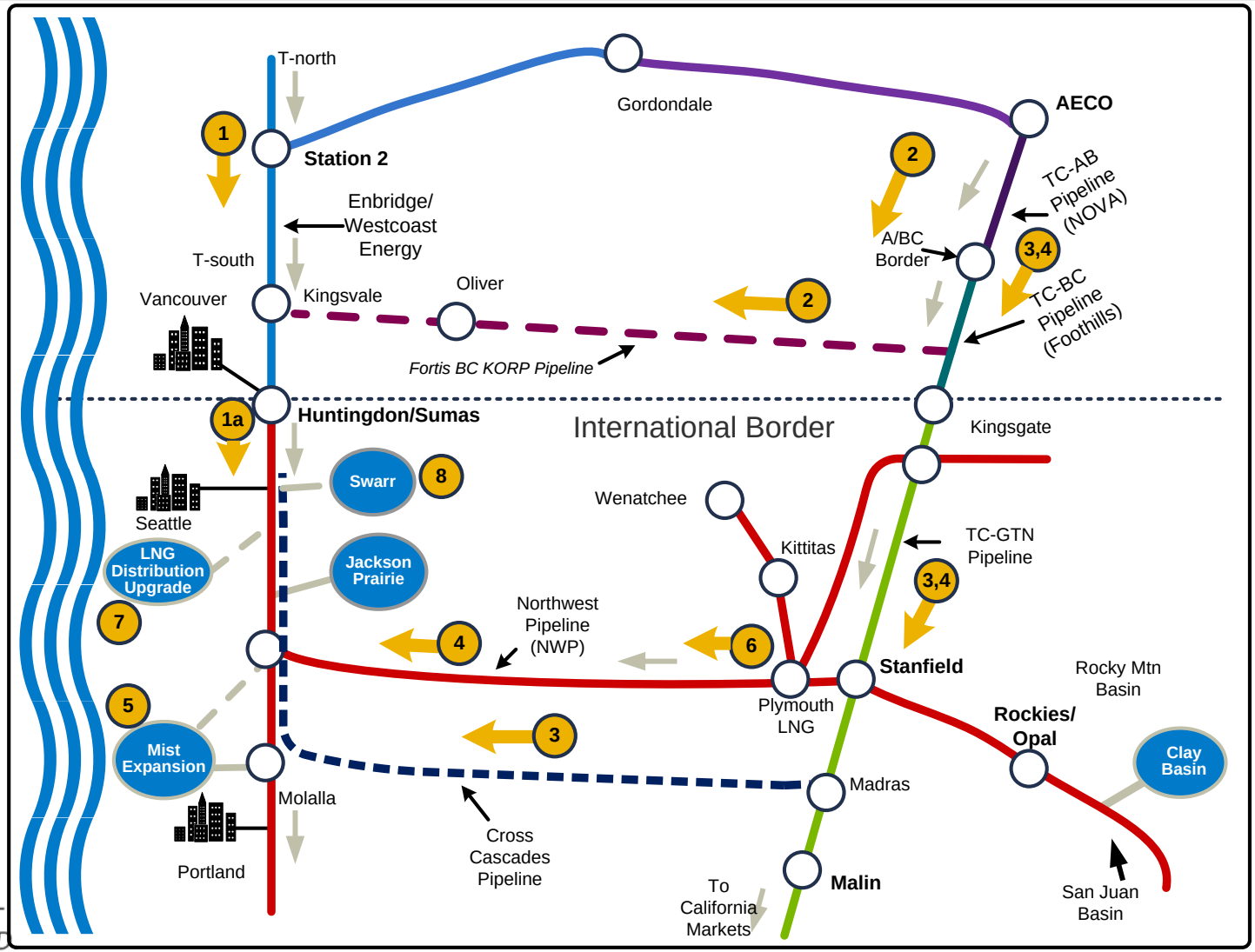
Gas portfolio modeling – supply resource alternatives



Lunch break

Social Cost of Carbon

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Social cost of carbon as a cost adder

Electric utilities in Washington State are required to incorporate the social cost of carbon (SCC) in conservation decisions, IRPs, and in making intermediate and long-term resource decisions. The Clean Energy Transformation Act (CETA) treats the cost adder as a factor to consider when planning for whether to build/acquire or retire generating resources rather than in the operation of the plant.

Section 14 (1) (l) (3) (a), beginning at line 32 states:

An electric utility must incorporate the social cost of greenhouse gas emissions as a cost adder when:

i. Evaluating and selecting conservation policies, programs, and targets;
ii. Developing integrated resource plans and clean energy action plans; and
iii. Evaluating and selecting intermediate term and long-term resource options.

Social cost of carbon as a cost adder

- The social cost of carbon is not applied in economic dispatch decisions; rather, the SCC is calculated for possible fossil fuel plants after economic dispatch, then reflected as a cost when deciding whether to add the plant.

- When making a decision to add or retire a resource, PSE looks at the full value of the resources. This includes
  - Variable costs (fuel, VOM, start-up, variable gas transport, variable transmission charges)
  - Fixed costs (emissions cost, FOM, capital, fixed gas transport, fixed transmission charges, taxes, insurance)
  - Benefits (flexibility, PTC, ITC)
  - Revenue

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Social cost of carbon as a cost adder

- How is social cost of carbon being modeled as a cost adder different than a CO_2 tax?
  - Modeling the SCC as a CO_2 tax would understate the costs and emissions associated with the plant. The model is set to optimize the dispatch of the plant including an emission price.

2019 IRP

	SCC as a CO_2 tax	SCC as a cost adder
Annual capacity factor from economic dispatch	30%	70%
Annual CO2 emissions	400,000 tons	1,000,000 tons
Total cost of CO2 emissions	$32 Million	$80 Million

- The higher cost associated with the cost adder will make baseload gas plants less economic.
- 2015 IRP, 2017 IRP, 7th Power Plan results show that modeling a CO_2 tax increased the baseload gas plant builds.

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Scenario electric power price forecast

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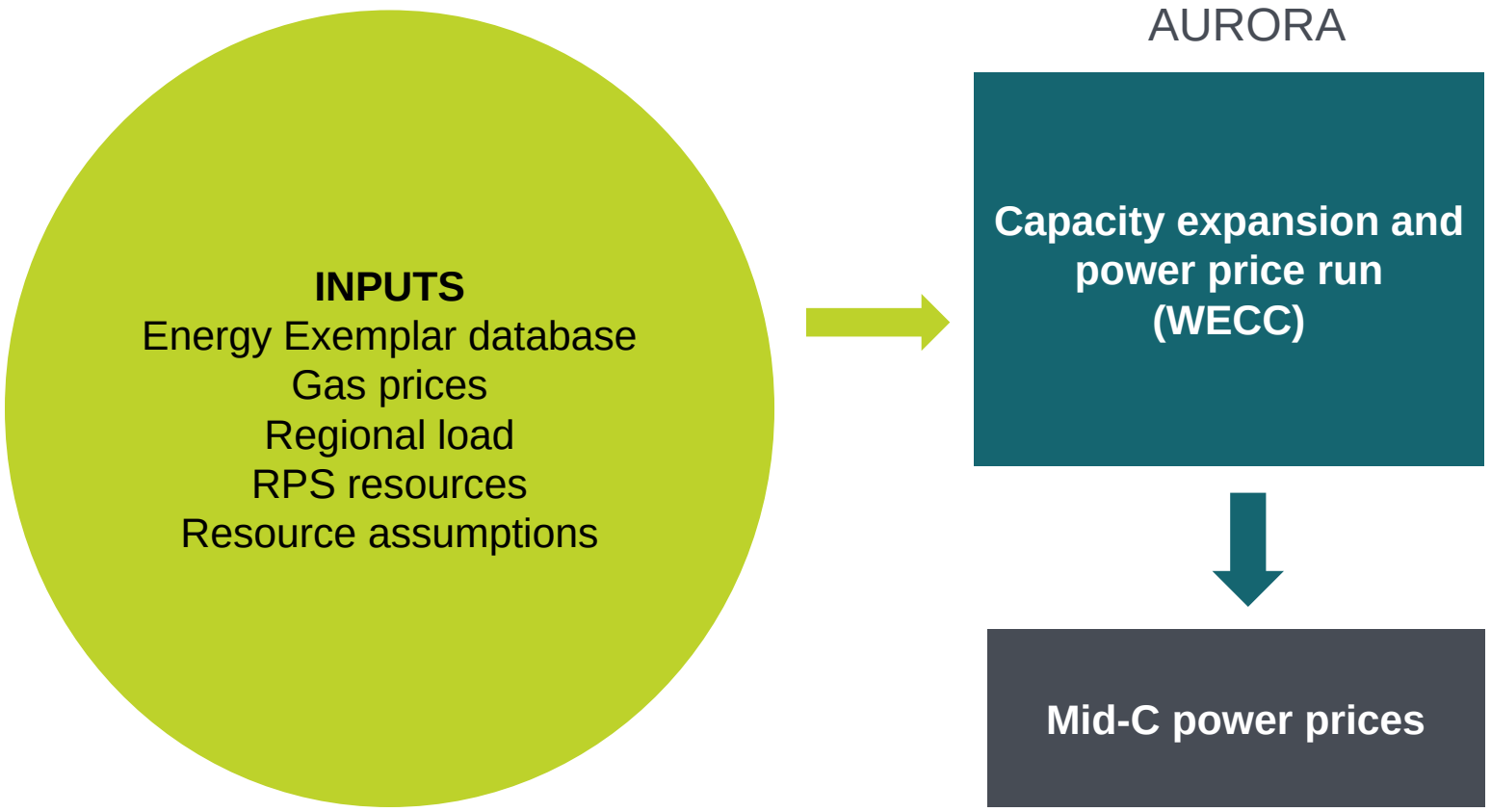
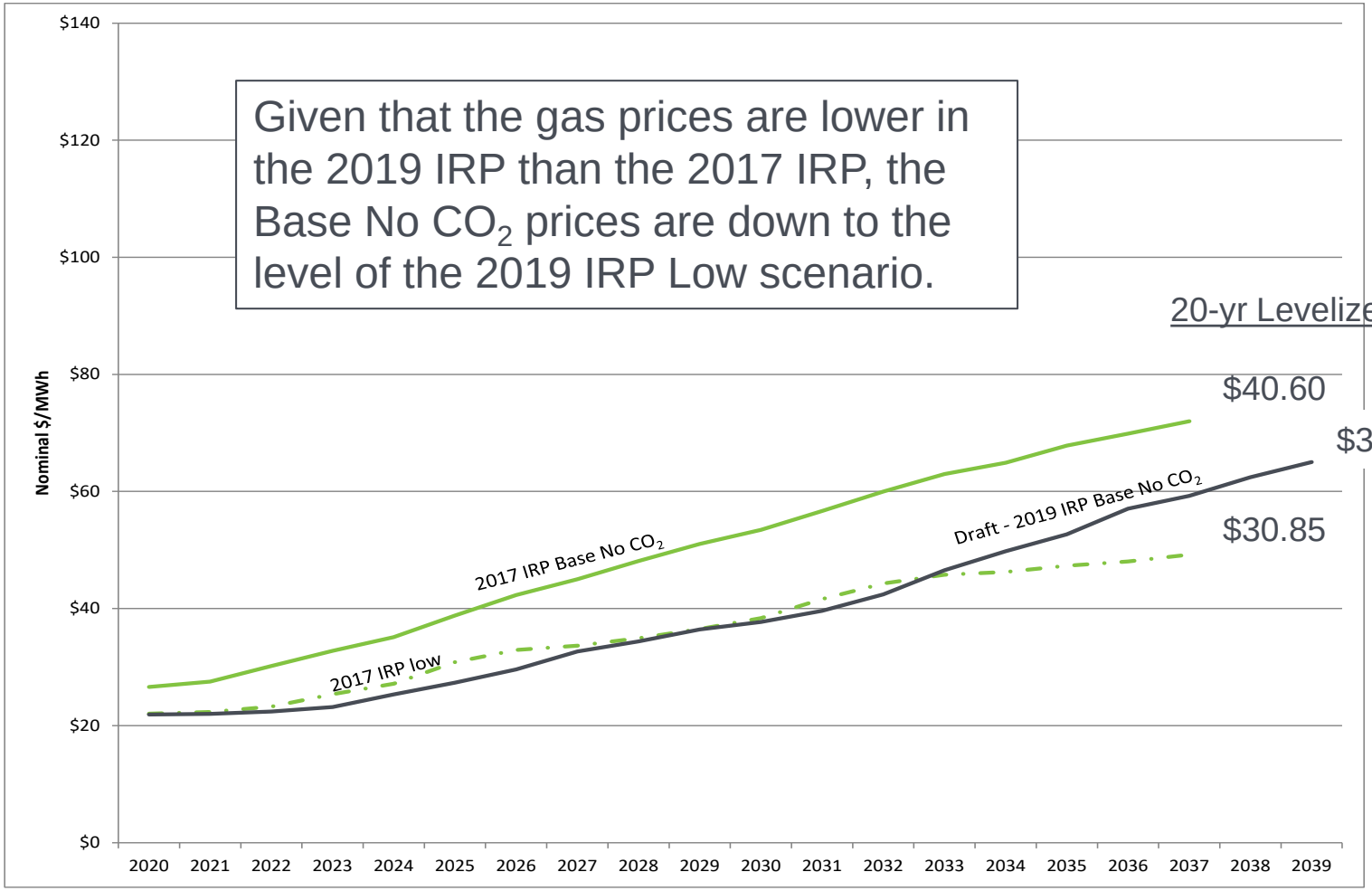
Review of the power price forecast model



Power price forecast presented at the TAG #2 meeting on October 11, 2018



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Modeling updates to the electric price forecast since October 2018 TAG #2

- Gas Prices
  - Updated to Wood Mackenzie fundamental gas price forecast fall 2018, levelized $3.56/MMBtu. Previously spring 2018 forecast, levelized $3.74/MMBtu

- Renewable Portfolio Standard (RPS)/ Clean Electricity Standards
  - California Senate Bill (SB) 100 signed into law in September 2018
  - New Mexico SB 489 signed into law on March 22, 2019
  - Nevada SB 358 signed into law on April 22, 2019
  - Washington SB 5116 signed by Governor on May 7, 2019

- Social cost of carbon starting at $86/US ton (nominal) in 2020 and growing to $184/US Ton (nominal) in 2039 as a planning adder in Washington

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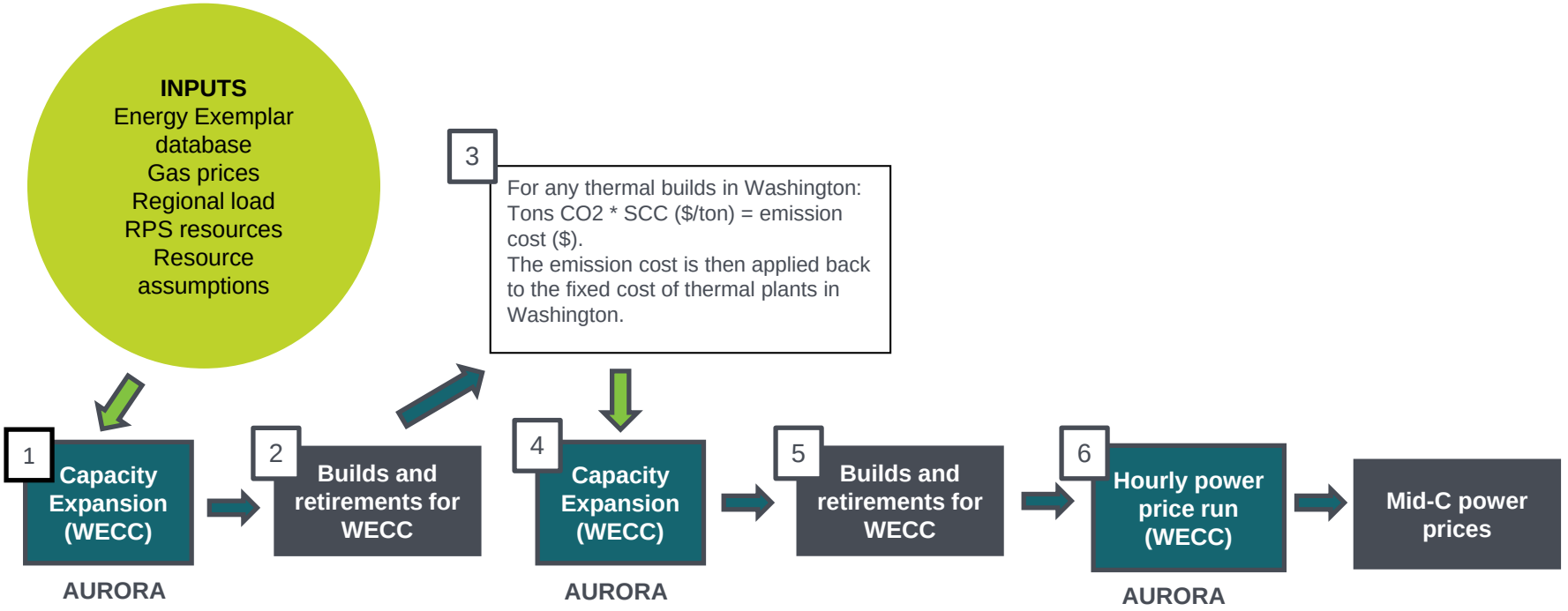
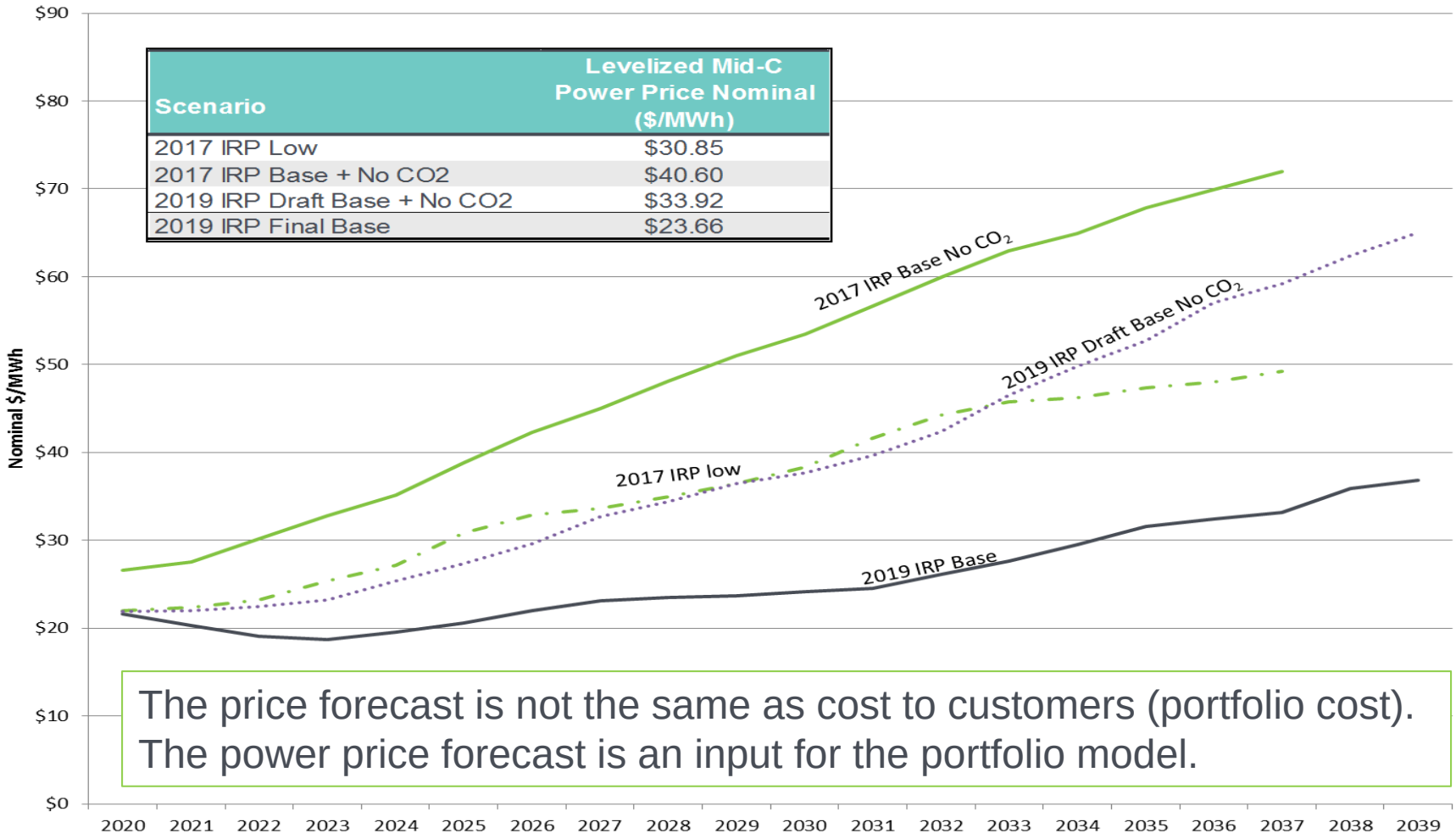
Reflecting the social cost of carbon as a planning adder in the power price model



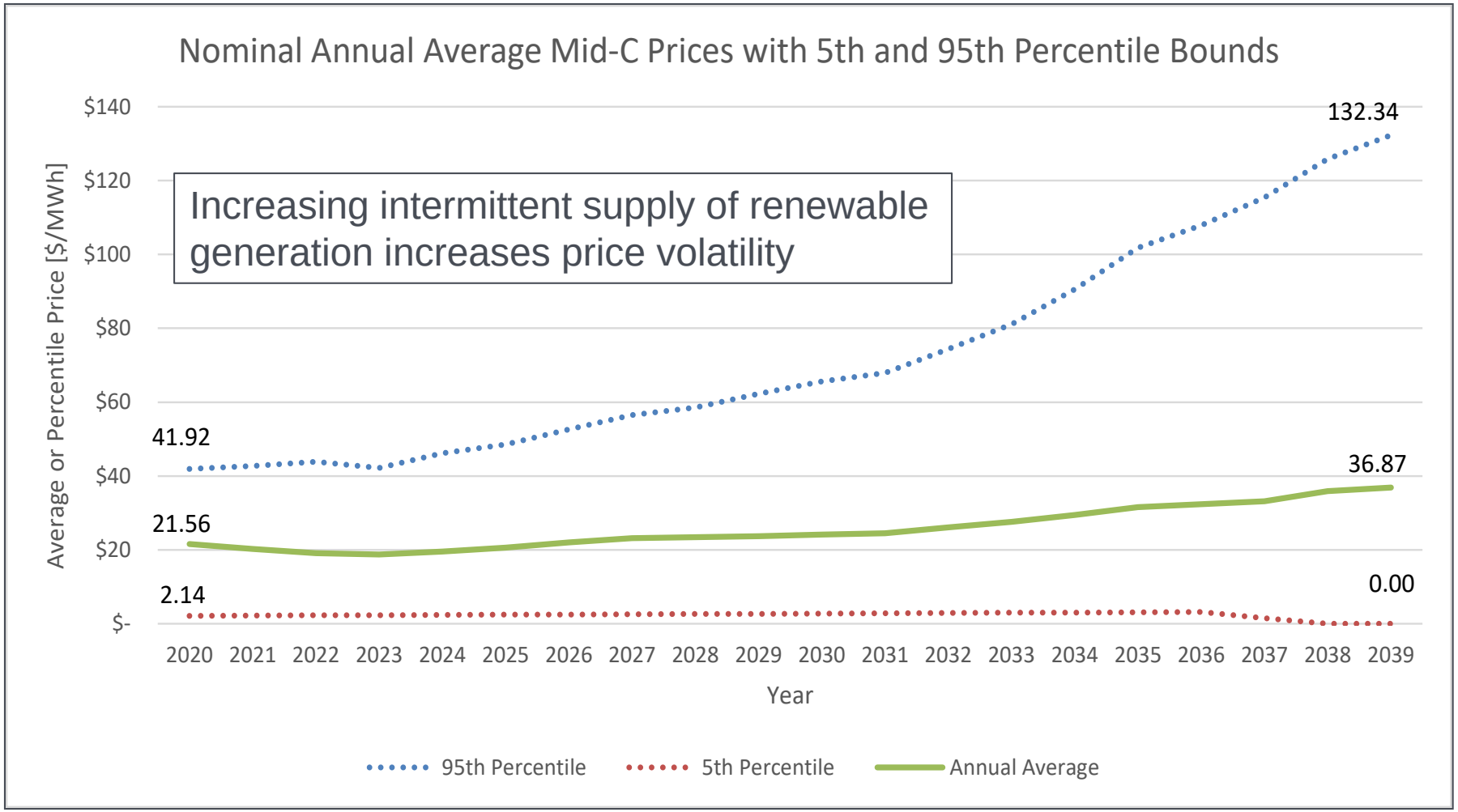
Mid-C electric price forecast

Scenario	Levelized Mid-C Power Price Nominal ($/MWh)
2017 IRP Low	$30.85
2017 IRP Base + No CO2	$40.60
2019 IRP Draft Base + No CO2	$33.92
2019 IRP Final Base	$23.66

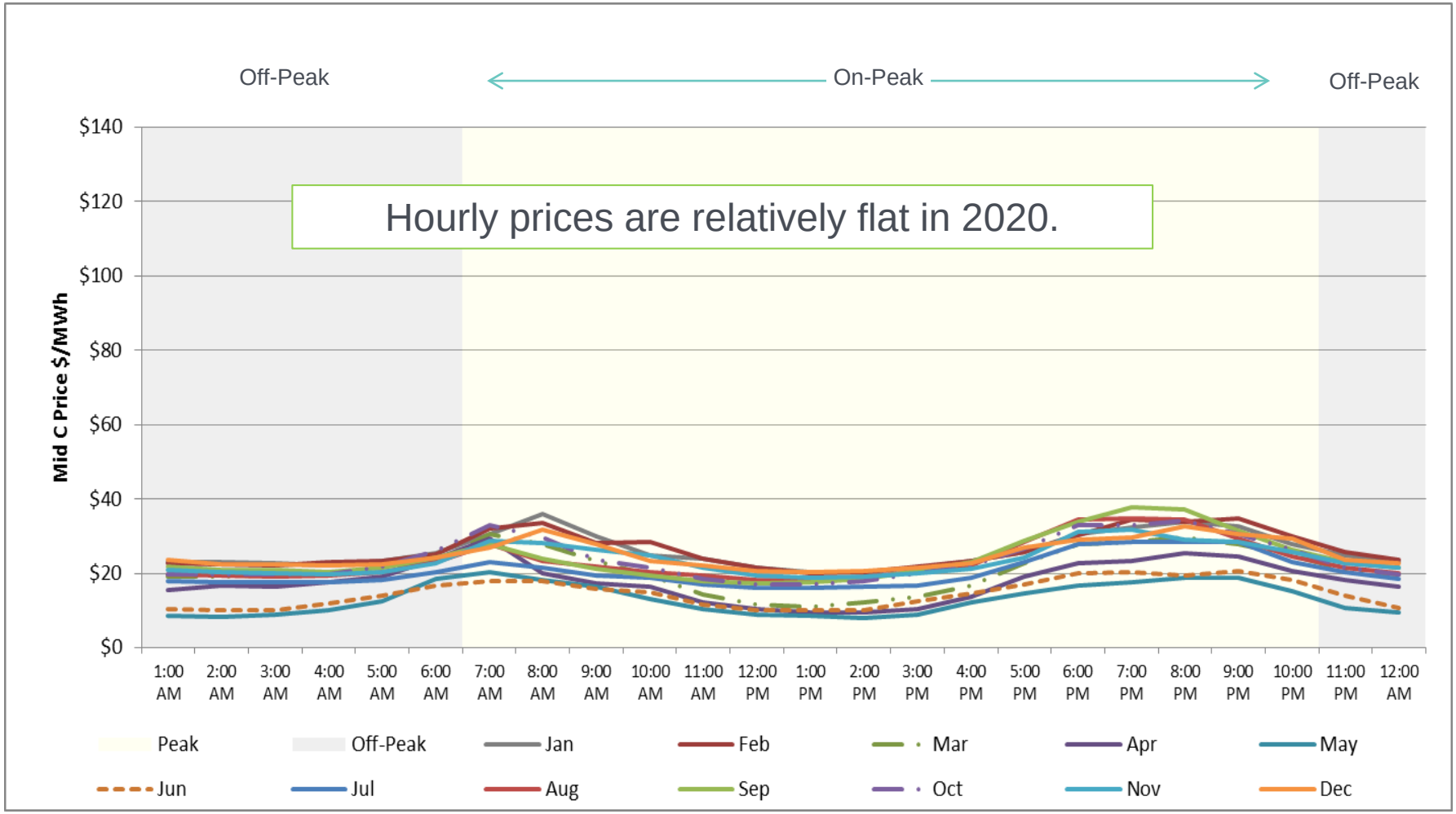


The price forecast is not the same as cost to customers (portfolio cost). The power price forecast is an input for the portfolio model.

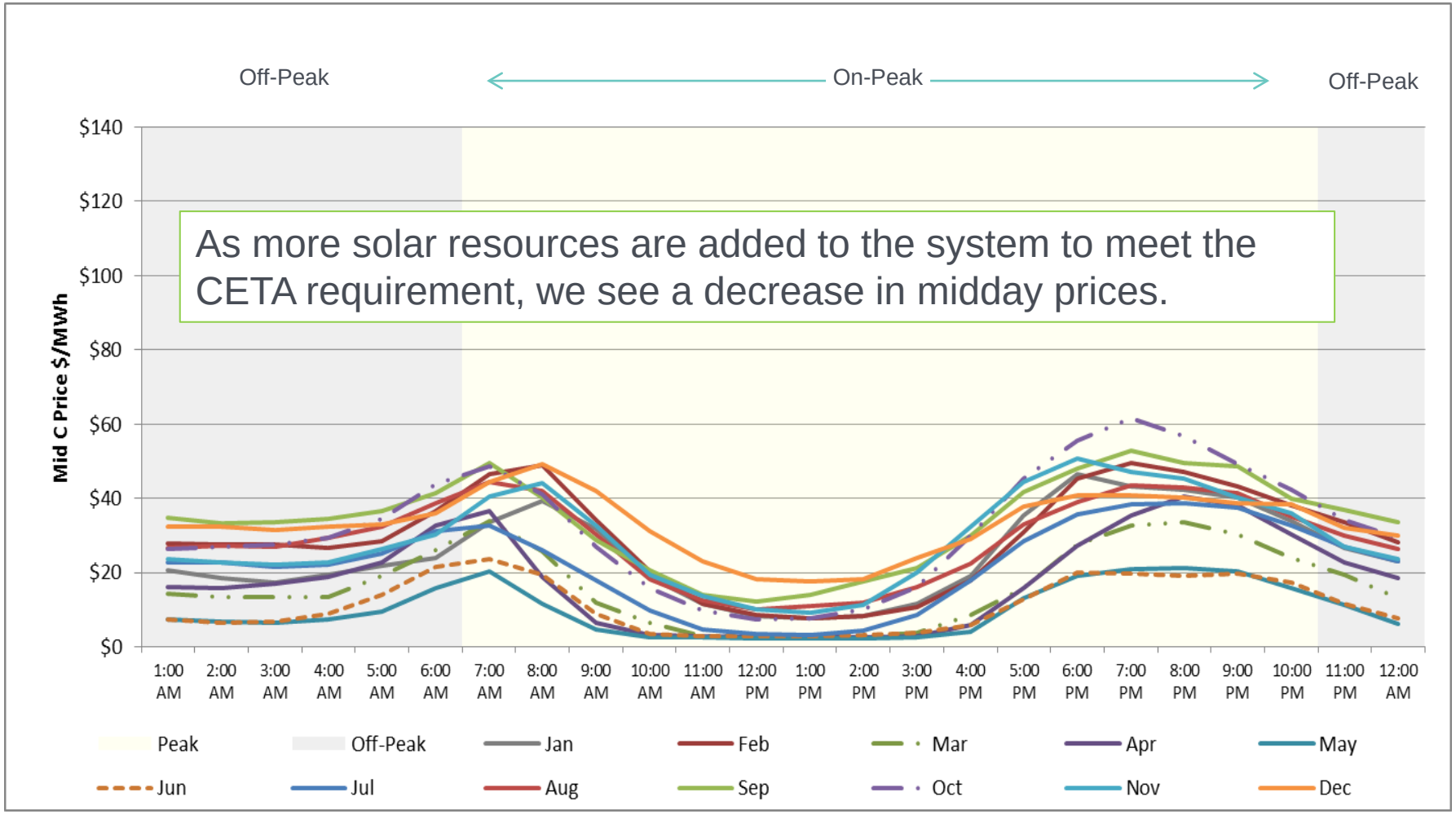
Mid-C electric price forecast for base scenario



2020 hourly Mid-C price shape by month



2030 Hourly Mid-C price shape by month



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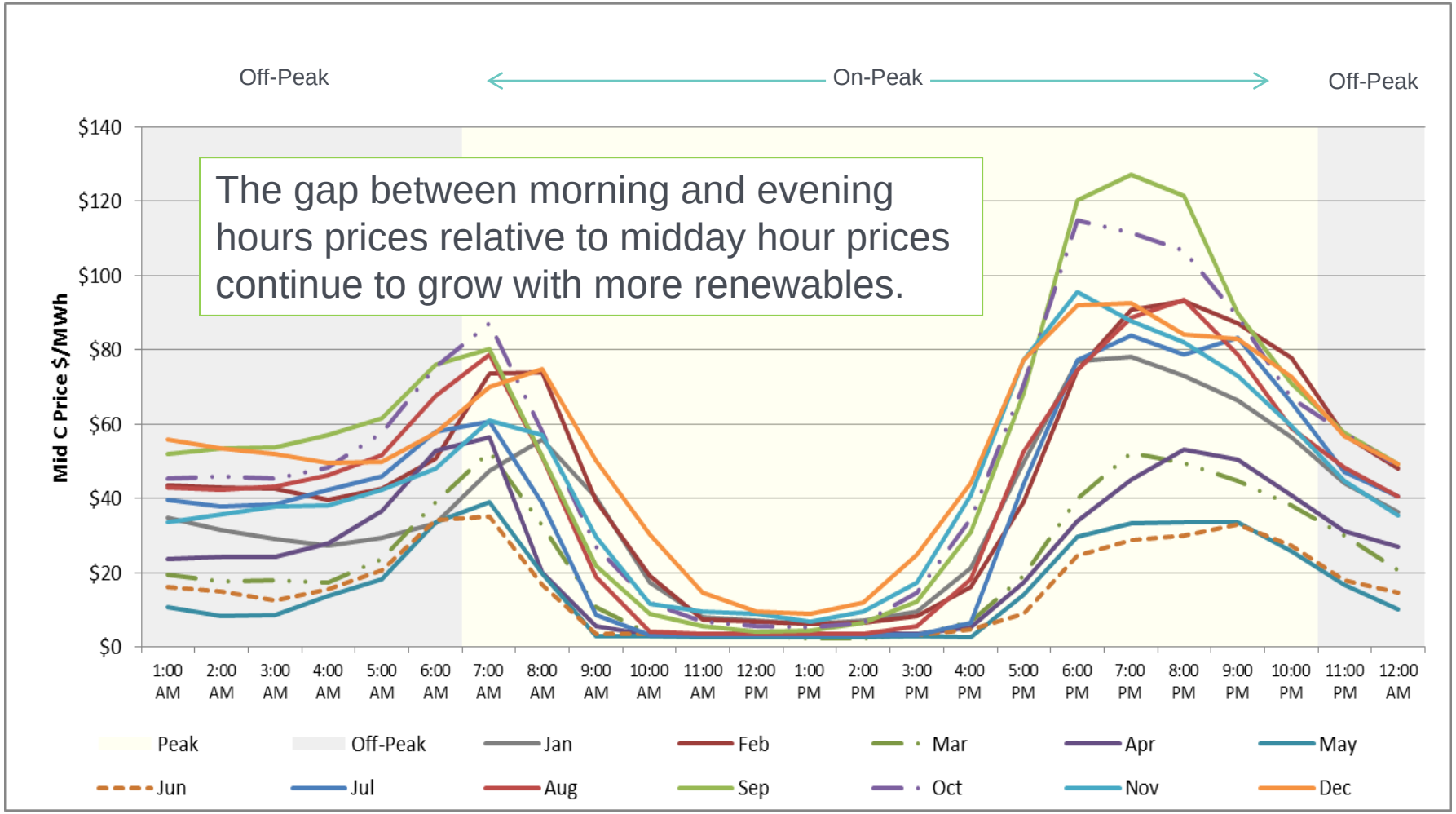
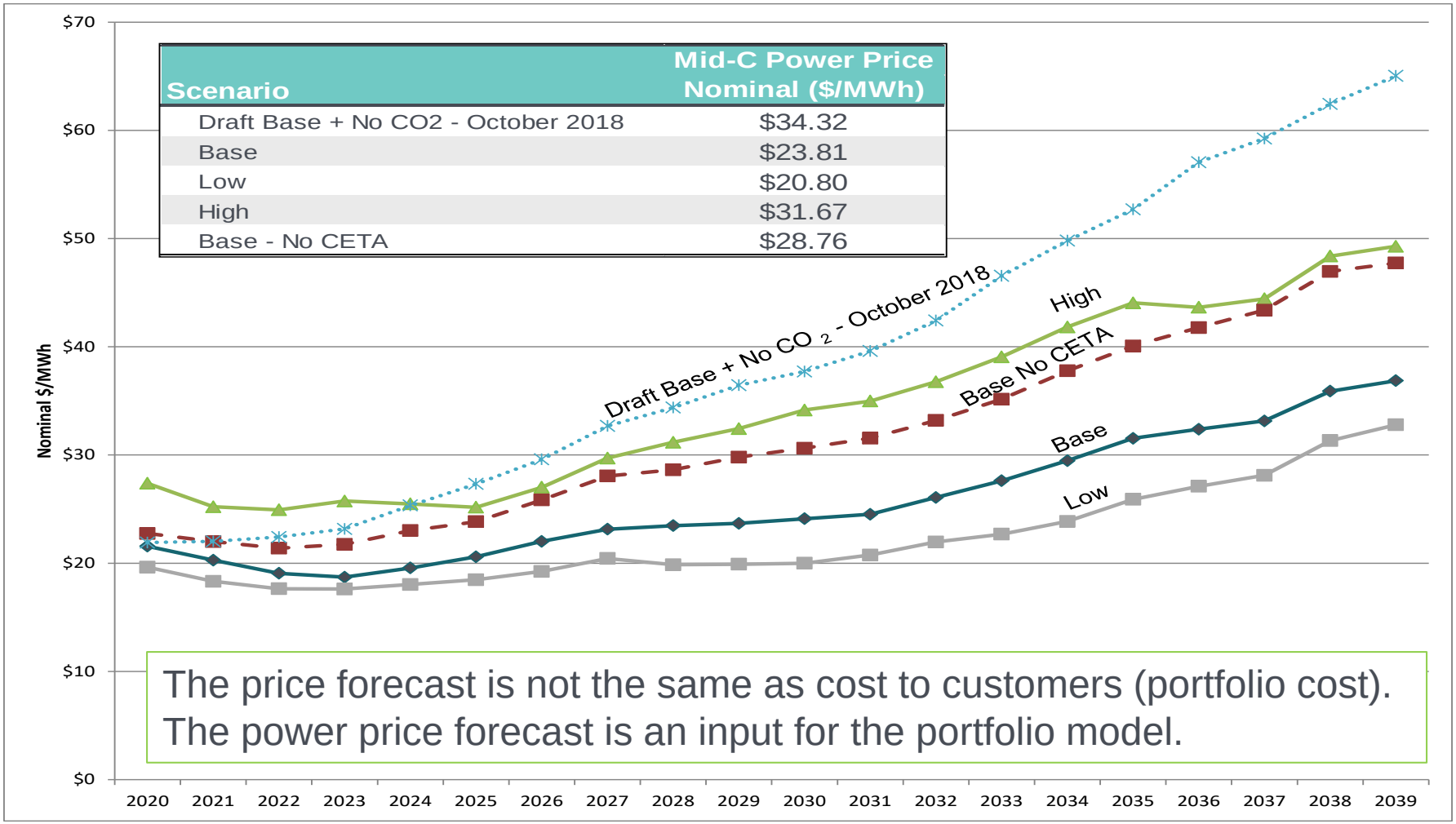
2039 Hourly Mid-C price shape by month



Electric Mid-C price forecast scenarios

Scenario	Mid-C Power Price Nominal ($/MWh)
Draft Base + No CO2 - October 2018	$34.32
Base	$23.81
Low	$20.80
High	$31.67
Base - No CETA	$28.76



The price forecast is not the same as cost to customers (portfolio cost). The power price forecast is an input for the portfolio model.

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Electric modeling process

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September 19, 2019 TAG #8

2019 IRP modeling process

The 2019 IRP will follow a 6-step process for analysis:

1. Analyze and establish resource need
2. Determine planning assumptions and identify resource alternatives
3. Analyze scenarios and sensitivities using deterministic and stochastic risk analysis
4. Analyze results
5. Develop resource plan
6. 10-year Clean Energy Action Plan

1 Establish resource needs

Three types of resource need are identified:

1. Peak capacity need
   - Physical peak need refers to the resources required to ensure reliable operation of the system. It is an operational requirement that includes three components: customer peak demand (demand forecast), planning margins (LOLP modeling) and operating reserves.

2. Renewable need
   - Washington State's Clean Energy Transformation Act (CETA) requires PSE to meet specific percentages of our load with renewable resources or renewable energy credits (RECs) by specific dates.

3. Energy need
   - Energy need refers to the resources required to meet customer demand in every hour. How the demand is met changes by scenario and is dependent on how resources are dispatched versus buying on the market.

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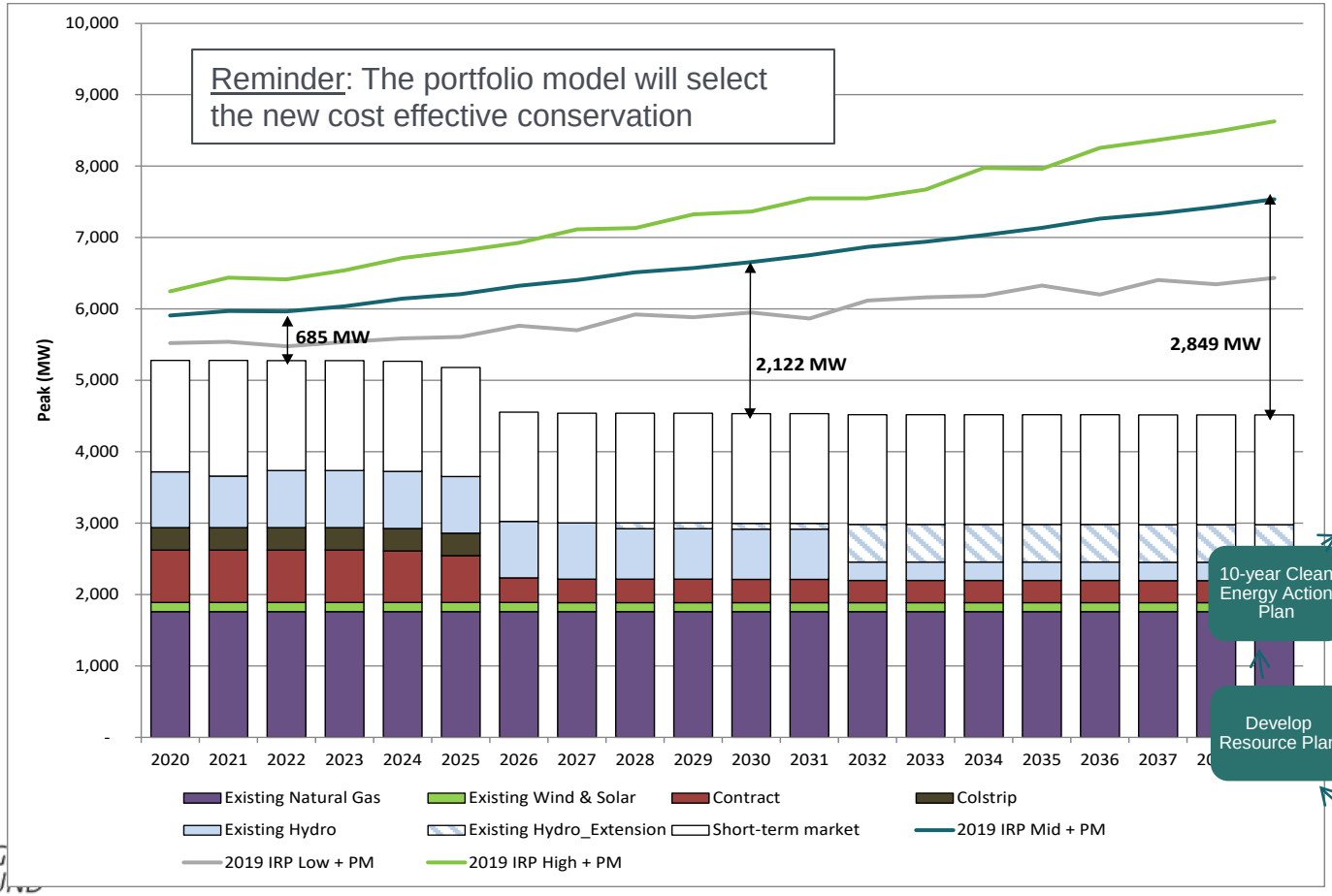
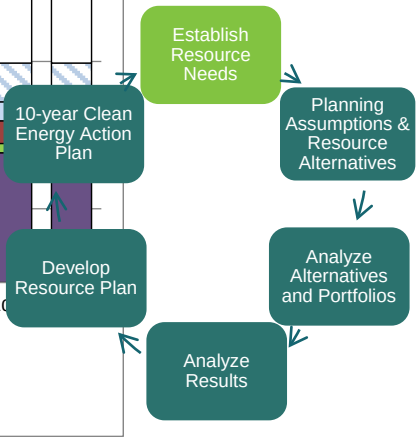
1 Establish resource needs

Electric peak hour capacity resource need

Projected peak hour need and effective capacity of existing resources.



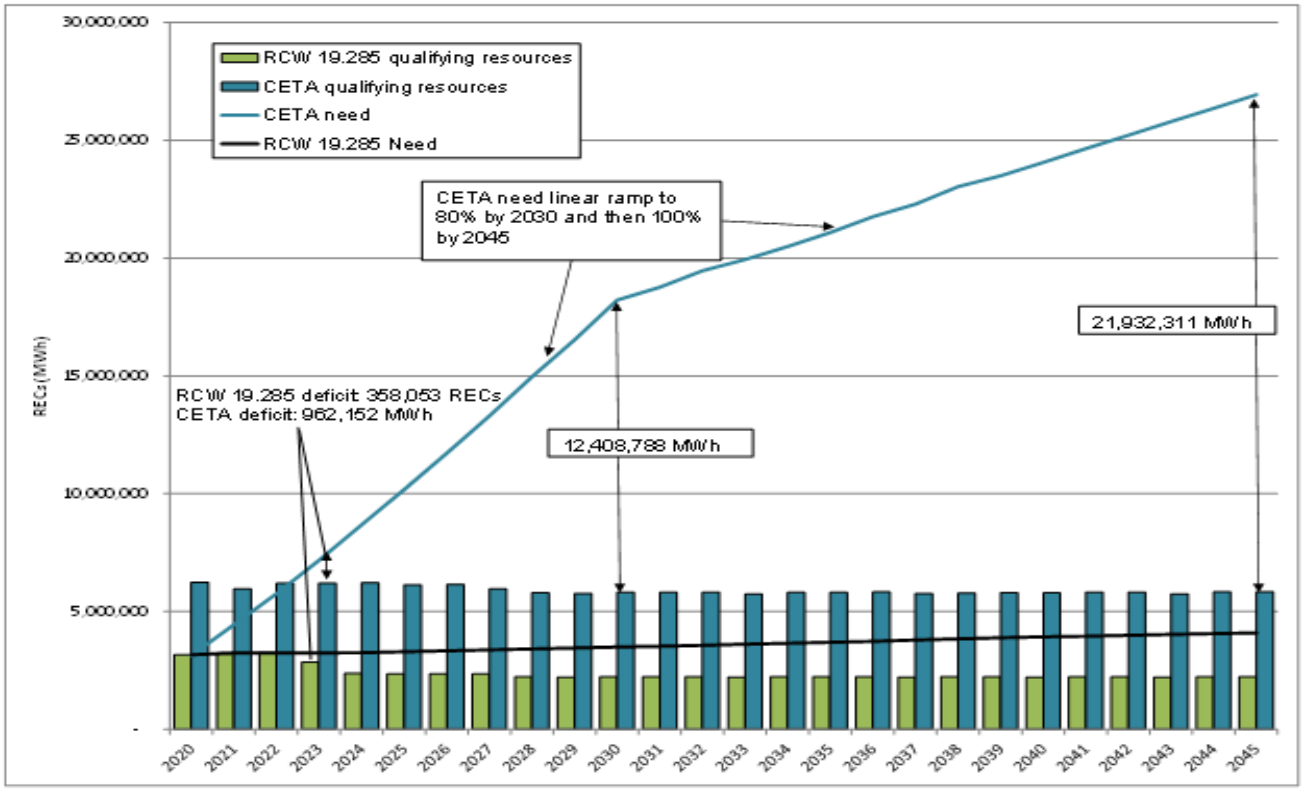


1 Establish resource needs

Reminder: The portfolio model will select the new cost effective conservation

Electric renewable need

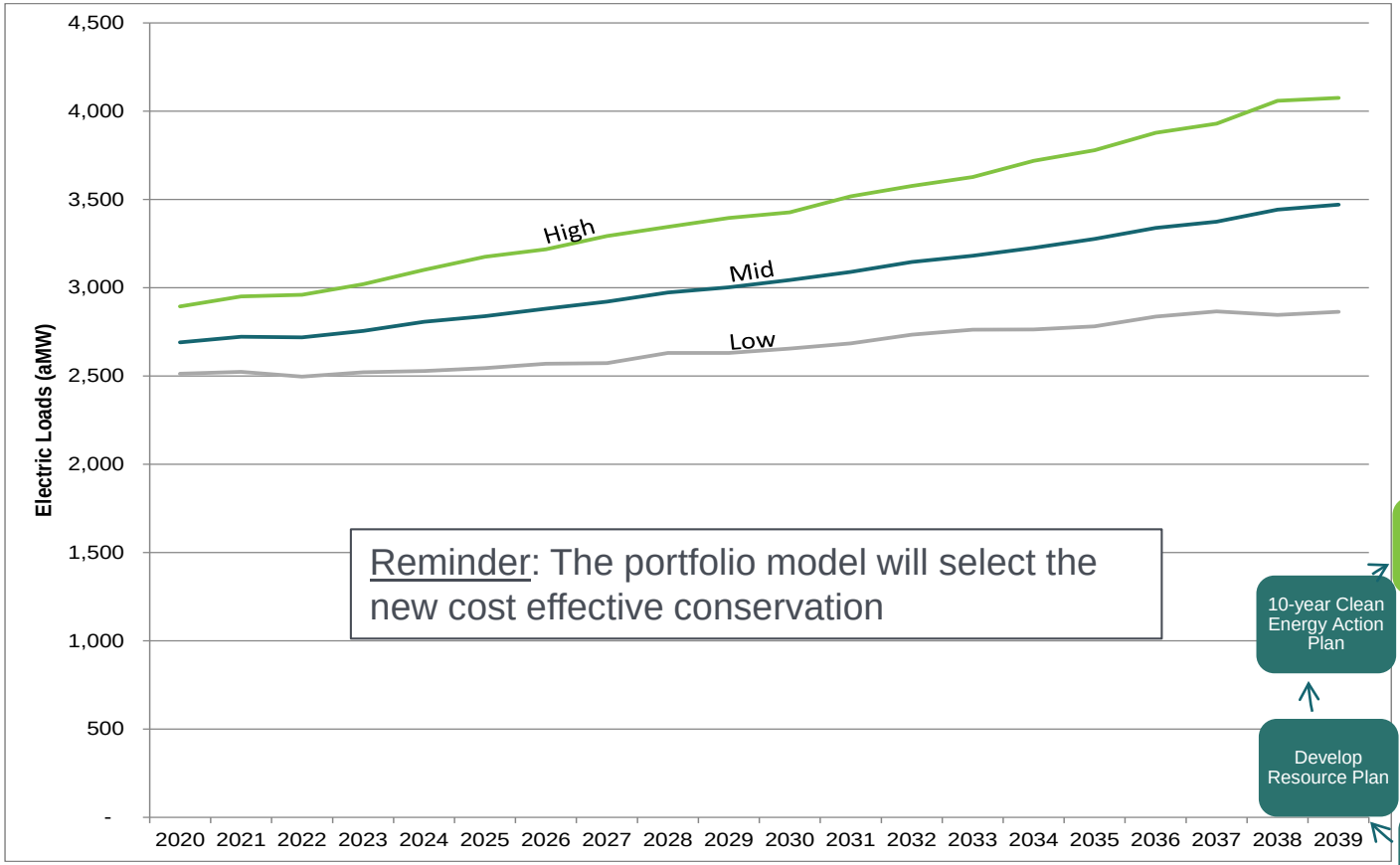
Renewable resource need/REC need for RCW 19.285 and CETA



1 Establish resource needs

Electric energy need

2019 IRP electric demand forecast



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2 Planning assumptions and resource alternatives

This category encompasses everything needed to run the portfolio analysis

- Scenarios
  - Gas prices
  - CO_2 prices
  - Electric demand

  The different combination of inputs results in different power prices.

- Resource alternatives
  - Supply side resources
  - Demand side resources

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2 Planning assumptions and resource alternatives

Three fully integrated scenarios are being analyzed in the 2019 IRP

Scenario	Demand	Gas Price	CO_2 price/Regulation	RPS/Clean Energy Regulation
1. Base	Mid	Mid	**CO_2 price:** CA AB32, and BC **CO_2 Regulation:** Social Cost of Carbon and upstream natural gas GHG in WA	WA CETA plus all other state regulations in the WECC
2. Low	Low	Low	**CO_2 price:** CA AB32, and BC **CO_2 Regulation:** Social Cost of Carbon and upstream natural gas GHG in WA	WA CETA plus all other state regulations in the WECC
3. High	High	High	**CO_2 price:** CA AB32, and BC **CO_2 Regulation:** Social Cost of Carbon and upstream natural gas GHG in WA	WA CETA plus all other state regulations in the WECC

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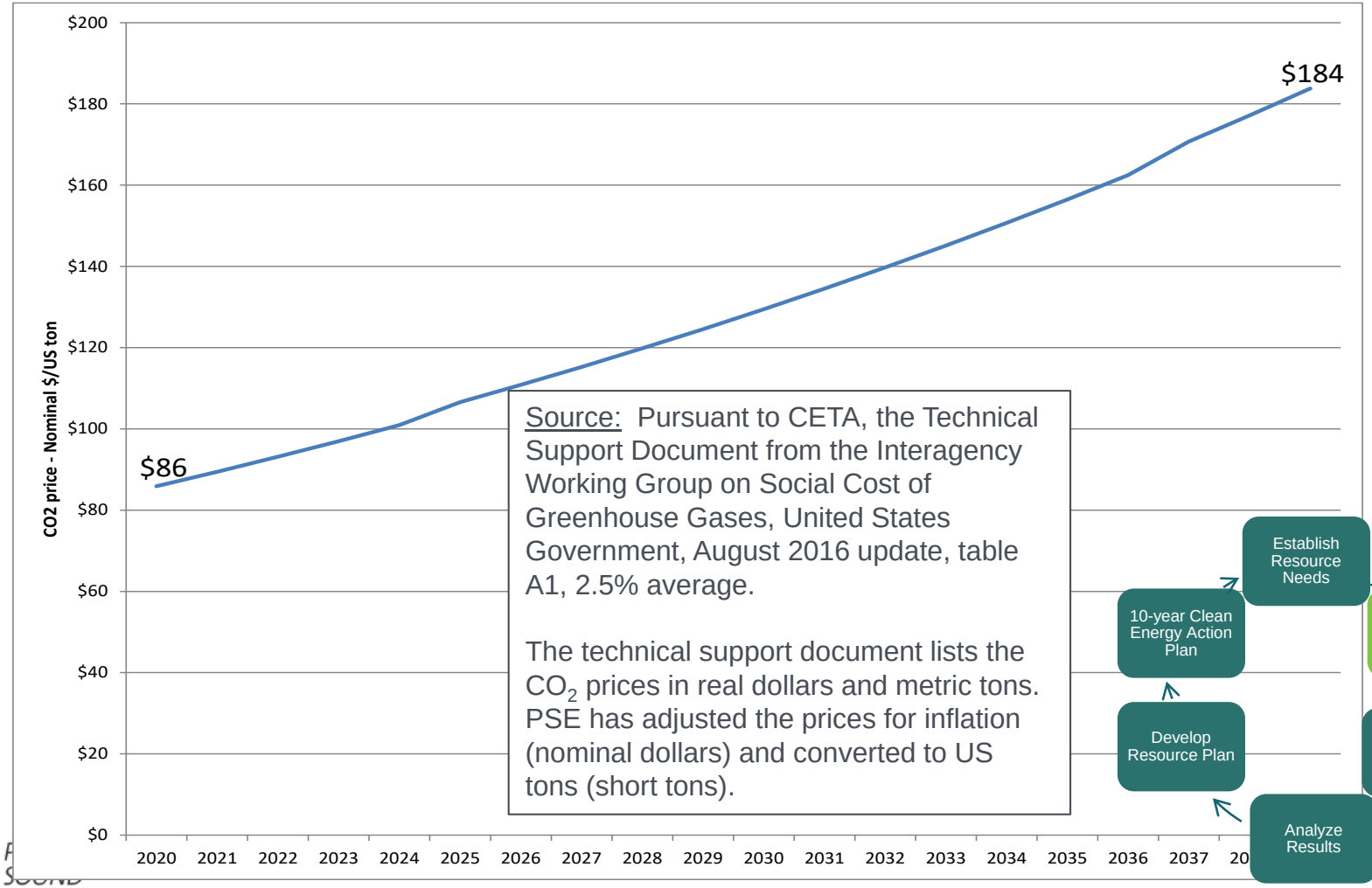
2 Planning assumptions and resource alternatives

Social Cost of Carbon ($/US tons)



2 Planning assumptions and resource alternatives

Upstream CO2 emission for natural gas plants and emission rate for market purchases

- Upstream emissions added to emission rate of NG plants
  - Example:

    New NG plant emission rate: 117 lbs/MMBtu

    Upstream emission rate: 23 lbs/MMBtu

    Total emission rate: 140 lbs/MMBtu

- Emission rate for unspecified market purchases.
  - PSE is using the 0.437 metric tons CO2/MWh for unspecified market purchases in the 2019 IRP from Section 7 of E2SSB 5116, paragraph 2.

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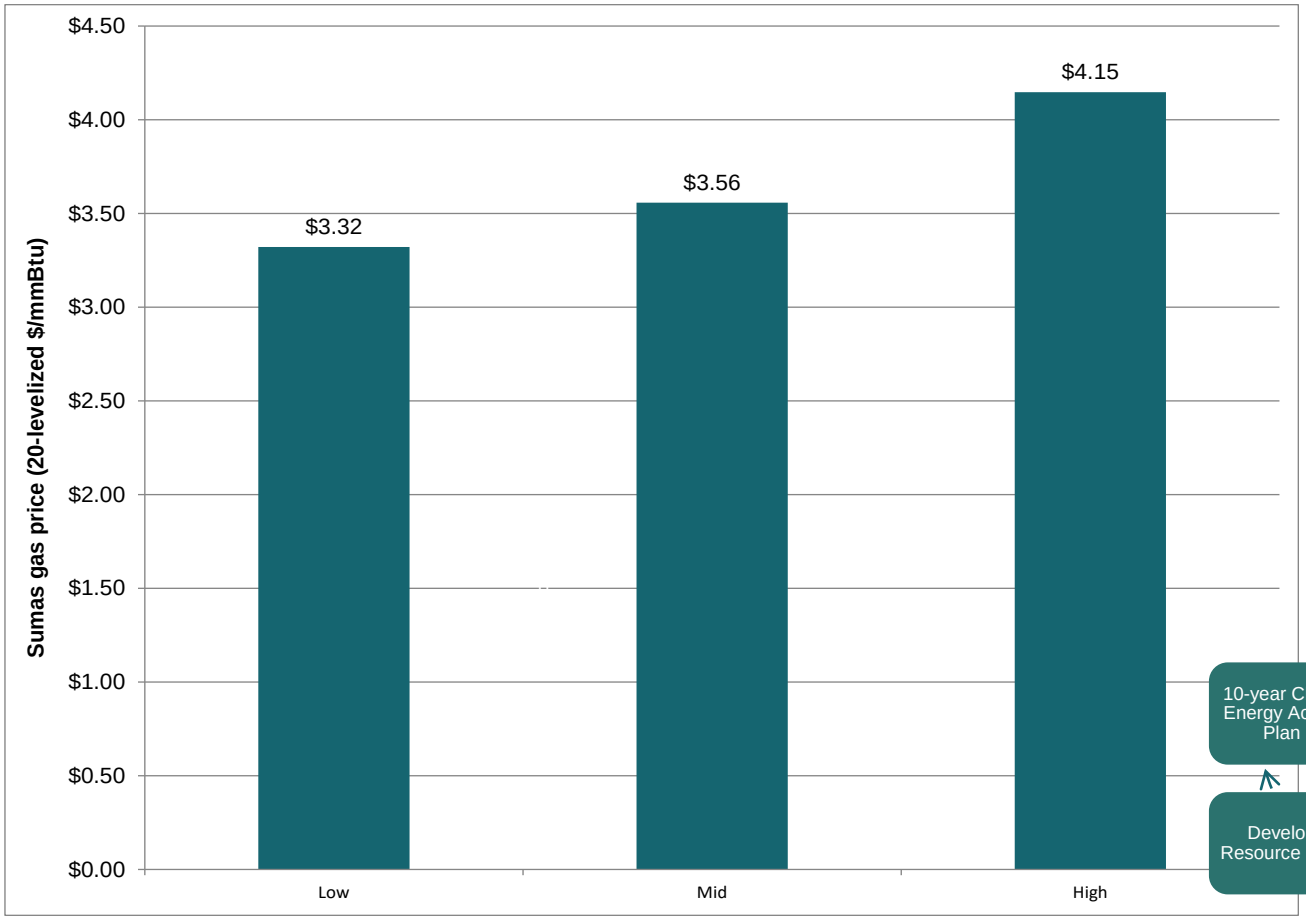
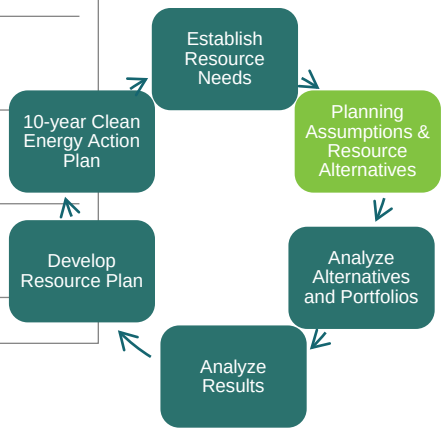
2 Planning assumptions and resource alternatives

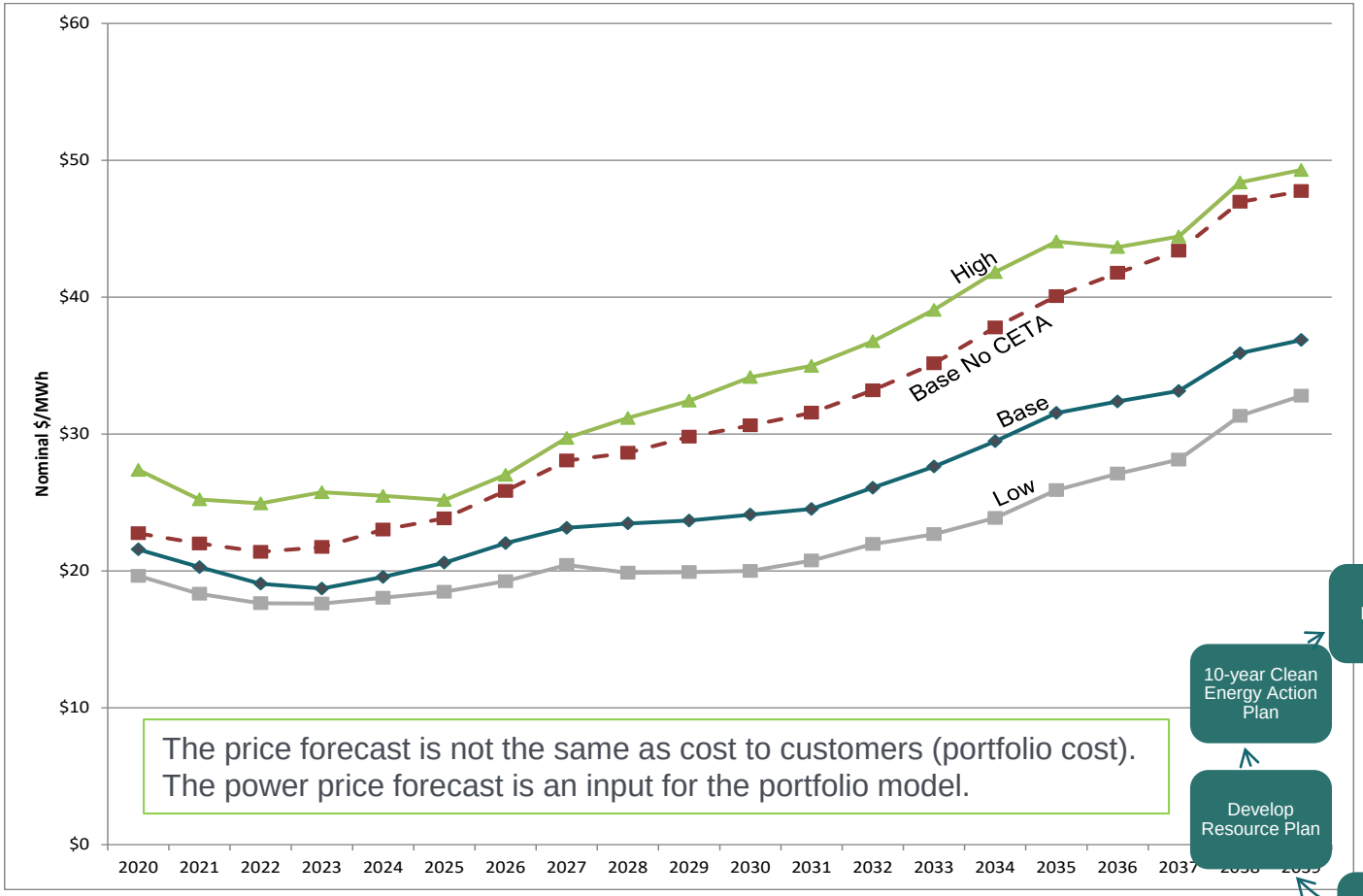
Natural gas prices at Sumas

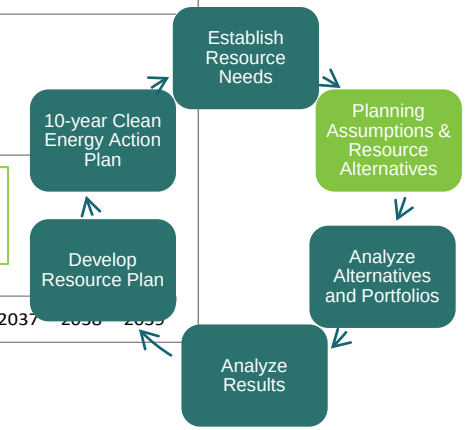




2 Planning assumptions and resource alternatives

Mid-C wholesale power prices





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2 Planning assumptions and resource alternatives

Electric supply and demand side resource assumptions

- Supply side resources being modeled
  - Gas plants
    - Combined cycle combustion turbines baseload gas plant (CCCT)
    - Simple cycle combustion turbine peaking plant (frame peaker)
    - Reciprocating internal combustion engines peaking plant (recip peaker)
  - Renewable resources
    - Solar in eastern Washington
    - Wind in eastern Washington, Montana, and offshore of Washington coast
    - Biomass
  - Energy storage resources
    - Battery storage
    - Pumped hydro storage
  - Combined resources
    - Solar + battery storage

- Demand sides resources being modeled
  - Energy efficiency
  - Distributed generation
  - Demand response
  - Distribution efficiency

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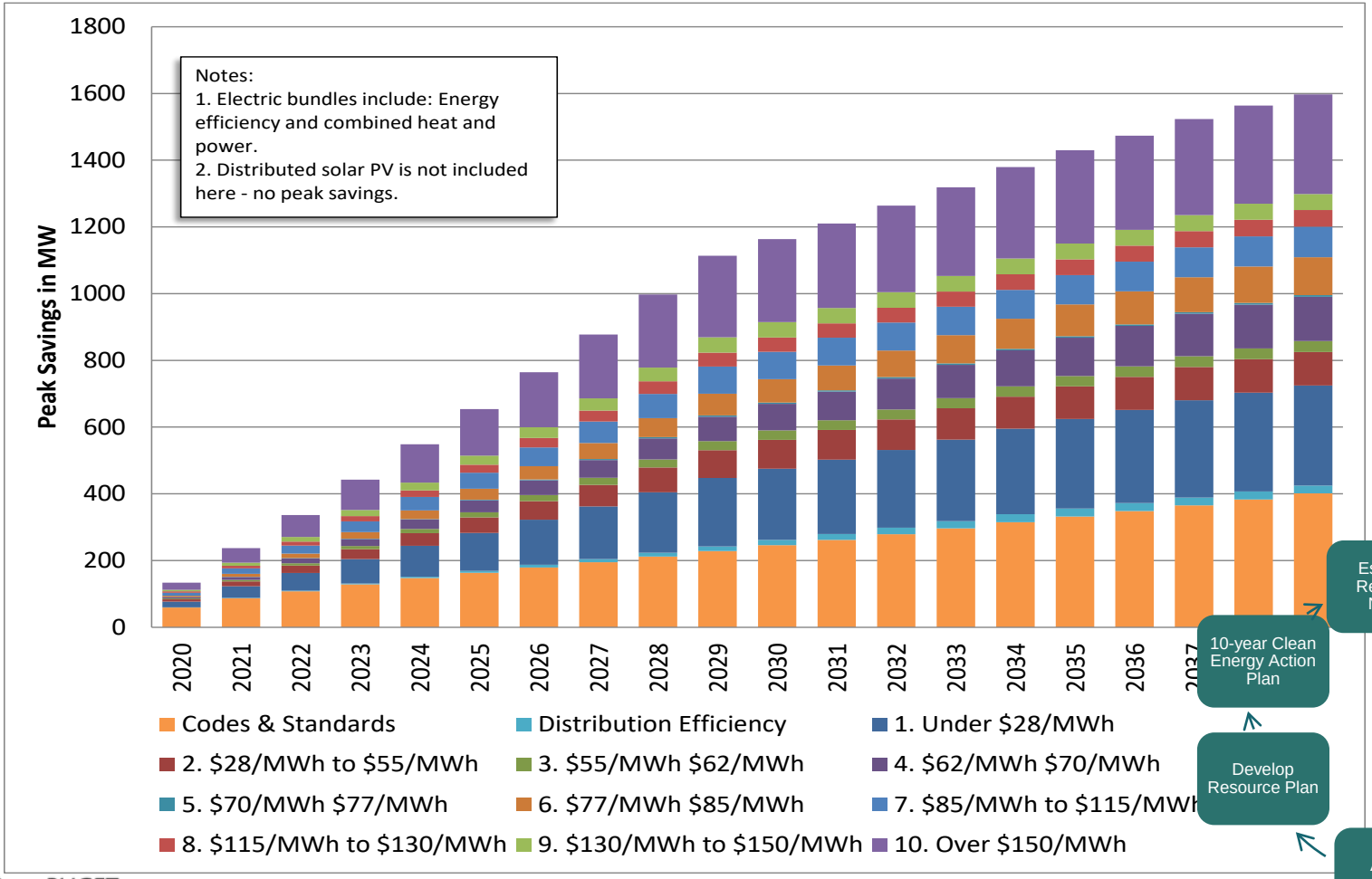
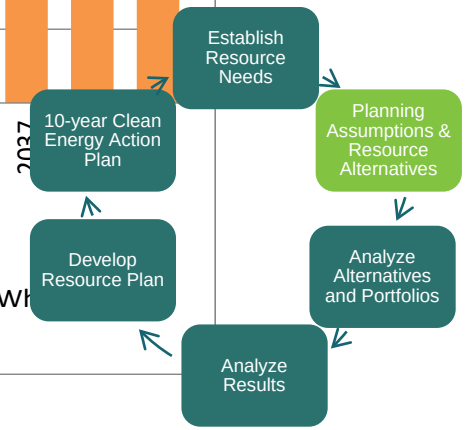
2 Planning assumptions and resource alternatives

Electric conservation peak savings (MW)





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2 Planning assumptions and resource alternatives

Sub-hourly system flexibility cost savings

- PLEXOS is an hourly and sub-hourly chronological production simulation model that utilizes mixed-integer programming (MIP) to simulate unit commitment of resources at a day-ahead level, and then simulate the re-dispatch of these resources in real-time to match changes in supply and demand on a 5-minute basis.
- For the sub-hourly cost analysis using PLEXOS, PSE first created a current portfolio case based on PSE's existing resources.
- Then tested each resource in the portfolio and calculated the cost difference in the real-time re-dispatch from the current portfolio case.

Resource	Flexibility Cost Savings ($/kw-year)
CCCT	0.03
Frame peaker	1.15
Recip peaker	8.16
Lithium-Ion battery 2hr	3.11
Lithium-Ion battery 4hr	7.89
Flow battery 4hr	1.53
Flow battery 6hr	7.44
Pumped Storage Hydro 10hr	10.24

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3 Analyze portfolios and alternatives

- Analyze scenarios and sensitivities using deterministic and stochastic risk analysis
- The portfolio model is an optimization model that determines the mix of supply and demand-side resources that meets the objective function to minimize total portfolio cost while meeting all the constraints.
- The purpose of the stochastic analysis is to understand how uncertainty affects findings

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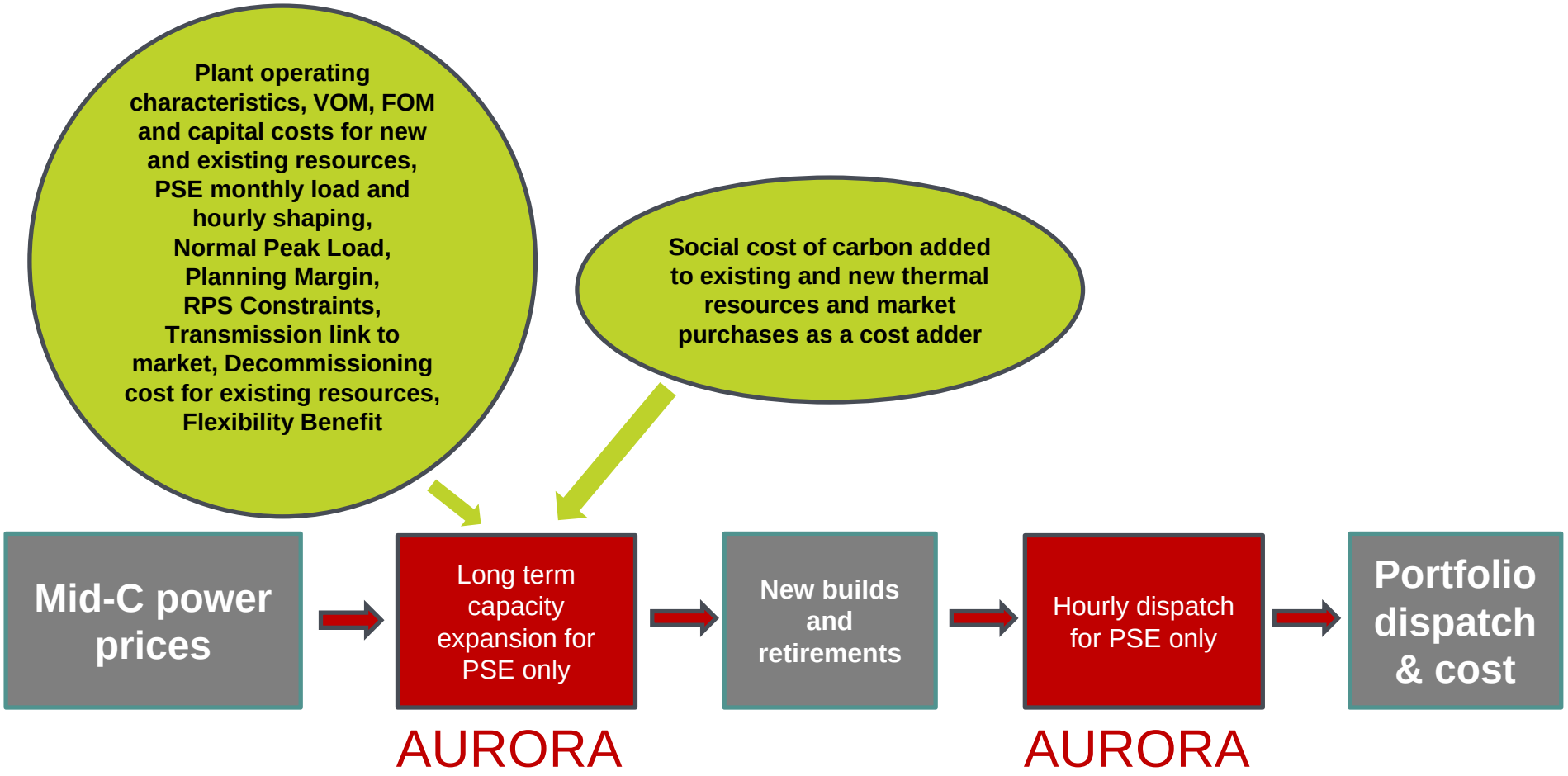
3 Analyze portfolios and alternatives

IRP portfolio modeling process



3 Analyze portfolios and alternatives

Electric portfolio sensitivities

	Sensitivities	Alternatives Analyzed
A	Emission reduction	100% non-emitting/renewable resources by 2030
B	Reduced market reliance	Reliance on market for peak capacity reduced
C	Alternative resource cost assumptions	Lower wind and solar costs
D	Extended DSR potential	Future DSR measures extend benefits through second half of the study period
E	Alternative DSR discount rate	Alternate discount rate for residential energy efficiency

3 Analyze portfolios and alternatives

Stochastic analysis

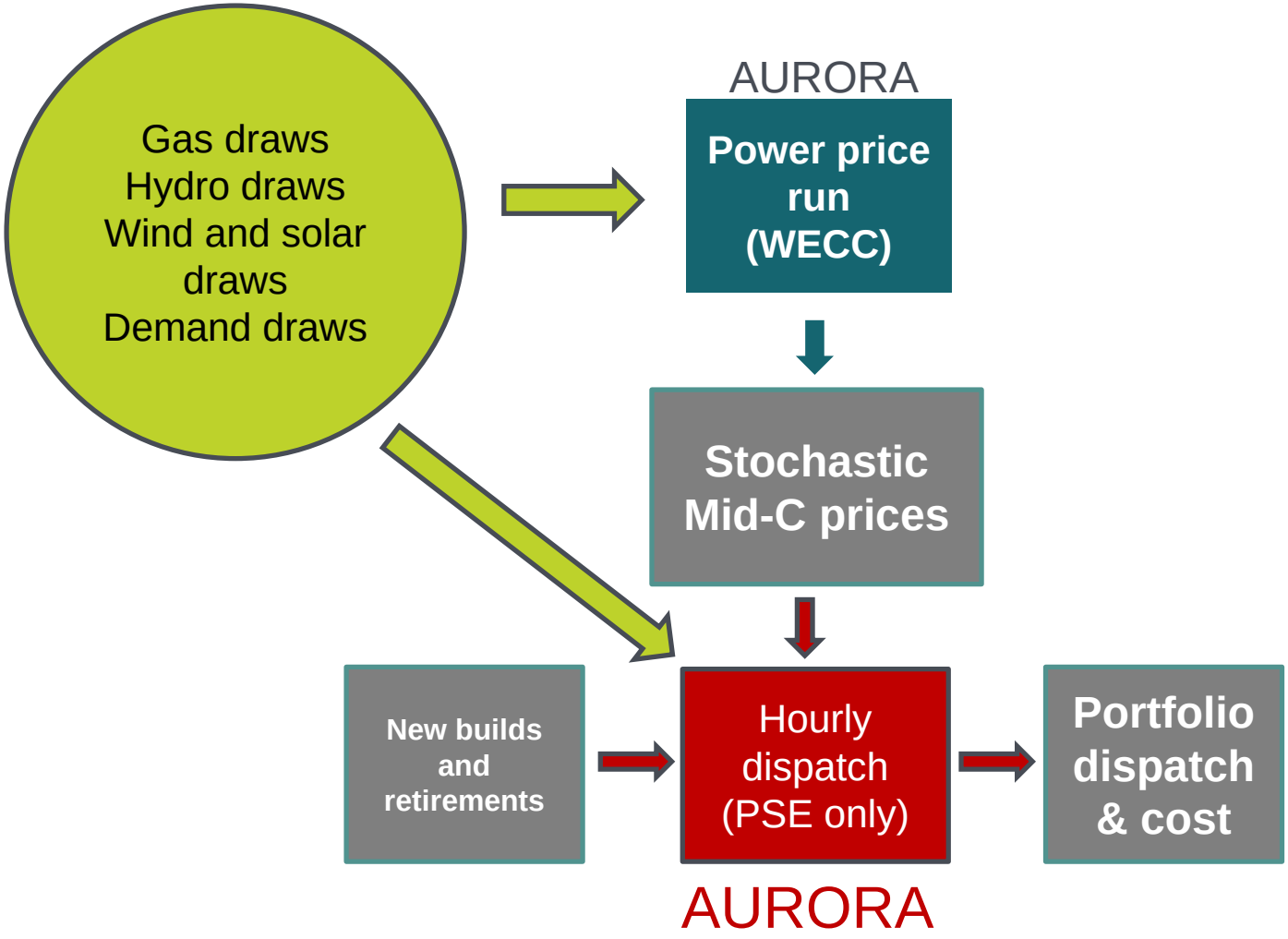
Stochastic variability applied to

- Gas prices
- Electric demand (energy and peak)
- Hydro generation
- Wind and solar generation

The different combination of inputs results in different power prices.

3 Analyze portfolios and alternatives

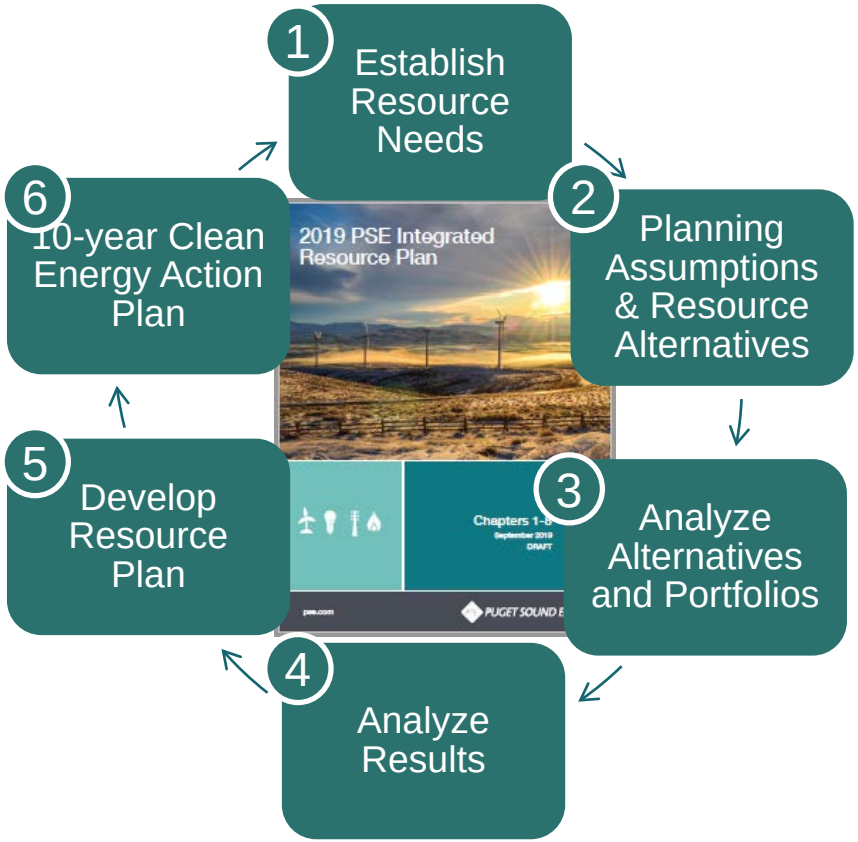
Stochastic Analysis



2019 IRP modeling process

Results, electric and gas resource plans and the 10-year Clean Energy Action Plan will be discussed at the November 26 IRPAG meeting and the December 11 TAG meeting.

1. Analyze and establish resource need
2. Determine planning assumptions and identify resource alternatives
3. Analyze scenarios and sensitivities using deterministic and stochastic risk analysis
4. Analyze results
5. Develop resource plan
6. 10-year Clean Energy Action Plan



Next steps

Action items review and next steps

Date	Action
October 3	PSE posts draft meeting notes with action items on IRP website and distributes draft meeting notes to TAG members
October 10	TAG members review meeting notes and provide comments to PSE at irp@pse.com
October 17	PSE posts final meeting notes on IRP website: www.pse.com/irp

PUGET SOUND ENERGY

IRP comment period

Action items for inclusion in the 2019 draft and final IRP

PUGET SOUND ENERGY

September 19, 2019 TAG #8

Action items for inclusion in the draft and final 2019 IRPs

Action item #	Description (and meeting reference)	PSE action	Status
1	Include carbon impact in scenarios or sensitivities. (IRPAG #1, May 30, 2018 and TAG #2, October 11, 2018)	PSE will model various carbon impacts.	In progress
2	Investigate converting the gas emission rate to a percentage. (TAG #2, October 11, 2018 and TAG #3, December 6, 2018, and January 9, 2019)	PSE will include gas emission rate as a percentage and details on methodology in the draft IRP and final IRP. PSE will consider distributing the details before the draft.	In progress
3	Add line miles and project status to the planned major projects list and include cost ranges. (TAG #4, January 9, 2019)	To be included in the draft IRP and final IRP. Cost ranges will be included if publically available.	In progress

Action items for inclusion in the draft and final 2019 IRPs

Action item #	Description (and meeting reference)	PSE action	Status
4	Include several previous IRP load forecasts in the IRP and compare those forecasts to actuals for multiple years. (TAG #4, January 9, 2019)	To be included in the draft and final IRP.	In progress
5	Verify the calculation used to develop the EV load as a percentage of load in 2035. (TAG #4, January 9, 2019)	To be included in the draft IRP and final IRP.	In progress
6	Add a recommendation for time-of-day rate analysis to the 2019 IRP action plan. (TAG #4, January 9, 2019)	PSE will add a recommendation for time-of-day rate analysis to the 2019 IRP action plan.	In progress