Northwest **Power** and **Conservation** Council

March 4, 2025

MEMORANDUM

TO: **Council Members**

FROM: **Annika Roberts**

SUBJECT: **Proposed Reference Plants for the Ninth Plan (Part 2)**

BACKGROUND:

Presenter: Annika Roberts, Resource Policy Analyst

Summary: A reference plant is a collection of characteristics that describe a resource technology and its theoretical application in the region. It includes estimates of typical costs, logistics, and operating specifications. These reference plants become resource options—along with energy efficiency, demand response and distributed energy resources—for the Council's power system models to select to fulfill future resource needs. The Council develops a defined set of reference plants that represent the range of resources to be considered in planning.

At the February Council meeting, staff started the process of reviewing proposed reference plants to be analyzed in the Ninth Plan. This initial presentation covered the many components of a reference plant, their development process, and the proposed technologies for which reference plants will be built for the plan.

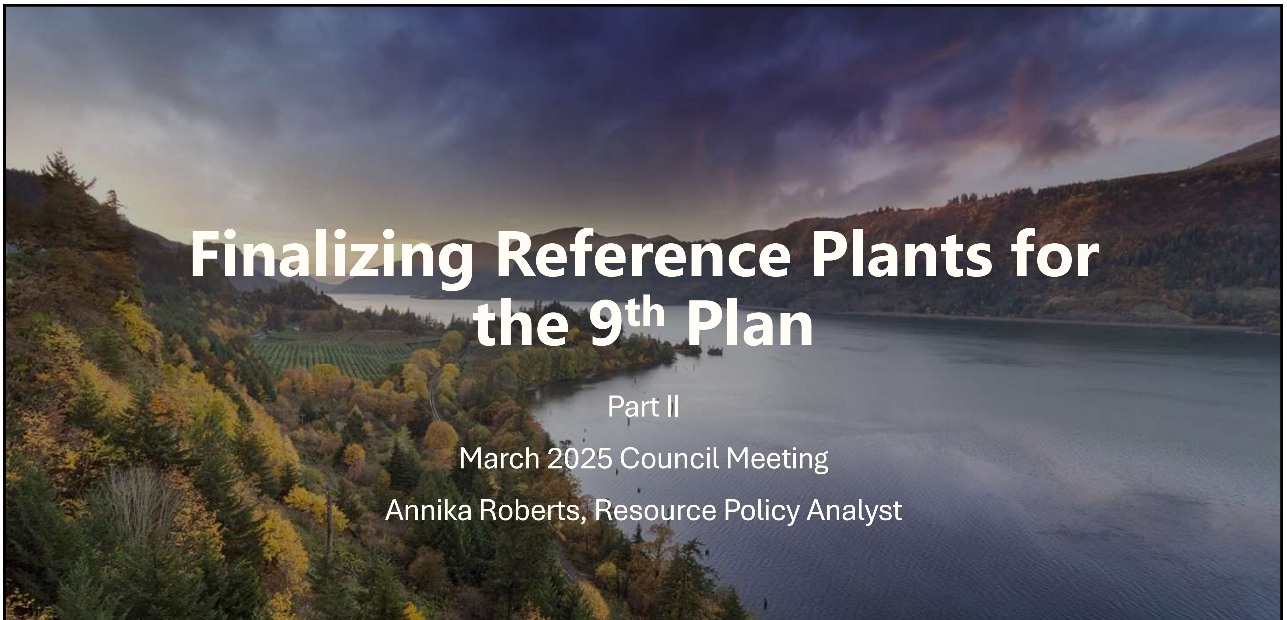
At the March Council meeting, staff will be returning with the details of each reference plant and defining their characteristics by technology. These will include the costs of each resource, the resources availability, the timing and their generation shape to name a few of the most impactful assumptions. The presentation will incorporate feedback from the Generating Resource Advisory

Committee and how staff has worked with stakeholders to reflect that input in the final proposed reference plants. Staff will also flag a few outstanding questions and their status towards being resolved. These questions are primarily concerned with how resource characteristics are represented in the models and should not get in the way of finalizing resource reference plants.

Relevance: The Power Act directs the Council in its power plan to put forth a general strategy for implementing conservation measures and developing generating resources. The Council uses reference plants as a means of characterizing generating resource options for modeling by representing the different attributes of different resources for the model to consider.

Workplan: B.2.3. Develop generating resource reference plants and related assumptions for plan analysis.

Background: Proposed reference plants for the Ninth Power Plan (Part 1), presented to the Council in February 2025: https://www.nwcouncil.org/f/19087/2025_02_3.pdf
Primer on generating resource reference plants presented to the Council in August 2024: https://www.nwcouncil.org/f/18846/2024_0813_10.pdf
Generating Resource Advisory Committee presentation: https://www.nwcouncil.org/meeting/generating-resources-advisory-committee-2025-01-31/



Finalizing Reference Plants for the 9th Plan

Part II

March 2025 Council Meeting

Annika Roberts, Resource Policy Analyst

Northwest **Power** and **Conservation** Council

1

Outline

- Quick recap
  - What is a reference plant & what resources are we building reference plants for
- Shared assumptions
  - Financing, maximum build out, interconnection, tax credits, cost curves
- Resources
  - Details of each reference plant (esp. availability, timing, costs, shapes)
- Summary and next steps
  - What have we finalized and what's left to do

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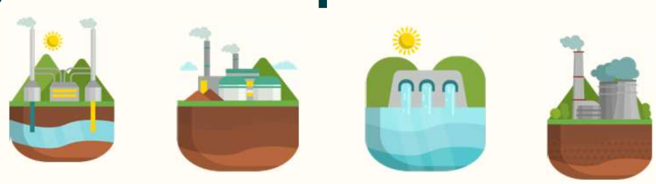
2

What is a Reference Plant?

A Recap

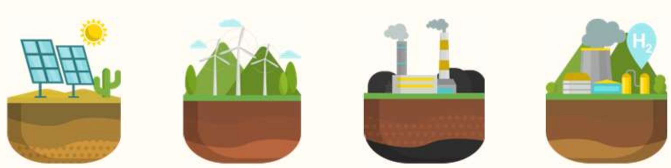
3

Defining a reference plant



A **reference plant** is a collection of characteristics that describe a resource technology and its theoretical application in the region. It includes estimates of typical costs, logistics, and operating specifications.

These reference plants become resource options—along with energy efficiency, demand response and distributed energy resources—for the Council's power system models to select to fulfill future resource needs



4

Components of a reference plant

Resource Attributes	Financials	Operating Characteristics	Developmental Potential
Technology Type	Financial Sponsor (IOU, IPP)	Capacity Factor	Location
Configuration (# of units x MW)	Overnight Capital Cost ($/MWh)	Heat Rate	Transmission/Gas Pipeline Access
Capacity (MW)	Fixed O&M ($/kW-yr)	Generation Shape	Maximum Build-out
Location(s)	Variable O&M ($/MWh)		
Operating Life (yrs)	Fixed Fuel Cost		
Development & construction schedule	Transmission Cost		
Earliest in operation date (year)			
Transmission access			

Proposed Reference Plants

PRIMARY	LIMITED AVAILABILITY	EMERGING
Utility Scale Solar PV	Pumped Storage	Long-Duration Storage (Iron Air Battery)
Onshore Wind	Geothermal (Conventional)	Clean Baseload Resource (Small Modular Reactor)
Gas (CCCT, SCCT—Frame/—Recip)	Offshore Wind	Clean Peaker/Medium-Duration Storage (Hydrogen turbine w/ onsite production/storage)
Li-Ion Battery (4-hr)		
Solar + Storage		
Community Solar		

Shared assumptions

Applicable to multiple reference plants

7

Financing Assumptions

GRAC supported these proposed assumptions

Financial Assumption	Investor-Owned Utility*
Federal Income Tax Rate	21 %
State Income Tax Rate	5 %
Property Tax	1.4 %
Insurance	0.25 %
Debt Fraction	50 %
Debt Term	25 – 30 years
Debt Interest Rate (nominal)	6.69 %
Return on Equity (nominal)	10 %
Discount Rate	3.75 %

2021 Plan Assumptions

	60:40 Utility: Merchant/IPP
Federal income tax rate	21%
State income tax rate	6.45%
Property tax	0.9%
Insurance	0.3%
Debt fraction	52/48
Debt term	15-30
Debt interest rate (nominal)	4.608%
Return on equity (nominal)	8.09%
Discount rate (real)*	3.7%

*not final, testing ongoing per previous Council discussion

Source: https://www.epa.gov/system/files/documents/2021-09/chapter-10-financial-assumptions.pdf

8

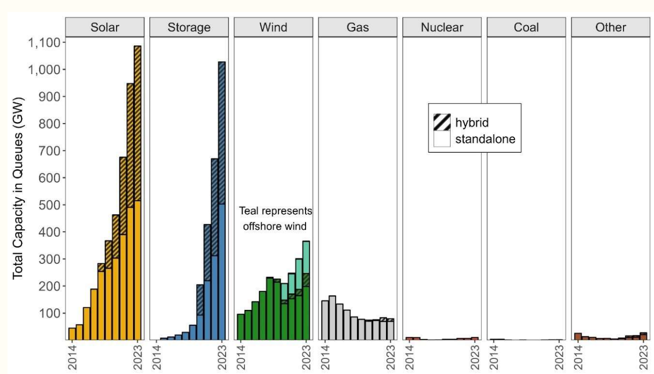
Maximum buildout methodology

- Not limiting primary resource builds beyond the physical constraints of the system
- Relies on the model to test the economics of a given future not being constrained by contractual encumberments
  - The future will be constrained by system operations, policies etc.
- Recognizing there might be limits on various resources from siting or supply chain limitations (e.g. transformers) and are proposing those be tested in the Resource and Transmission Risk Scenario

Note from the GRAC: Members were supportive of this method.
They expressed appreciation for our efforts to avoid being overly prescriptive around limitations and endorsed letting the model solve

Resource Interconnection

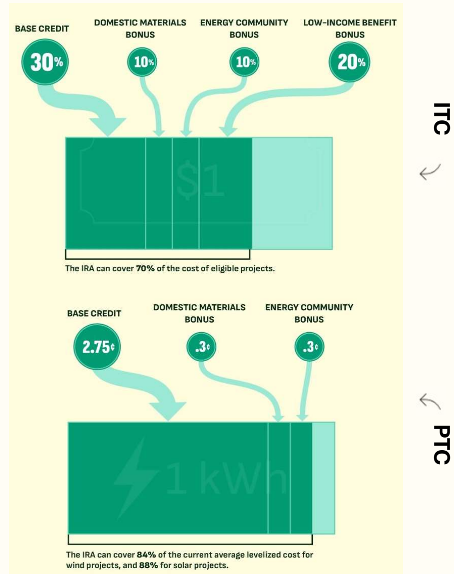
- Concerns, through the GRAC, were raised about the state of the interconnection queue and the timing assumed around resources coming online
- Similar to our maximum build-out logic, we want the model to solve without imposing contractual limits on what is built
  - There is an assumed amount of time by resource for construction/development but that is a separate consideration to interconnection
  - This is another case where slowing down the ramping of resources in scenarios can give us more information



Graphic from LBNL's Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection

Tax Credits

- The IRA extended/expanded tax credits for clean generating resources
  - Tax credits are now technology neutral and developers can choose between applying the investment tax credit or the production tax credit
- In the models:
  - ITC: Will be incorporated into the total fixed cost in our financial revenue requirements tool (Microfin), as it was treated in the 2021 plan but more broadly applied
  - PTC: Will be applied in the modeling, as it is necessarily based on plant production



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11

Which resources get which credit?

- **Current Proposal: Assuming developers make the most financially advantageous choice**
  - **Solar and wind will receive the *Production Tax Credit***
  - **All other technologies will use the *Investment Tax Credit***
  - It is our understanding that this treatment is consistent with the assumptions of others in the region

Note from the GRAC:
It was proposed at the GRAC that applying the ITC to all resources might be more realistic given the uncertainty around the ongoing availability of the PTC
This is something we'll do some testing around as staff and return to the GRAC for a final check

As a way to account for some insecurity around the long-term certainty of these tax credits we are planning a sensitivity in the Resource and Transmission Risk scenario where we could test resource costs without these credits

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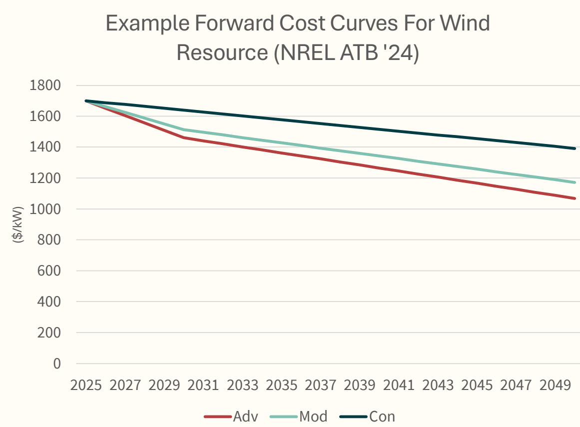
12

Cost Curves

- Why:
  - We know technology improves in both performance and price over time, these learning curves vary often based on the maturity of the technology, but apply to all technology types
- Source:
  - We use the NREL Annual Technology Baseline's cost curves
    - The industry standard, used in most planning in the region
    - Well supported and documented
- Which future:
  - In past Plans we have utilized the moderate cost curve, however discussions with the GRAC as well as general energy industry outlook/uncertainty prompted us to adopt the conservative curve for this Plan



Transmission

- Wheeling Costs
  - Tied to usage of the line, not a particular resource
  - Contractual, variable cost associated with transmitting power—adds up per wheeling segment
    - Accounted for in the model per MWh

- Electric Transmission—cost associated with connecting a resource to the grid
  - Two primary options: Point to point long term firm & Point to point short term/non firm
    - Different resources are assigned different transmission assumptions, and those costs are incorporated in our fully delivered fixed costs of a resource
  - Spur/Feeder Lines
    - An additional cost applied to specific resources by location if that resource might be cited particularly far from the existing transmission system

These assumptions will be updated from the 2021 Plan and run through the GRAC at an end of March meeting

From our financial revenue requirement tool (Microfin), from the 2021 Plan. Not yet updated for the 9th Plan

Electric Transmission			
	1	2	3
	None	BPA P2P Short-Term/Non Firm	BPA P2P Long-Term Firm
Fixed Cost ($2012/kW-yr)	$[redacted]	$[redacted]	$[redacted]

Locational adjustment

- Will be applying a locational cost adjustment factors from the EIA Energy Outlook to each resources overnight capital costs
- This adjustment is based on labor rates and the environmental affect on material costs for each location
- These factors are specific by resource and by representative city, but broadly it is more expensive to build in the west of the region (Seattle/Portland) than the east (Spokane/Boise/Great Falls)

Illustrative Example

Table 1-19 — Location Adjustment for Battery Storage: 4 hours
(2023 USD)
Case Configuration: 150 MW / 600 MWh

State	City	Base Project Cost ($/kW)	Location Variation	Delta Cost Difference ($/kW)	Total Location Project Cost ($/kW)
Alabama	Huntsville	1,744	1.01	21	1765
Arizona	Phoenix	1,744	0.99	(17)	1727
Arkansas	Little Rock	1,744	1.03	58	1802
California	Bakersfield	1,744	1.07	126	1870
California	Los Angeles	1,744	1.09	149	1893
California	Modesto	1,744	1.07	130	1874
California	Sacramento	1,744	1.08	136	1880
California	San Francisco	1,744	1.11	187	1931
Colorado	Denver	1,744	0.99	(18)	1726
Connecticut	Hartford	1,744	1.05	83	1827
Delaware	Dover	1,744	1.01	22	1766
District of Columbia	Washington	1,744	1.01	24	1768
Florida	Tallahassee	1,744	0.99	(15)	1729
Florida	Tampa	1,744	1.00	(4)	1740
Georgia	Atlanta	1,744	1.02	34	1778
Idaho	Boise	1,744	1.02	31	1775
Illinois	Chicago	1,744	1.07	121	1865
Indiana	Indianapolis	1,744	1.02	37	1781
Iowa	Davenport	1,744	1.01	13	1757
Iowa	Waterloo	1,744	1.00	(5)	1739
Kansas	Wichita	1,744	1.00	(4)	1740
Kentucky	Louisville	1,744	1.02	35	1779
Louisiana	New Orleans	1,744	1.03	56	1800
Maine	Portland	1,744	1.01	19	1763
Maryland	Baltimore	1,744	1.01	19	1763
Massachusetts	Boston	1,744	1.07	123	1867
Michigan	Detroit	1,744	1.02	32	1776
Michigan	Grand Rapids	1,744	1.00	1	1745
Minnesota	Saint Paul	1,744	1.01	15	1759
Mississippi	Biloxi	1,744	0.99	(17)	1727
Missouri	St. Louis	1,744	1.07	121	1865
Missouri	Kansas City	1,744	1.01	25	1769
Montana	Great Falls	1,744	0.99	(13)	1731
Nebraska	Omaha	1,744	1.00	(4)	1740
New Hampshire	Manchester	1,744	1.03	60	1804
New Jersey	Newark	1,744	1.06	112	1856
New Mexico	Albuquerque	1,744	1.03	61	1805
New York	New York	1,744	1.12	204	1948
New York	Syracuse	1,744	1.02	34	1778
Nevada	Las Vegas	1,744	1.07	116	1860
North Carolina	Charlotte	1,744	1.00	(5)	1739
North Dakota	Bismarck	1,744	0.99	(22)	1722
Ohio	Cincinnati	1,744	0.99	(17)	1727
Oklahoma	Oklahoma City	1,744	0.99	(19)	1725
Oregon	Portland	1,744	1.06	107	1851
Pennsylvania	Philadelphia	1,744	1.06	105	1849
Pennsylvania	Scranton	1,744	1.01	23	1767
Rhode Island	Providence	1,744	1.04	75	1819
South Carolina	Charleston	1,744	1.07	119	1863
South Dakota	Rapid City	1,744	0.98	(35)	1709
Tennessee	Nashville	1,744	1.04	66	1810
Texas	Houston	1,744	0.99	(23)	1721
Utah	Salt Lake City	1,744	1.03	60	1804
Vermont	Burlington	1,744	1.08	143	1887
Virginia	Alexandria	1,744	1.01	21	1765
Virginia	Roanoke	1,744	1.00	(8)	1736
Washington	Seattle	1,744	1.08	138	1882
Washington	Spokane	1,744	1.03	44	1788
West Virginia	Charleston	1,744	1.00	(1)	1743
Wisconsin	Green Bay	1,744	0.99	(8)	1736
Wyoming	Cheyenne	1,744	0.99	(22)	1722

https://www.eia.gov/analysis/studies/powerplants/capitalcost/pdf/capital_cost_AEO2025.pdf

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15

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15

Resources

16

Structure

Within each resource:

- Availability
  - Maximum buildout
  - Locations
  - Limiting considerations
- Timing
  - Online dates
  - Development timelines
  - Lifetimes
- Costs
  - Capital, O&M, etc.
  - Cost curves
- Shapes
  - Specifically for renewables

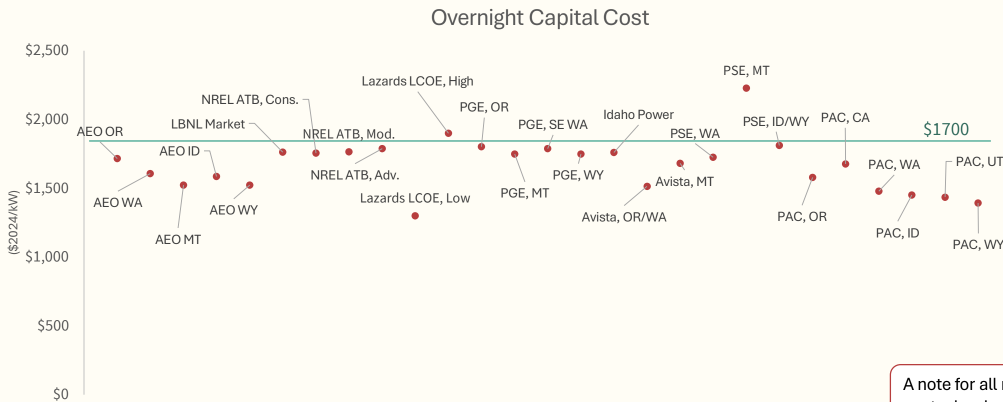
Reference Plant	
Configuration	
Location (BA)	
Year Available	
Development/Construction Period (Years)	
Capacity (MW)	
Overnight Capital Cost ($/kW)	
Fixed O&M Cost ($/kW-yr)	
Variable O&M ($/MWh)	
Economic Life (years)	

17

Land-Based Wind

18

Overnight Capital Costs *literature review*

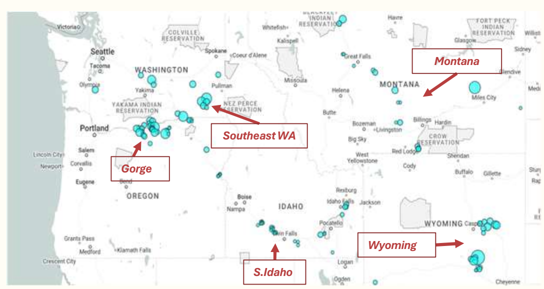


A note for all resources: O&M costs developed the same way

Timing & Location

- Wind is a primary resource and is therefore available at the beginning of the study
- 3 years for development & construction

GRAC supported both these proposed locations and the timing of the resource with the understanding that interconnection queues are a separate question from development/construction



- Want our reference plants to reflect where resources are being built
  - Above is a map of existing wind plants that serve the region
- We want to reflect the differences in daily/monthly wind shapes and will do that by building a reference plant for each
  - The actual shapes for each location are still being developed with the help of the CWAC

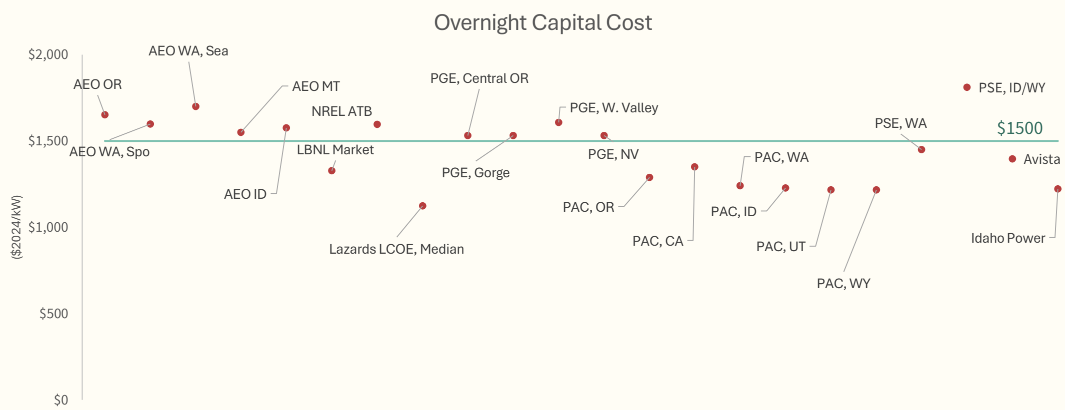
Reference Plant	Onshore Wind – Gorge	Onshore Wind – SE. Washington	Onshore Wind – Southern Idaho	Onshore Wind – Montana	Onshore Wind – Wyoming
Configuration	60 x 3.6 MW, 105 meter hub height	60 x 3.6 MW, 105 meter hub height	60 x 3.6 MW, 105 meter hub height	60 x 3.6 MW, 105 meter hub height	60 x 3.6 MW, 105 meter hub height
Location	Precise zones TBD				
Year Available	At start of study				
Development/Construction Period (Years)	3	3	3	3	3
Capacity (MW)	100	100	100	100	100
Capacity Factor	See Shape				
Overnight Capital Cost ($/kW)	1827	1768	1717	1666	1666
Fixed O&M Cost ($/kW-yr)	30	30	30	30	30
Variable O&M ($/MWh)	0	0	0	0	0
Economic Life (years)	30	30	30	30	30

21

Utility Scale Solar

22

Overnight Capital Costs *literature review*

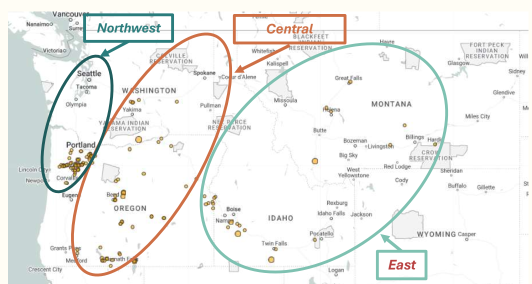


23

Timing & Location

- Solar is a primary resource and is therefore available at the beginning of the study
- 2 years for development & construction

GRAC supported both these proposed locations and the timing of the resource with the understanding that interconnection queues are a separate question from development/construction



- Similar to wind, want our reference plants to reflect where resources are being built
  - Above is a map of existing solar that serve the region grouped as we see similar solar regimes
- We'll reflect the differences in daily/monthly solar shapes by building a reference plant for each grouping
  - The actual shapes for each location are still being developed with the help of the CWAC

24

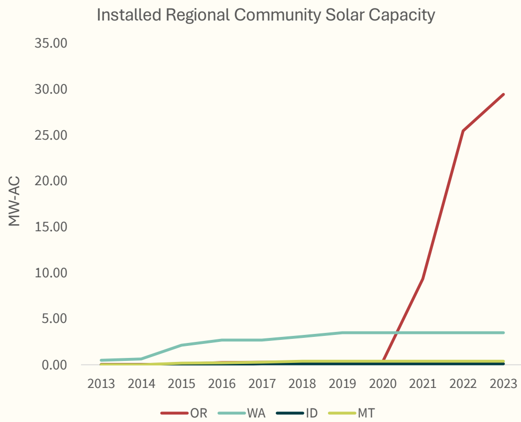
Reference Plant	Solar PV – Northwest	Solar PV – Central	Solar PV – East
Configuration	100 MW_{AC} mono PERC c-SI with single axis tracker	100 MW_{AC} mono PERC c-SI with single axis tracker	100 MW_{AC} mono PERC c-SI with single axis tracker
Location (zone)	Precise zones TBD		
Year Available	At start of study		
Development/Construction Period (Years)	2	2	2
Capacity (MW)	100	100	100
Inverter Loading Ratio (DC:AC Ratio)	1.4:1	1.4:1	1.4:1
Capacity Factor	See shape		
Overnight Capital Cost ($/kW)	1612	1575	1500
Fixed O&M Cost ($/kW-yr)	25	25	25
Variable O&M ($/MWh)	0	0	0
Economic Life (years)	30	30	30

25

Community Solar

26

Installed Capacity in the Northwest



States	# of Projects	Total installed capacity (MW-AC)	Average Size of Project (MW-AC)
ID	2	0.1	0.05
MT	8.00	0.38	0.05
OR	23.00	29.44	1.28
WA	35.00	3.51	0.10
Grand Total	68.00	33.44	0.49

Oregon's RPS has a small-scale renewable requirement for the large IOUs (PGE & PAC)

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Data from NREL's "Sharing the Sun Community Solar Project Database"
Data collected through December 2023

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Costs

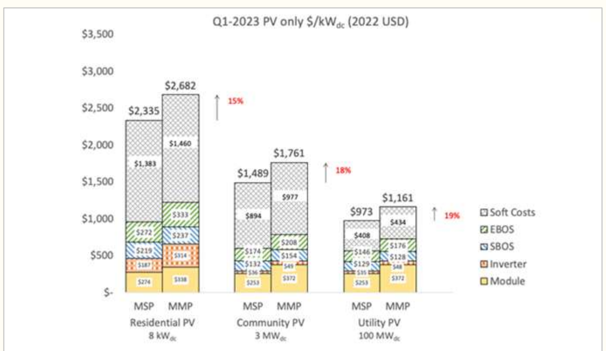

Figure ES-1. Q1 2023 U.S. PV cost benchmarks

→ Notably, community solar is more expensive than utility scale primarily due to those "soft costs" or initial costs incurred from acquiring numerous subscribers Community solar systems also incur unique costs for ongoing subscriber management, such as bill management, ongoing marketing, and customer acquisition costs to manage customer turnover

Source	Overnight Capital Cost ($/kW)	Fixed O&M ($/kW-yr)	Capacity (MW)
PAC IRP (2025)	1960	19	20 MWac
NREL	1660-1960	13 (+22.47 for program management)	3 MWdc**
PGE IRP (2023)	2400		50MWac

**This NREL report notes that the per-unit cost results are meant to be generally applicable to systems with PV sizes between about 1.5 and 6 MWdc

Approx. $500 in additional soft costs

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Reference Plant	Community Solar
Configuration	Ground mounted single axis
Location	Locations to mirror utility scale solar
Year Available	Start of study
Development Period (Years)	1
Construction Period (Years)	6 mo.
Capacity (MW)	5 MW
Capacity Factor	See shape
Overnight Capital Cost ($/kW)	2000
Fixed O&M Cost ($/kW-yr)	35
Variable O&M ($/MWh)	0
Economic Life (years)	30

Note from the GRAC: Interest in this resource being available across the region with some cautions around definition that we believe this reference plant is broad enough to address

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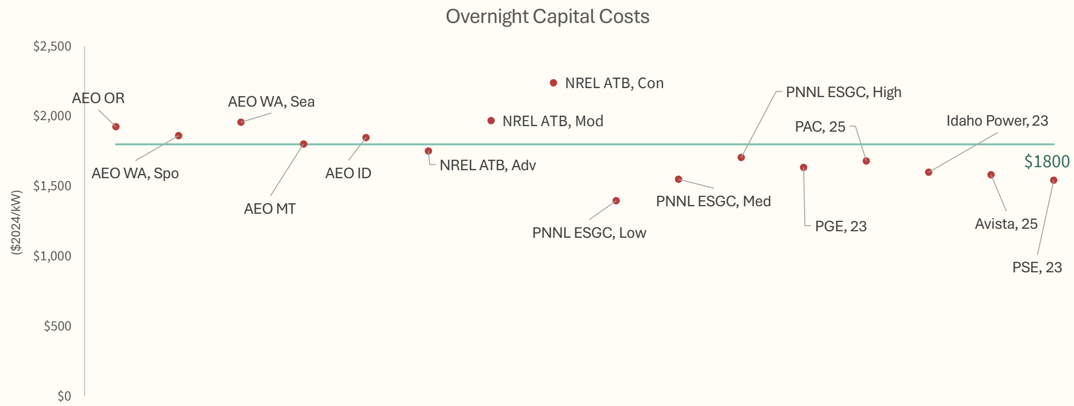
29

Lithium-Ion Batteries

30

Overnight Capital Costs *literature review*



Timing & Location

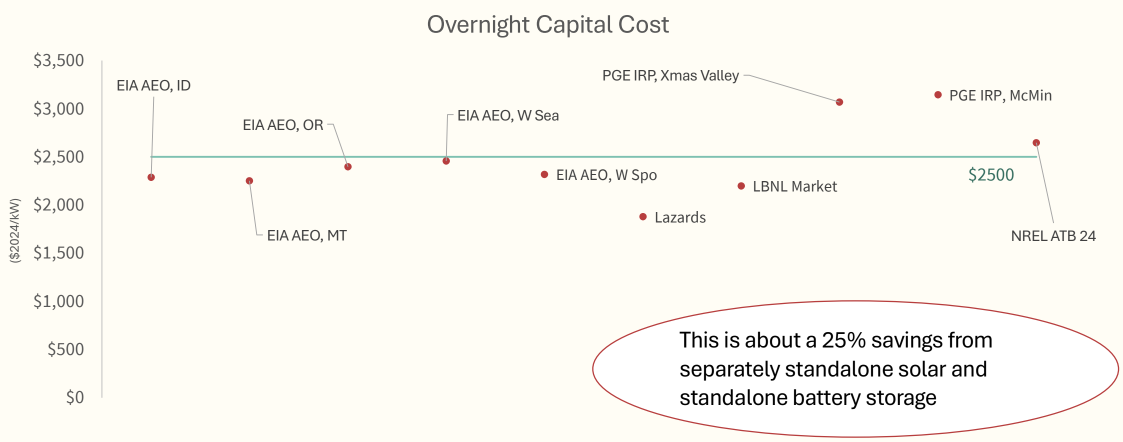
- Li-Ion batteries are a primary resource and is therefore available at the beginning of the study
- 2 years for development & construction
- Batteries are less influenced by location than renewable resources and only have one representative reference plant

- GRAC supported the proposed timing/location of the resource with the understanding that interconnection queues are a separate question from development/construction

Reference Plant	Utility Scale Lithium Ion Battery Storage - 4 hour
Configuration	100 MW, 400 MWh, Lithium-ion
Year Available	Start of study
Development/Construction Period (Years)	2
Capacity (MW)	100
Roundtrip Efficiency	88%
Overnight Capital Cost ($/kW)	1800
Fixed O&M Cost ($/kW-yr)	38
Variable O&M ($/MWh)	0
Economic Life (years)	15

Hybrid Plant: Solar + Battery

Overnight Capital Costs *literature review*



35

Solar + Battery Storage

- This hybrid resource was built up as a combination of the solar and the battery reference plants with shared/combined characteristics as appropriate.
- Ex. max buildout is assumed to mirror solar

Reference Plant	Solar + Battery Storage
Configuration	100 MWAC Solar Co-Located with DC-Coupled 100 MW, 400 MWh Battery
Location	Locations to mirror utility scale solar
Year Available	Start of study
Development/Construction Period (Years)	2
Capacity (MW)	100
Capacity Factor	See shape (Solar) 88% (Battery)
Overnight Capital Cost ($/kW)	2500
Fixed O&M Cost ($/kW-yr)	65
Variable O&M ($/MWh)	0
Economic Life (years)	30

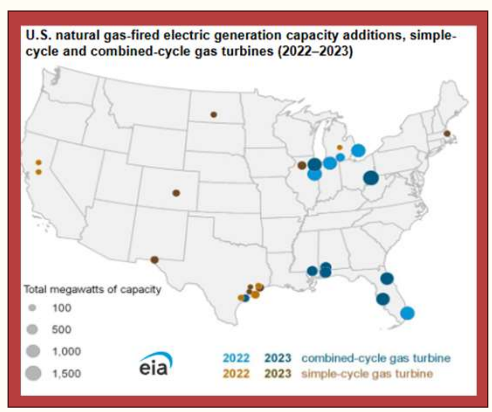
36

Natural Gas Turbines: Technology

37

Gas Technology Types

- Combined Cycle Combustion Turbine (CCCT)
  - Largest, most efficient gas technology
  - Operates more as a baseload resource
- Gas Peaker Plants
  - Smaller and more flexible than CCCT, can ramp up and down quickly to meet sharp demand spikes
  - Lower efficiency than CCCT, run less often
  - Proposing two peaker technologies for this plan
    - Frame Simple Cycle Combustion Turbine (SCCT)
      - Lowest cost but lower efficiency & flexibility
    - Reciprocating Engine Generating Units (Recips)
      - Modular reciprocating engines driving a generator
      - Most efficient and flexible peaker technology



https://www.eia.gov/todayinenergy/detail.php?id=60663

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38

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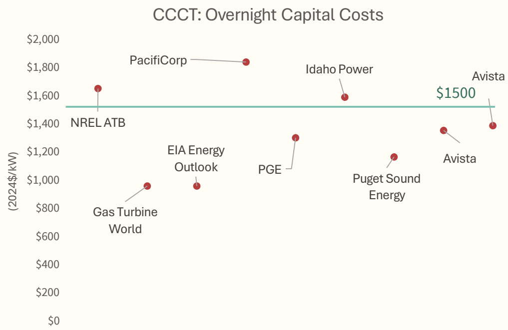
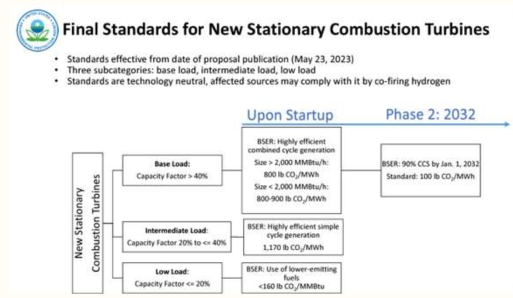
38

Costs: Combined Cycle Combustion Turbines



Clean Air Act Section 111(b): New Sources



- On the books for now, though only applicable for CCCTs beyond 2032
- Would impose additional costs to this technology: However, in the evolving federal policy landscape sensitivity, these costs would not apply

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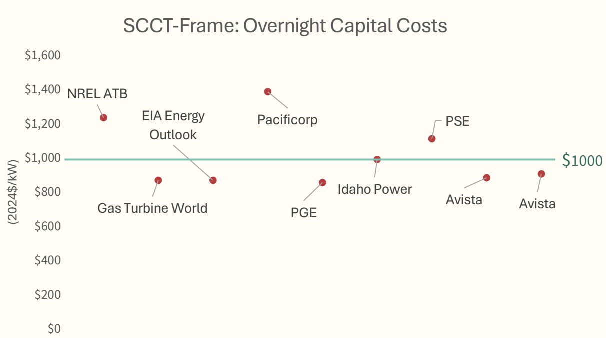
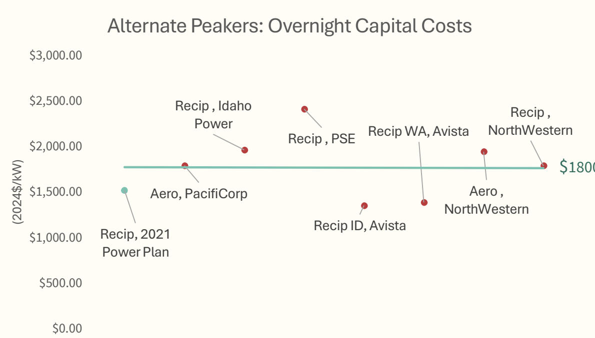
39

Costs: Peaker Plants





We opted to model a Recip as our alternative peaker technology based on stakeholder feedback and analysis of what is actually being built nationally and in the region

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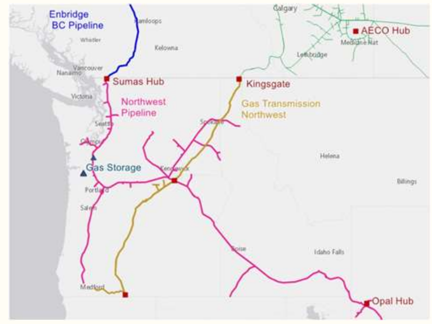
40

Timing & Availability

- Natural Gas needs both transmission access as well as pipeline access to be built
- In past plans we have made the assumption that westside pipelines are fully subscribed and therefore unable to support new gas plants
  - This assumption raised flags at the GRAC prompting a fresh look
- NW Pipeline (pink) and Gas Transmission NW (yellow) are both fully subscribed, but that doesn't mean no gas can get built
  - Discussions with gas utilities in the region pointed us to their solution which is including a price adder for gas plants that reflects the cost of ensuring a firm fuel supply
  - We're exploring options with the Fuels Advisory Committee, early conversations point to LNG or Oil back up
- This solution will mean gas is available throughout the region (though not in Oregon due to policy) but there will be an additional cost associated with meeting peak need without a firm pipeline contract



- Natural Gas is a primary resource and is therefore available at the beginning of the study
- Development & construction:
  - 4yr CCCT
  - 3yr SCCT-Frame
  - 2yr Recip

Reference Plant	CCCT H-Class 1x1	SCCT-Frame	Recip.
Configuration	1x1	1x__	__x18
Location	Available in whole region but OR (due to policy)		
Year Available	Start of study		
Development/Construction Period (Years)	4	3	2
Capacity (MW)	500	250	100
Heat Rate (Btu/kWh)	6250	9500	8500
Overnight Capital Cost ($/kW)	$1500 $3000 w/ 95% CCS	$1000	$1800
Price adder for firm fuel supply	TBD		
Fixed O&M Cost ($/kW-yr)	$28.00	$16.00	$17.00
Variable O&M ($/MWh)	$4.00	$3.50	$5.00
Economic Life (years)	30	30	30

Note from the GRAC:
Supported technology types and characteristics
Raised concerns about availability which we are working with the FAC to address

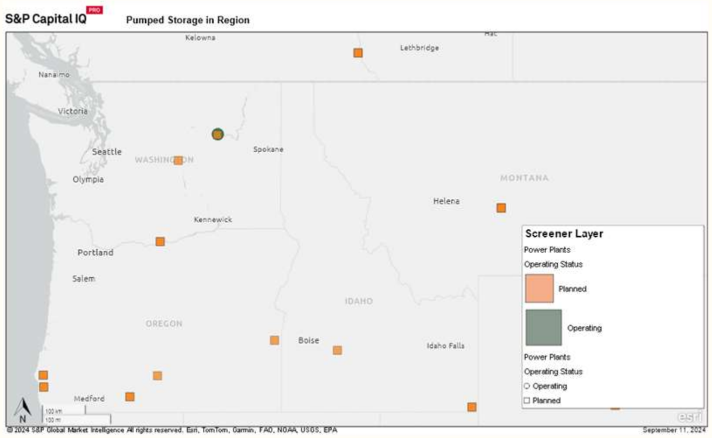
Limited Availability Resources

43

Pumped Storage

44

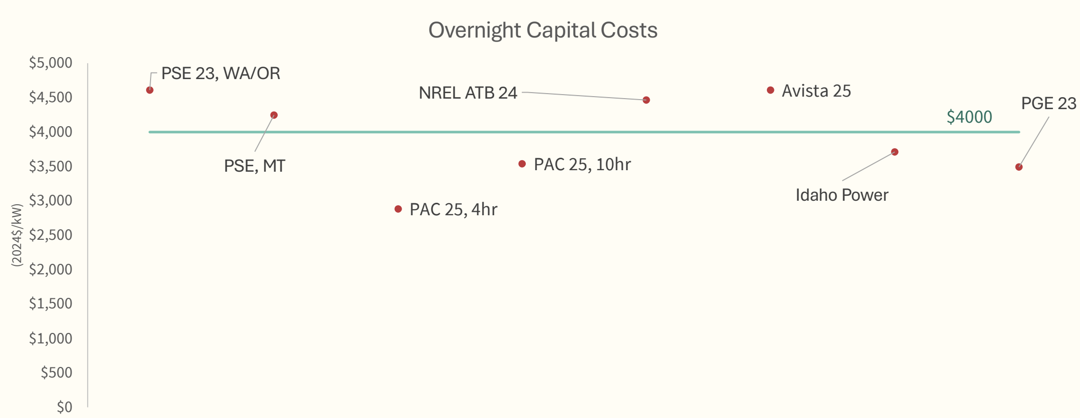
Timing & Max Buildout



Plant Name	State	Planned Capacity (MW)
Badger Mt	WA	500
Banks Lake	WA	500
Cat Creek	ID	720
Dry Canyon	ID	1800
Elephant Rock (Neptune 1)	OR	318
Goldendale	WA	1200
Gordon Butte	MT	400
Owyhee	OR	600
Soldier Camp	OR	549.6
Swan Lake	OR	393.3
Winter Ridge	OR	501

4,000 MW (10 reference plants) is the current max build estimate based off of the projects currently in development in the region and what is realistically achievable over the next two decades.

Overnight Capital Costs *literature review*



Reference Plant	Pumped Storage - 8 hour
Configuration	Closed loop, variable speed pump
Configuration	400MW/8hr
Year Available	5 yr lead time
Development/Construction Period (Years)	2
Capacity (MW)	400 (avg.)
Round trip Efficiency	80%
Overnight Capital Cost ($/kW)	4000
Fixed O&M Cost ($/kW-yr)	15
Variable O&M ($/MWh)	0
Economic Life (years)	50
Max Buildout	10 Plants (4000MW)

Note from the GRAC:
Supported pumped storage's inclusion in this limited capacity

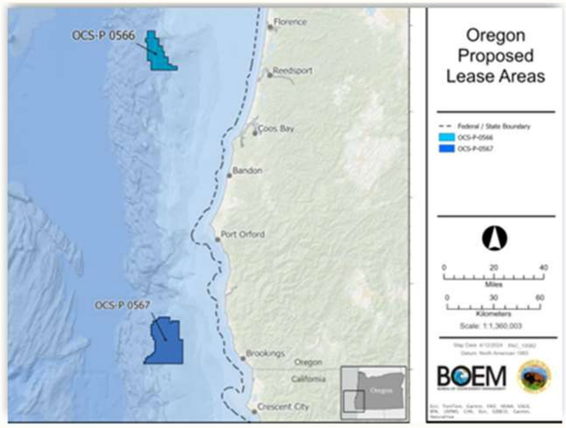
47

Offshore Wind

48

Offshore Wind: Maximum Buildout & Timing

- Max Buildout:
  - Coos Bay Lease Area has a capacity of 991 MW & Brookings' is 2,166 MW
  - For a total offshore wind capacity of about 3GW
- Timing:
  - The latest estimates from BOEM for earliest online dates are 2032
    - Recent developments led us to push this later with support of the GRAC



Reference Plant	Offshore Wind
Configuration	15MW turbine, 248-meter rotor diameter, 150-meter hub height, semisubmersible (floating technology)
Location	Brookings call area Coos Bay call area
Availability Date	2035
Development Period (Years)	5
Construction Period (Years)	3
Capacity Factor	See Shape (~50%)
Overnight Capital Cost ($/kW)	$7,000
Fixed O&M Cost ($/kW-yr)	$100
Variable O&M ($/MWh)	0
Economic Life (years)	30
Maximum Buildout	3 GW

Note from the GRAC:

- Prompted us to revisit generation shapes—we are working with stakeholders to develop shapes that are more specific to the offshore wind resource and the regional call areas
- Expressed appreciation for the inclusion of offshore wind as this limited availability resource

Note on Costs:
These costs are directly from the NREL Annual Technology Baseline. Because floating offshore wind doesn't exist in the US and because NREL is responsible for much of the existing US offshore wind development research there isn't the kind of cost variation we see with other resources, most are just citing the NREL ATB

Geothermal

51

Overnight Capital Costs *literature review*

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52

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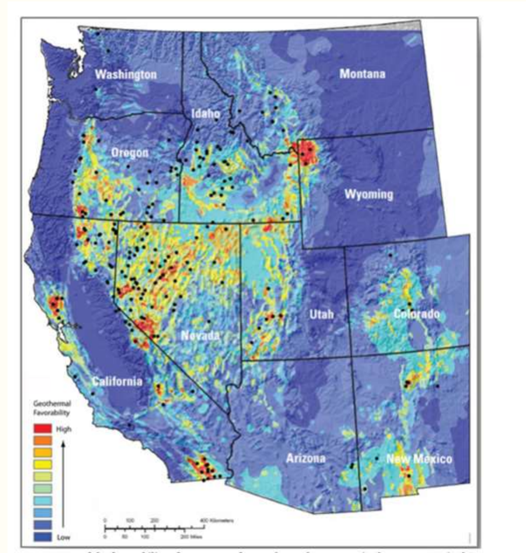
52

Max Buildout & Timing

- By nature of this being a limited availability resource, we will assign a harder limit to the resource
- The 2008 USGS Geothermal Potential Assessment (with additional allowances for undiscovered potential) identified ~462 MW of development potential in the region, or about 22 plants
  - This was the methodology in the 2021 Plan with little change in the meantime



Map of the favorability of occurrence for geothermal resources in the western United States Warmer colors equate with higher favorability. Identified geothermal systems are represented by black dots.
Source: Williams et al. 2008

Reference Plant	Conventional Geothermal
Configuration	Binary, Closed loop
Location	East of the Cascades (OR/ID)
Available Date	Start of study
Development/Construction Period (Years)	7
Capacity (MW)	30 (gross)
Avg Capacity Factor	80%
Overnight Capital Cost ($/kW)	$5,000
Fixed O&M Cost ($/kW-yr)	130
Variable O&M ($/MWh)	0
Economic Life (years)	30
Maximum Buildout	462 MW (22 plants)

Note from the GRAC: Voiced general skepticism about geothermal as a resource thought our limits were appropriate. Expressed interest in advanced geothermal.

Emerging Technology

55

Clean Long Duration Storage Proxy

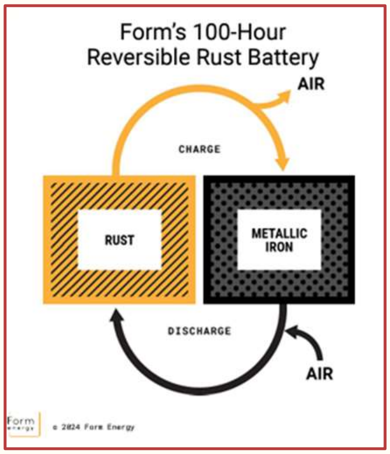
- What are the defining characteristics of this resource
  - What does this resource being selected tell us about the systems need?

Variable resource integration	Operational Flexibility	Seasonal & Daily Demand Shifting

56

Long Duration Proxy: Iron Air Batteries

- Technically Available
  - 4 pilot projects under construction or in operation and the factory in West Virginia
  - Showing up in lots of regional IRPs
- Limit availability
  - The planned production capacity is roughly 30GWh by 2025
    - Not available to the grid before 2028
    - Assuming the region will not be the first to receive the technology, not available in models until 2030
  - Based on Form energy estimates for ramping/manufacturing capability limited to about 2 GW/yr



Reference Plant	Standalone Long Duration Storage – 100 hours
Configuration	X MW, 100X MWh Iron-Air Battery Storage
Available online date	2030
Development/Construction Period (Years)	2
Capacity (MW)	5 MW
Round trip Efficiency	40%
Overnight Capital Cost ($/kW)	$2500
Fixed O&M Cost ($/kW-yr)	$20
Variable O&M ($/MWh)	0
Economic Life (years)	30
Maximum Buildout	300 MW

Note from the GRAC:
Supported this resource and understood the reasoning behind its emerging technology status

Clean Baseload Proxy

- What are the defining characteristics of this resource
  - What does this resource being selected tell us about the systems need?

Reliability

Firm supply

59

Clean Baseload Peaker: SMR

60

Small Modular Reactor: *Literature Review*

Source	Overnight Capital Costs	Variable O&M	Fixed O&M	Capacity	Heat Rate	Development/ Implementation time	Lifetime
	$/kw	$/MWh	$/kW-yr	MW	HHV Btu/KWh	Yrs	Yrs
PAC IRP-Moderate Tech Case	9662	9.74	97.42	600	9180	5	
PAC IRP-Advanced Tech Case	6368	8.74	84.52	600	9180	4	
PGE IRP	7425	3.60	113.94	600	10046		
EIA	9296	3.32	126.90	480	10046		
AEO23 EIA	9291	3.76	118.99	600	10447	6	
NREL ATB	8903	2.90	151.35	300	9180	3-5	60
PSE IRP	12881	3.35	134.34	600			30
ID Power IRP	8134	4.30	136.80	100	10461		60
Avista IRP	7820	3.42	108.41	100	10443		
2021 PP	6555	2.03	151.16	685	11000	4	40

Reference Plant	Clean Baseload Proxy
Configuration	Small Modular Nuclear Reactor
Availability Date	2035
Heat Rate (HHV Btu/kWh)	9800
Construction/Development Period (Years)	5
Capacity (MW)	600
Overnight Capital Cost ($/kW)	$9000
Fixed O&M Cost ($/kW-yr)	$120
Variable O&M ($/MWh)	$4.50
Economic Life (years)	40
Maximum build out	5 units

Note from the GRAC: Support of this proxy & the SMR characterization it's based on—expressed appreciation for the caution we're approaching this and all emerging tech with

Clean Peaker & Medium Duration Storage Proxy

- What are the defining characteristics of this resource
  - What does this resource being selected tell us about the systems need?

High peak demand

Operational Flexibility

Daily & Hourly Demand Shifting

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63

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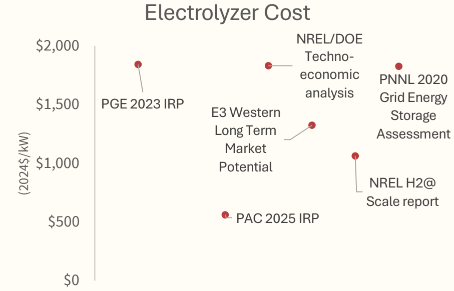
63

Clean Peaker w. Med. Duration Storage Proxy: Hydrogen Peaker

- An all hydrogen burning resource that would fulfill the niche of a clean, mid duration storage & peaker-style plant
- Not available at the start of the action plan period
- Why this resource:
  - There *is* a hydrogen hub in the PNW with 8 potential project nodes which will likely drive development
    - And hydrogen is showing up in regional IRPs
  - However, there is no existing H_2 infrastructure and most forecasts don't show significant H_2 for power until the 2040s
- Therefore, hydrogen would have to be produced and stored on site:
  - Electrolysis technology: Clean, separate from gas system, has a load implication (takes energy to produce)

Electrolyzer Cost



- Component parts (2024$/kW):
  - Electrolyzer (PEM)—$1500
  - Storage 24hr (Tank/Pipe)—$800
  - Turbine (SCCT)—$1000
  - Other infrastructure (Compressor/Rectifier)—$200

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64

Natural Gas → Hydrogen Conversion

- Natural Gas Plant Upgrade
  - Include additional simple cycle gas turbine reference plant that after a certain year will convert to burning hydrogen
  - At the conversion point, the additional costs of having onsite hydrogen production and storage will be incorporated, as well as the change in plant emissions
    - In an effort to capture multiple means of hydrogen production—particularly one that makes more direct use of the existing natural gas system, we are proposing onsite production for converted gas plants is from pyrolysis
    - NW natural has a small pilot project currently operating
- Pyrolysis technology
  - Bridge fuel—makes use of existing NG infrastructure
  - Cleaner than natural gas but not entirely emission free (mostly methane)
  - Uses about 2x the gas fuel to produce the same amount of energy from hydrogen
  - Still uses some electricity, less than electrolysis
  - Solid carbon biproduct, traditionally 'carbon black', has commercial uses but limited
- This was a technology flagged by the GRAC which prompted our further investigation
  - We will bring this proposal to the GRAC/FAC at the end of the month

Reference Plant	Clean Medium Duration Storage/Peaker	Simple Cycle Gas Plant Conversion to Hydrogen Pyrolysis
Configuration	SCCT w/ onsite hydrogen production (via PEM) and storage (tank/pipe)-24hr	SCCT w/ onsite hydrogen production via pyrolysis
Availability Date	2040	2035-40
Development Period (Years)	1	1
Construction Period (Years)	1	1
Capacity (MW)	250	250
Heat Rate (Btu/kWh)	9500	9500
Round trip Efficiency	40%	
Overnight Capital Cost ($/kW)	3500	TBD
Fixed O&M Cost ($/kW-yr)	16.00	
Variable O&M ($/MWh)	3.50	
Economic Life (years)	30	30
Maximum build out	TBD: Discuss with GRAC at end of March meeting	

Note from the GRAC: Raised some questions about hydrogen production, noting that electrolysis is not the only option. With the guidance of stakeholders we've worked to incorporate pyrolysis.

Summary

Finalizing	Outstanding	Next

• Resource Types
• Resource Characteristics:
  • Costs
  • Availability
  • Timing
	• Renewable shapes
	• Firm gas adder
	• Tax credit application
	• Sensitivity specifics
	• Added transmission costs
	• Hydrogen:
	  • Build limitations
	  • Pyrolysis
		• These final reference plants will become inputs for the power system models to select to fulfill future resource needs to be considered along-side demand side resource inputs like EE, DR & DERs

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67

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67

Questions?

68