Northwest **Power** and
Conservation Council

February 4, 2020

MEMORANDUM

TO: **Power Committee**

FROM: **Gillian Charles**

SUBJECT: **Geothermal Reference Plant for draft 2021 Power Plan**

BACKGROUND:

Presenter: Gillian Charles

Summary: As part of the development of inputs for the draft 2021 Power Plan, staff develops generating resource reference plants as resource options – along with energy efficiency and demand response – for the Council's power system models to select to fulfill future resource needs. A generating resource reference plant is a collection of characteristics that describe a realistic and likely implementation of a given technology within the region. It includes estimates of costs, operating and performance specifications, and developmental potential.

Staff presents reference plants for review and discussion with the Generating Resources Advisory Committee (GRAC) and incorporates feedback before bringing the reference plant to the Council for review.

At the February Council Meeting, staff will present the reference plant for geothermal.

Relevance: Development of inputs for the 2021 Power Plan

Workplan: A.4.1 Develop generating resource reference plants for 2021 Power Plan

851 S.W. Sixth Avenue, Suite 1100
Portland, Oregon 97204-1348
www.nwcouncil.org

Steve Crow
Executive Director

503-222-5161
800-452-5161
Fax: 503-820-2370

Conventional Geothermal Reference Plant for the 2021 Plan

February 11, 2020 -- Power Committee

Gillian Charles

THE 2021 NORTHWEST POWER PLAN
FOR A SECURE & AFFORDABLE ENERGY FUTURE

1

What is the difference between conventional geothermal and enhanced geothermal systems?

- "Conventional" geothermal is naturally occurring and requires:

heat + water + permeability

- Enhanced geothermal systems only require heat and the fluid and permeability are ***engineered***

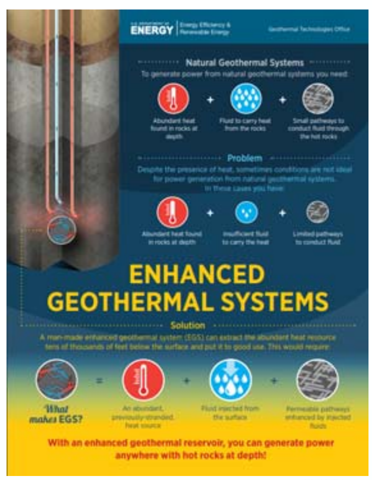


Image source: DOE EERE GTO

THE 2021 NORTHWEST POWER PLAN

2

2

Current Geothermal Activity in the PNW, WECC, US

Existing capacity, planned projects

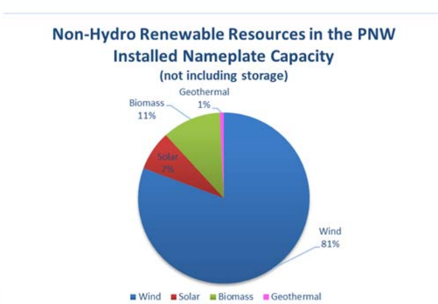
3

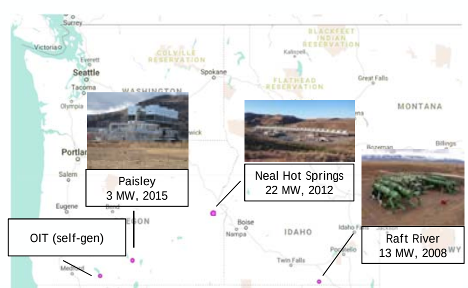
Operating Geothermal in PNW

~50 MW installed capacity across four projects

- Developed 2007 – 2015; all binary technology

Great resource potential in PNW, but little in terms of planned projects in the development pipeline





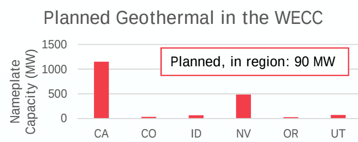
Data and map from Council's project database and generation map - https://www.nwcouncil.org/energy/energy-topics/power-supply/map-of-power-generation-in-the-northwest

THE 2021 NORTHWEST POWER PLAN

4

Recent developments in WECC

- ~150 MW installed nameplate capacity since 2016, across 8 projects
  - Includes 3MW repowering at Raft River in ID
  - Largest project is Tungsten Mountain Geothermal Development Project in Nevada, at 26MW installed nameplate capacity
    - Hybrid geothermal and 7MW on-site solar PV project, to offset parasitic load (equipment's energy use) and increase power output
  - Majority installations binary technology
- ~1,500 MW planned projects



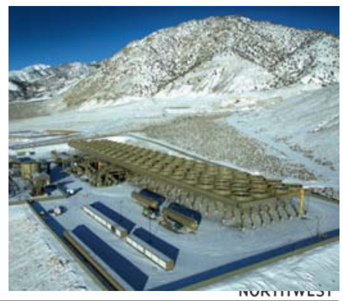


Image: Tungsten Mountain project, Ormat

NORTHWEST POWER PLAN

5

5

Geothermal Plants in Operation and Planned

Map created using S&P Global Market Intelligence

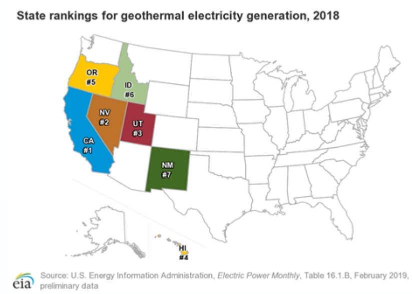
THE 2021 NORTHWEST POWER PLAN

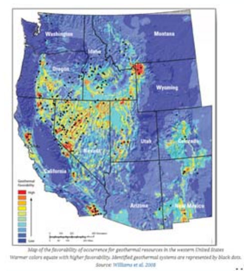
6

6

Existing Geothermal in the U.S.

- United States leader of installed geothermal capacity in the world - ~3.5 GW of ~14GW installed worldwide
  - Geothermal generation still only accounts for <0.5% electricity production nationwide
- California most installed capacity at 2,760 MW, accounting for ~6% of total state electricity generation
  - Nevada ranks #2 with ~650MW, ~9% of state generation





THE 2021 NORTHWEST POWER PLAN

Data source: EIA 2018 data

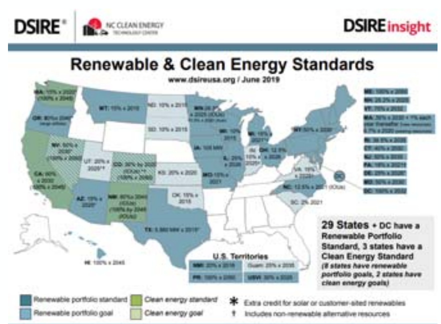
7

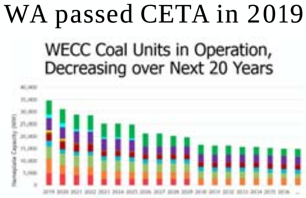
7

Policy Landscape

Geothermal electricity is a qualifying resource -

- Renewable portfolio standards (RPS)
  - 10 states in WECC
  - Oregon increased standard in 2016
- Clean energy policies
  - 5 states in WECC
  - WA passed CETA in 2019





- Carbon regulations enacted, considered in WECC
- ~15 GW coal unit capacity retirements over the next 10 years within the WECC

THE 2021 NORTHWEST POWER PLAN

8

8

Federal Incentives

Investment Tax Credit (ITC)

- Front-loaded incentive based on initial capital expenditures
- Phasing down/expiring for wind; solar and geothermal receive 10% indefinitely

2021 Power Plan – 10% ITC for geothermal included in levelized cost analysis and modeling, indefinitely

Production Tax Credit (PTC)

- Production-based corporate income tax credit, based on project generation during first ten years of operation
- For qualifying facilities (non-wind) commencing construction by January 1, 2018, qualify for this credit for the first ten years of operation

2021 Power Plan – Effectively expired for new geothermal resources considered as resource options; not included

THE 2021 NORTHWEST POWER PLAN

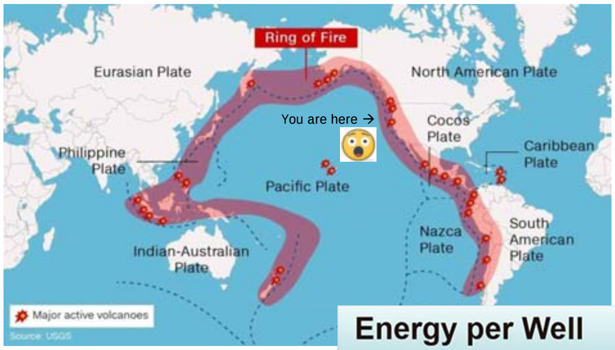
9

9

Geothermal Potential

10

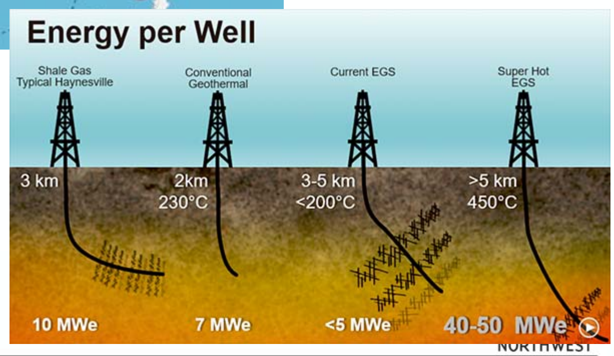
10



"Ring of Fire" is an area of active volcanoes and frequent earthquakes…

Majority of geothermal resources are found near the earth's tectonic plates

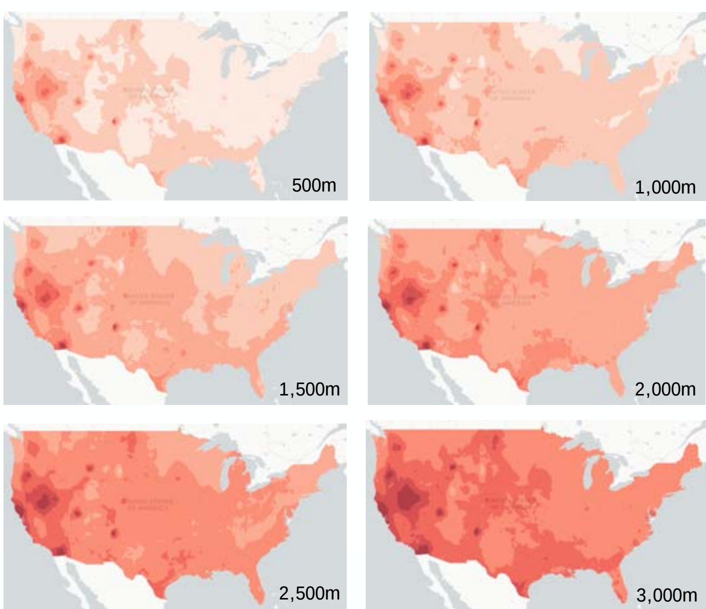
How low can you go?



NORTHWEST
POWER PLAN

11

11



Estimated Temperature (Degrees Celsius)

- 0 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 125
- 125 - 150
- 150 - 250

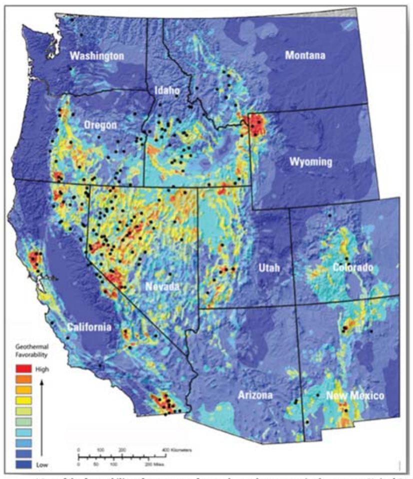
Images made using the NREL geothermal prospector

THE 2021
NORTHWEST
POWER PLAN

12

12

2008 USGS Assessment of Moderate- and High-Temperature Geothermal Resources



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

- 2008 assessment of geothermal electric power generation at moderate (90 – 150°C) and high-temperature (>150°C)
- Three categories:
  - Identified Geothermal Systems – development of known geothermal resources
  - Undiscovered Resources – modeled using GIS (no surface manifestations, e.g. geysers, to indicate presence)
  - Enhanced Geothermal Systems

Require hydrothermal fluid high temps, permeability

- Reference: In 2008, there was about 2,500 MWe (roughly 2,750 MW capacity) in US

THE 2021 NORTHWEST POWER PLAN

13

MWe = the capability of generating 1MWa continuously for 30 years

13

Table 1. Electric power generation potential in Megawatts-electric (MWe) from identified and undiscovered geothermal resources and Enhanced Geothermal Systems in the western United States.

[All electric power generation figures are calculated on a basis of 30 years of production. F95 represents a 95% chance of at least the amount tabulated; other fractiles are defined similarly. Fractiles are additive under the assumption of perfect positive correlation. N is the number of identified geothermal systems included in the estimate].

		Identified Resources (MWe)				Undiscovered Resources (MWe)				Enhanced Geothermal Systems (MWe)			
State	N	F95	F50	Mean	F5	F95	F50	Mean	F5	F95	F50	Mean	F5
Alaska	53	236	606	677	1,359	537	1,428	1,788	4,256	NA	NA	NA	NA
Arizona	2	4	20	26	70	238	775	1,043	2,751	33,000	52,900	54,700	82,200
California	45	2,422	5,140	5,404	9,282	3,256	9,532	11,340	25,439	32,300	47,100	48,100	67,600
Colorado	4	8	11	30	67	252	821	1,105	2,913	34,100	51,300	52,600	75,300
Hawaii	1	84	169	181	320	822	2,027	2,435	5,438	NA	NA	NA	NA
Idaho	36	81	283	333	760	427	1,391	1,872	4,937	47,500	66,700	67,900	92,300
Montana	7	15	51	59	130	176	573	771	2,033	9,000	16,100	16,900	27,500
Nevada	56	515	1,216	1,391	2,551	996	3,243	4,364	11,507	71,800	101,300	102,800	139,500
New Mexico	7	53	153	170	343	339	1,103	1,484	3,913	35,600	54,400	55,700	80,100
Oregon	29	163	485	540	1107	432	1,406	1,893	4,991	43,600	61,500	62,400	84,500
Utah	6	82	171	184	321	334	1,088	1,464	3,860	32,600	46,500	47,200	64,300
Washington	1	7	20	23	47	68	223	300	790	3,900	6,300	6,500	9,800
Wyoming	1	5	31	39	100	40	129	174	458	1,700	2,900	3,000	4,800
Total	248	3,675	8,356	9,057	16,457	7,917	23,739	30,033	73,286	345,100	507,000	517,800	727,900

Total US Potential (mean):

- Identified - 8,356 MWe
- Undiscovered – 30,033 MWe
- EGS – 517,800 MWe

MWe = the capability of generating 1MWa continuously for 30 years

Images: USGS Assessment of Moderate- and High-Temperature Geothermal Resources of the US, 2008

Regional % of Total US Potential (mean)

- Identified – 10.5%
- Undiscovered – 16.1%
- EGS – 29.7%

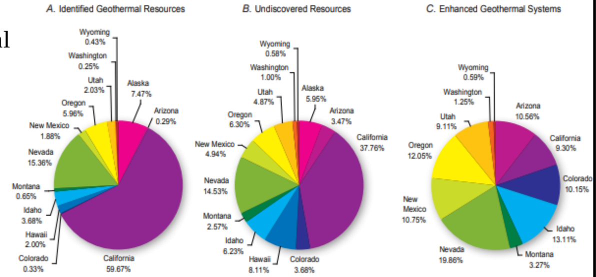
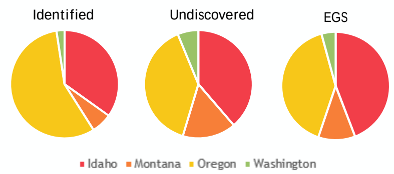


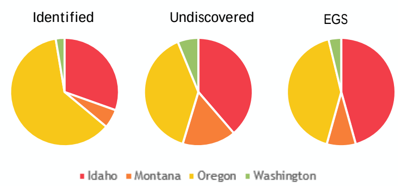
Figure 2. *Pie charts illustrating the distribution of (A) identified, (B) undiscovered and (C) Enhanced Geothermal Systems (EGS) resources (mean estimates) among the western states. Alaska and Hawaii were not included in the assessment of EGS resources because of a lack of information in those states.*

14

US Potential → Regional Level (MW)



Mean	Identified Resources	Undiscovered Resources	EGS
Idaho	366 MW	2,059 MW	74,690 MW
Montana	65 MW	848 MW	18,590 MW
Oregon	594 MW	2,082 MW	68,640 MW
Washington	25 MW	330 MW	7,150 MW
Region Total	1,050 MW	5,319 MW	169,070 MW



F95	Identified Resources	Undiscovered Resources	EGS
Idaho	89 MW	470 MW	52,250
Montana	17 MW	194 MW	9,900
Oregon	179 MW	475	47,960
Washington	8 MW	75	4,290
Region Total	293 MW	1,213 MW	114,400 MW

*F95 represents a 95% chance of at least the amount tabulated

Original data source: USGS Assessment of Moderate- and High-Temperature Geothermal Resources of the US, 2008

MWe is defined as the capability of generating 1MWa continuously for 30 years – the assumed lifetime of the resource)

Conversion of MWe to MW capacity = 1MWe * 1.10

(1.10 represents assumption of 90% capacity factor for geothermal)

POWER PLAN

15

15

Potential in the Seventh Plan vs. 2021 Plan

- Seventh Power Plan assumed 475 MW potential
  - All of the identified resources (F95) and 15% of undiscovered resources
  - Conservative estimate, based on limited activity and development at the time

2021 Power Plan – Same assumption – 475 MW. No new development since Seventh Power Plan, little activity in the pipeline.

F95	Identified Resources	Undiscovered Resources	EGS
Idaho	89 MW	470 MW	52,250
Montana	17 MW	194 MW	9,900
Oregon	179 MW	475	47,960
Washington	8 MW	75	4,290
Region Total	293 MW	1,213 MW	114,400 MW

*F95 represents a 95% chance of at least the amount tabulated

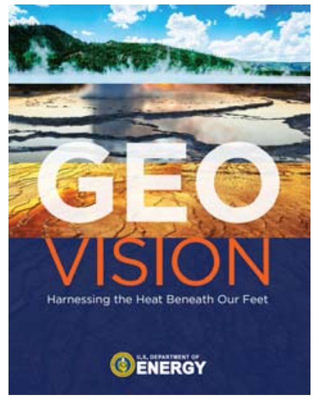
THE 2021 NORTHWEST POWER PLAN

16

16

US DOE: GeoVision
Harnessing the Heat Beneath Our Feet

- U.S. DOE identified geothermal as a potential renewable and "diverse" domestic electricity solution to future U.S. heating and cooling needs
- DOE Geothermal Technologies Office (GTO) provided a comprehensive assessment of the current state of the industry and identified "deployment opportunities and pathways for targeted action that could achieve a shared vision for industry growth"
- Analysis projected that through **technology improvements**, geothermal electricity capacity has the potential to **increase 60 GWe+ by 2050** – and provide 8.5% of all U.S. generation (and 3.7% of installed capacity)
  - Many pathways point to... EGS



THE 2021 NORTHWEST POWER PLAN

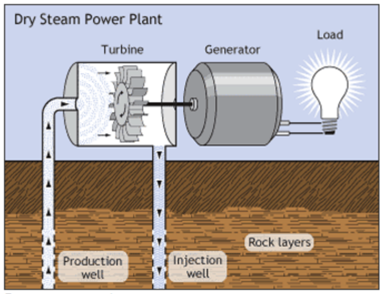
17

17

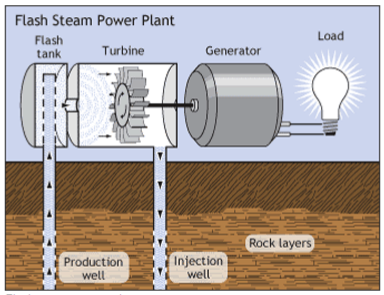
Technology & Cost Trends

18

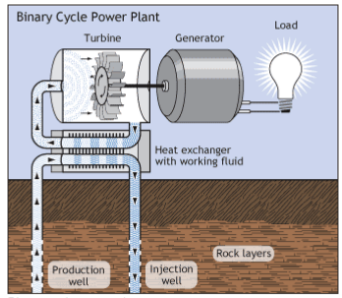
Geothermal Technology Types



Dry steam power plant.



Flash steam power plant.



Binary cycle power plant.

Of the 14GW geothermal installed globally, ~60% are flash steam, 25% are dry steam, and 15% are binary

THE 2021 NORTHWEST POWER PLAN

Image source: US DOE

19

Geothermal: Benefits and Challenges

- **Renewable, clean energy resource**
- **No/low emissions -** minimal excess steam (and CO2) is emitted by flash plants, otherwise geothermal has no emissions
- **High capacity factor** – 80-90% depending on technology
- **Reliable**, baseload power at a consistent output
- **Low, predictable operating costs** (and no reliance on volatile fuel prices)

- **High risk exploration** – Extremely complex and expensive identification and assessment
  - Risk of “dry hole” – when water is not available at site
- **Large upfront capital investment**
- **Technological improvements required to reach full potential**
- **Operational flexibility is costly** using traditional PPAs – there have been specific flexibility PPAs (Puna Geothermal in Hawaii) with both specified capacity and energy payments, which make flexibility economically possible.
- **Regional challenge – transmission availability**

THE 2021 NORTHWEST POWER PLAN

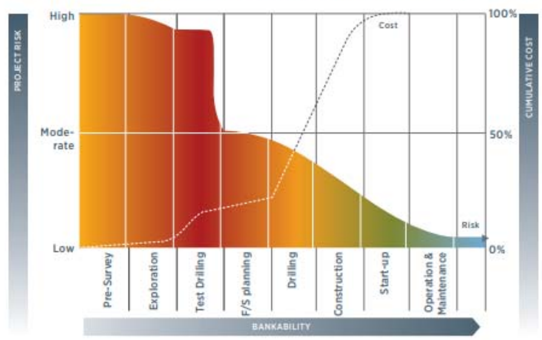
20

20

Geothermal: Cost of exploration

- The cost of exploration and initial testing of a geothermal site can equal about 30-60% of the total project cost
  - Which means… you need capital before you can confirm resource potential and return on investment

Figure 14: Typical uncertainty and expenditure profiles for a geothermal project



Source: Gehringer and Loksha, 2012

21

Image source: IRENA 2017

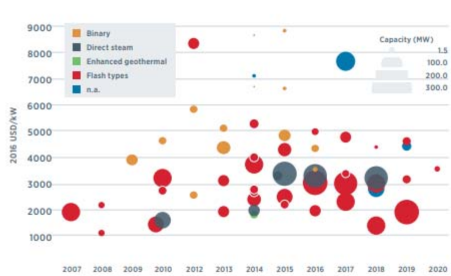
THE 2021 NORTHWEST POWER PLAN

21

Capital Costs Vary Widely

- Extremely site-specific
- Huge variation in exploration and drilling costs
- Variation between technology – binary tends to be most expensive
- Limited (if any?) improvements in cost over the past decade

Figure 8: Geothermal project-level installed costs by technology, 2007-2020



Source: IRENA, 2017b

Figure 9: Forecast of capital expenditures (CAPEX) for geothermal power plant in the European Union

Source: Sigfusson and Uihlein, 2015

NORTHWEST POWER PLAN

22

22

Geothermal in IRPs*

- PGE 2019 IRP – Assessed 30MW flash-steam geothermal resource located in the PNW as resource option
- PAC 2019 IRP – Assessed geothermal through a PPA structure, not as a utility-owned investment, to mitigate the financial risks to the utility
  - In response to the 2016 OR renewables RFP, several geothermal projects submitted proposals – none were selected
- Avista 2019 IRP – Modelled a 20MW off-system geothermal PPA as a resource option
- NorthWestern 2019 IRP – Eliminated geothermal (and CAES) from consideration due to high cost, after HDR evaluation
- PSE 2019 IRP – did not analyze geothermal (as far as I can tell)
- Idaho 2019 IRP- assessed binary geothermal, concluding it was more likely in IPC's service territory

Note: Many IRPs are still either in draft form, or ongoing; this information is subject to change

THE 2021 NORTHWEST POWER PLAN

23

23

Proposed 2021 Plan Reference Plant

Conventional Geothermal - Binary

24

Selecting a Technology for Reference Plant: Binary or Flash-Steam?

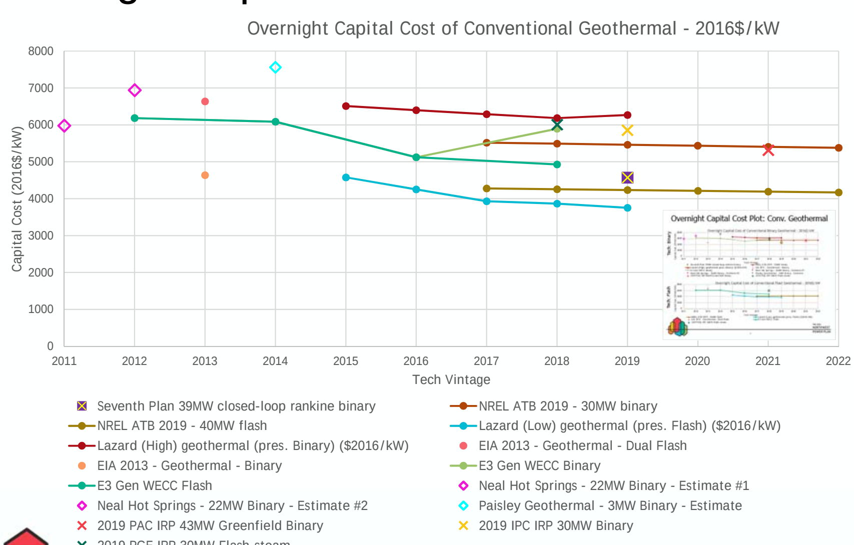
- Depending on resource temperature, flash-steam or binary-cycle geothermal technologies could be used with the liquid-dominated hydrothermal resources of the Pacific Northwest.
- A preference for binary-cycle is emerging because of modularity, applicability to lower temperature geothermal resources, and the environmental advantages of a closed geothermal-fluid cycle.
  - Binary releases no carbon dioxide, whereas flash-steam releases a small amount of naturally occurring CO2 from the geothermal fluid

THE 2021 NORTHWEST POWER PLAN

25

25

Overnight Capital Cost Plot: Conv. Geothermal



Notes: Lazard data includes AFUDC and Council staff assumptions on technology; EIA 2016 did not include geothermal analysis; E3 WECC binary and flash same cost estimates until 2018

THE 2021 NORTHWEST POWER PLAN

26

26

2021 Plan Reference Plant: Geothermal

	Conventional Geothermal
Configuration & Technology	22 MW closed-loop, binary
Capacity (MW)	22 MW (net), 30 MW (gross)
Location	Cascades
Financial Sponsor	IPP
Economic Life (years)	30
Overnight Capital Cost ($/kW)	$5,400
Fixed O&M Cost ($/kW-yr)	$150
Variable O&M Cost ($/MWh)	$5
Development Time (years)	4
Construction Time (years)	3
Earliest Commercial Online Date	2024
Resource Maximum Build-out (potential)	475 MW (based on 2008 USGS survey)

THE 2021 NORTHWEST POWER PLAN

27

27

What's Next

- GRAC Meeting – February 27
- Future Power Committee meeting - Summary of generating resource reference plants for draft 2021 Power Plan
- Potential addition of emerging technology reference plant for scenario analysis

THE 2021 NORTHWEST POWER PLAN

28

28

Background

29

Proposed Resources for 2021 Plan

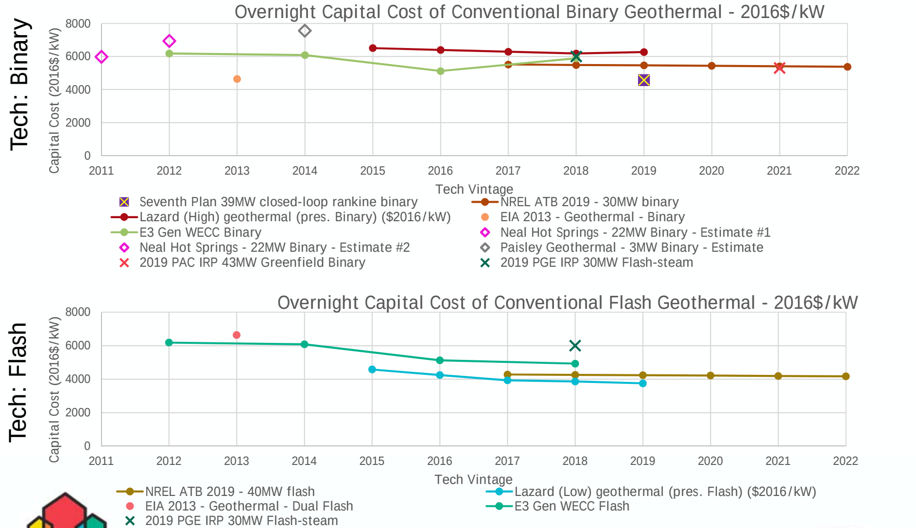
Primary	Secondary	Emerging/Long-term
✓ Solar PV ⚙	✓ Conv. Geothermal ⚙	✓ Enhanced Geothermal Systems
✓ Onshore Wind ⚙	✓ Offshore Wind	Small Modular Reactors
✓ Gas CCCT ⚙	✓ Distributed Generation*	Carbon Capture & Sequestration
✓ Gas SCCT – Frame ⚙	Biomass	Hydrogen Gas Turbine
✓ Battery storage (Li-ion) ⚙	Hydro Upgrades	Allam Cycle Gas
✓ Solar + Storage ⚙	Biogas	Wave, Tidal
✓ Pumped Storage ⚙	Power-to-Gas	
✓ Reciprocating Engine	Small Hydro	
✓ Gas SCCT - Aeroderivative	Combined Heat and Power	

⚙ = reference plant

THE 2021 NORTHWEST POWER PLAN

30

Overnight Capital Cost Plot: Conv. Geothermal



THE 2021 NORTHWEST POWER PLAN

31

31