Northwest Power and Conservation Council

February 26, 2009

MEMORANDUM

TO: Power Committee

FROM: Jeff King, Senior Resource Analyst

SUBJECT: Assessment of geothermal generating resource potential

Aggressive renewable portfolio standards and greenhouse gas control policies have increased the demand for sources of renewable or low-carbon energy. Geothermal energy, the crustal heat of the earth, is one such source. Conventional (hydrothermal) geothermal power generation relies on naturally-present water in near-surface porous heated rock as the heat transfer mechanism. The water is brought to the surface by means of wells and used directly or indirectly to drive a turbine-generator. The cooled geothermal fluid is then recycled to the underlying rock formation.

Geologic structures found in the Northwest thought to have potential for conventional geothermal electricity generation include the Basin and Range area of southeastern Oregon and southern Idaho, magma bodies underlying volcanic structures in the Cascade Range and certain locations in the Snake River Plain. Developable sites possessing the water, rock, and temperature qualities required for geothermal generation are rare, and geothermal exploration and development are expensive and financially risky ventures.

The 13 megawatt (net) Raft River project in southeastern Idaho, commissioned in January 2008, is the first commercial geothermal power plant in the Northwest. An expansion of Raft River is planned for 2009. Several additional Northwest projects have been announced in recent years, but only two of these appear to be under active development.

Incremental improvements to conventional technology and commercialization of advanced geothermal technology, especially that using impervious hot dry rock could greatly increase the availability of geothermal energy. The timeline for commercial development of advanced technology, however, is uncertain.

Staff will describe the potential availability, estimated cost of energy and issues associated with development of the geothermal resources. Presentation materials will be provided prior to the meeting.

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

Sixth Northwest Conservation & Electric Power Plan

Geothermal Power Generation Resource Assessment

Jeff King

Northwest Power and Conservation Council

Power Committee

Boise, ID

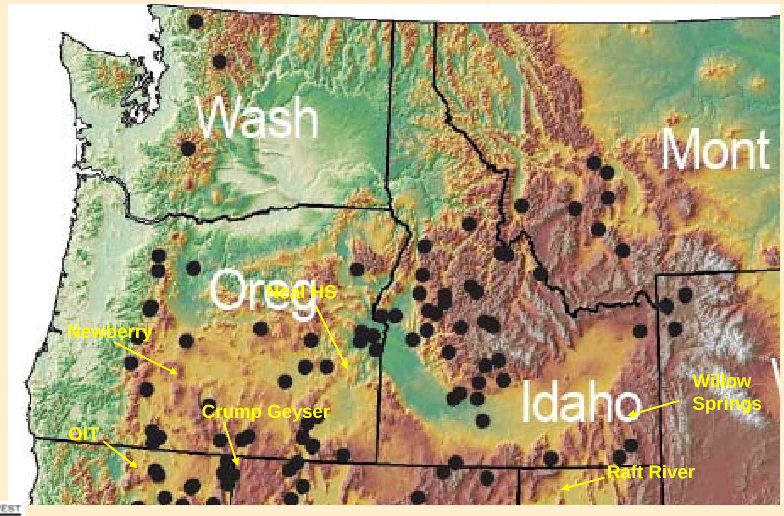
March 10, 2009

Geothermal energy in the Northwest

- Northwest hydrothermal potential
  - At one time thought to be very large (thousands of MW)
  - Lower expectations in recent years (hundreds of MW??)
- Many attempts at development, few successful
  - Land use & visual conflicts, esp. in Cascades
  - Low probability of locating natural hydrothermal resource (~ 20% success rate)
- First Northwest geothermal power plant in-service Jan 2008
  - Raft River Phase I - 13 MW net
  - 13 MW Phase II under contract; 13 MW Phase III proposed
- Exploratory drilling reported at 5 additional sites[1]
  - Idaho - Willow Springs
  - Oregon - Neal HS, OIT, Crump Geyser, Newberry

1) Geothermal Energy Association. U.S. Geothermal Power Production and Development Update. March 2009.

Reported geothermal exploration



Northwest Power and Conservation Council

Binary-cycle geothermal plant

Natural hydrothermal reservoir
- Temperature > 200ºF
- Permeable
- Fluid (water) present
- Feasible drilling depth (< 3km)

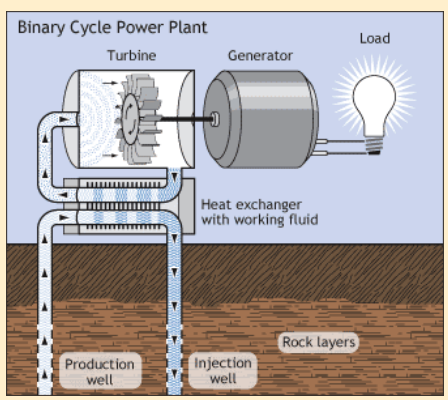
Hot geothermal fluid is extracted from reservoir via production wells

Heat is transferred to low boiling point working fluid in heat exchanger

Cooled geothermal fluid is re-injected to reservoir

Vaporized/pressurized working fluid drives turbine-generator

Working fluid is condensed, returned to heat exchanger



Northwest Power and Conservation Council

Reference plant: 40 MW binary-cycle

3 x 13 MW_{net} units

47 MW (gross); 39 MW (net) capacity

Closed-loop binary cycle

- Organic Rankine cycle (ORC) technology
- No release of CO2 or toxic materials
- Full reinjection of geothermal fluid

Air or water-cooled condenser

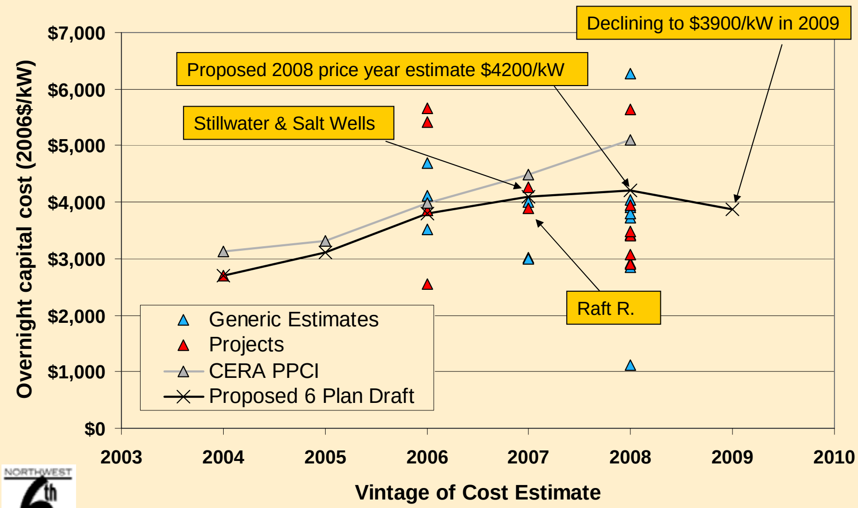
- Wet cooling - more efficient, more uniform seasonal output
- Dry cooling in water-scarce areas

Modular

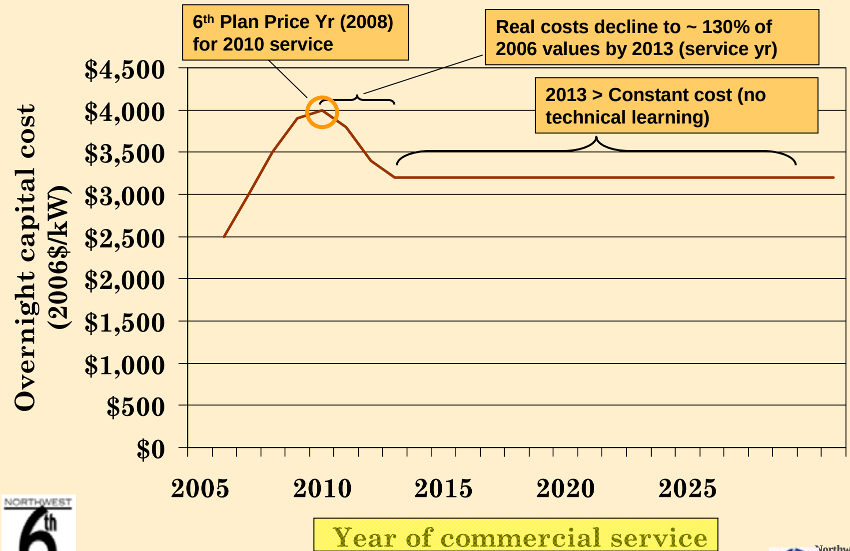
Widely-used, mature technology

Can utilize moderate temperature resources

Price year capital cost estimate



Capital cost forecast



7

Hydrothermal power plant assumptions

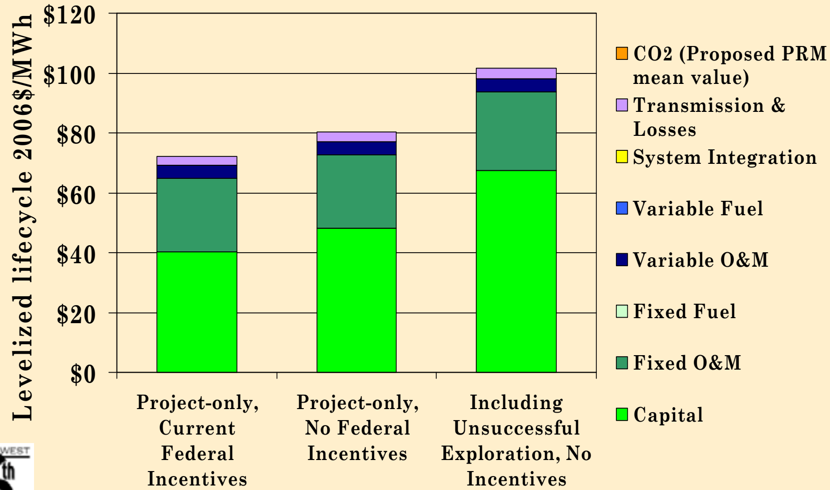
(2006 dollar values, 2008 price year)

	Binary	
Net capacity (MW)	39	
Heat Rate (Btu/kWh)	28,500	12% thermal efficiency
Availability (%)	95%	Assm 90% annual CF
Overnight capital ($/kW)	$4,200 +/- 25%	Successful development w/ unsuccessful prospects ~ $5800
Fixed O&M ($/kW/yr)	$175	Incl. well field maintenance
Variable O&M ($/MWh)	$4.50	
Planning	36 mo	Geologic assessment, permits & exploratory drilling
Early construction	12 mo	Production drilling
Final construction	24 mo	Power plant construction
Earliest new PNW unit	2010	

8

Hydrothermal geothermal costs ca. 2020

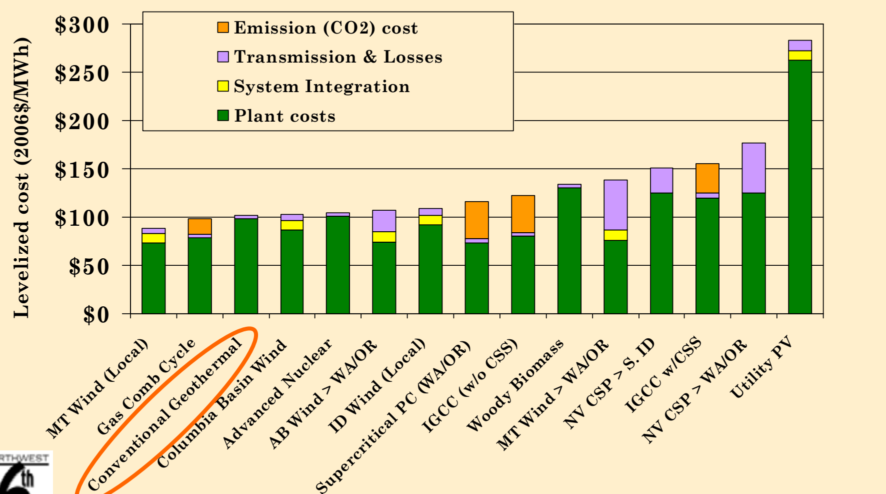
IOU financing
2020 service
90% CF



9

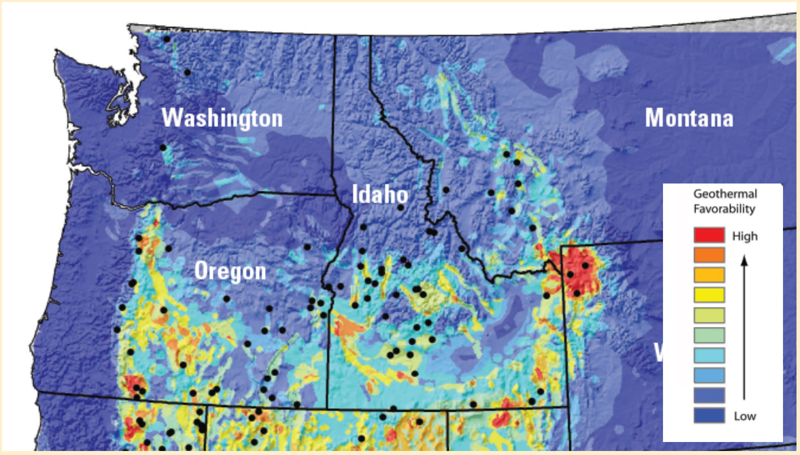
Energy resource options Early 2020s

Transmission cost & losses to point of LSE wholesale delivery
No federal investment or production tax credits
Baseload operation (CC, Nuc, SCPC 85%; IGCC, Bio - 80%)
Medium NG and coal price forecast (Draft 6th Plan)
Proposed Draft 6th Plan CO2 price.



10

USGS assessment of resource potential



Identified geothermal systems are represented by black dots.

Hydrothermal resource potential (MW)[1]

	Identified F95	Identified Mean	Identified F5	Undiscovered F95	Undiscovered Mean	Undiscovered F5
ID	81	333	760	427	1872	4937
MT	15	59	130	176	771	2033
OR	163	540	1107	432	1893	4991
WA	7	23	47	68	300	790
Totals	**266**	**955**	**2044**	**1103**	**4836**	**12751**

1) U.S. Geological Survey. Assessment of Moderate and High-Temperature Geothermal Resources of the United States. 2008.

Developable hydrothermal potential

2008 USGS assessment is most current available

Estimate is akin to theoretical potential

- Excludes inaccessible federal land (e.g., National Parks)
- Includes all other prospective resources

For planning purposes, developable potential:

- Mean Identified Resource + Mean Unidentified resource
- Low: 20% of F95 - 300 MW
- Expected: 20% of Mean – **1200 MW** (WGA near-term 1300 MW)
- High: 20% of F5 - 3000 MW
- MW = aMW in USGS report (assumed 100% capacity factor)

Historically slow rate of development may limit potential

- e.g., 40 MW/yr over period of plan - **800 MW**

Conclusions: Hydrothermal geothermal

Northwest hydrothermal potential

- Thought to be very large potential at one time
- Cascades volcanic resource less promising than previously thought
- Recent USGS assessment more optimistic for non-volcanic resources

First Northwest geothermal power plant in-service Jan 2008

- Raft River Phase I, 13 MW net
- 13 MW Phase II under contract; 13 MW Phase III proposed

Economics appear to be competitive w/ Columbia Basin wind and gas combined-cycle

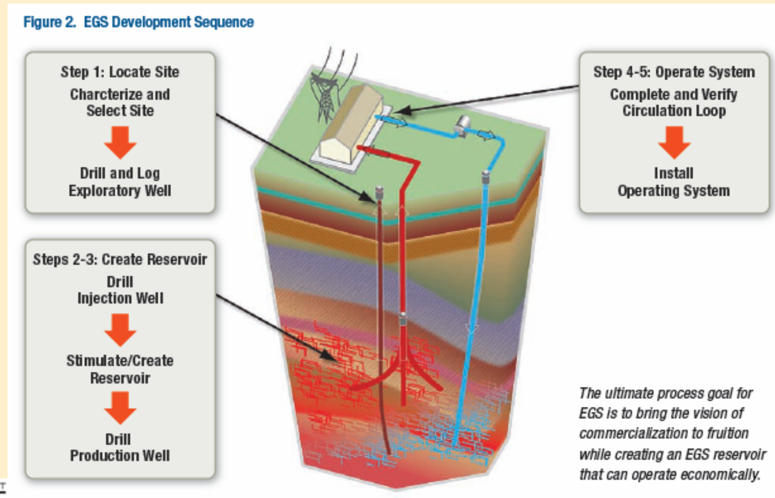
Very high initial investment risk

- High up-front exploration cost (~10% of total plant cost)
- High dry (or cold) hole risk (80%)

Closed-cycle binary technology is becoming technology of choice

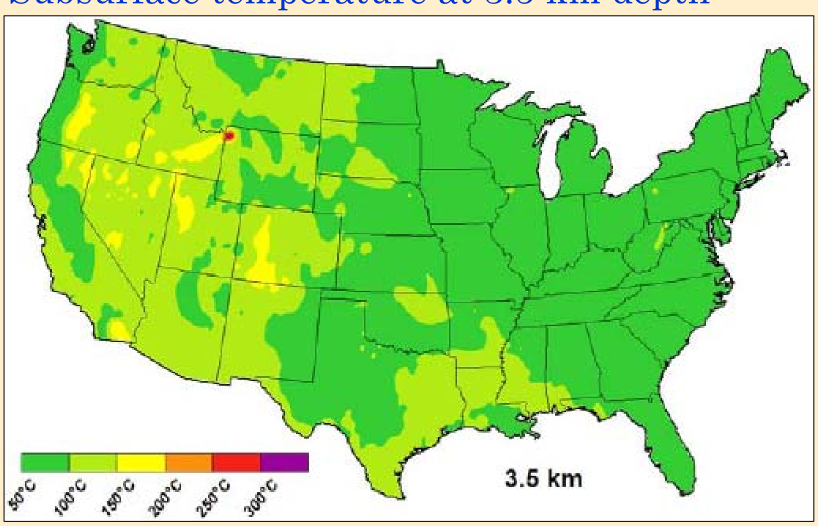
- Can utilize moderate-temperature resources
- Negligible releases of CO_2 or hazardous materials
- Base load energy production w/sustained peaking capacity value

Enhanced geothermal systems



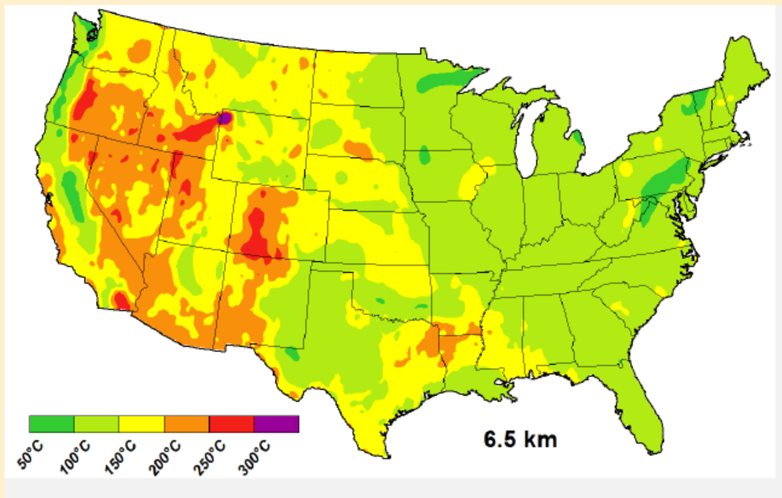
USDOE, Geothermal Tomorrow 2008

Subsurface temperature at 3.5 km depth[1]



1) 11,500 feet

Subsurface temperature at 6.5 km depth[1]

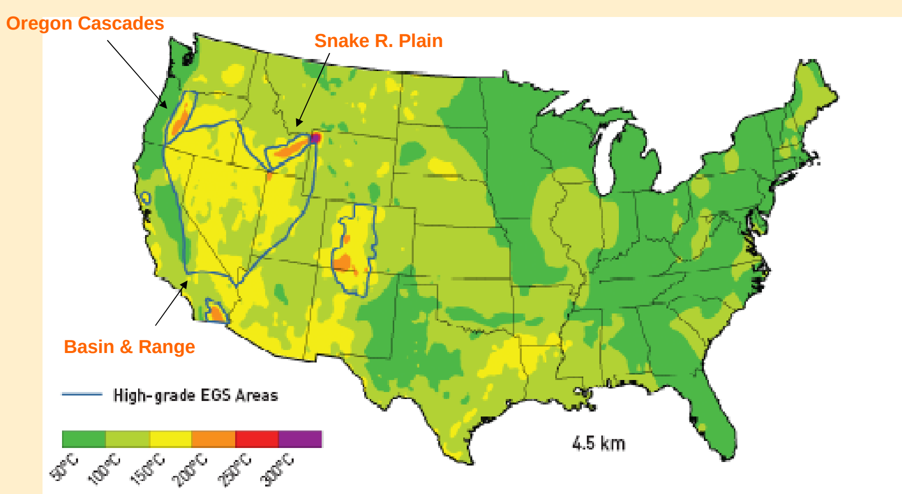


NORTHWEST 6th POWER PLAN

1) 21,330 feet

Northwest Power and Conservation Council

Areas of special EGS interest

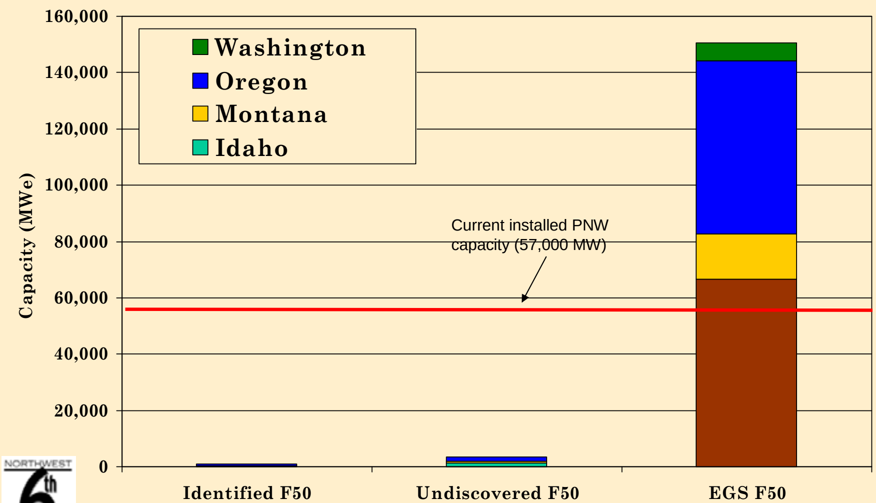


NORTHWEST 6th POWER PLAN

MIT. The Future of Geothermal Energy. 2004

Northwest Power and Conservation Council

USGS Provisional estimate of EGS potential



Needed for commercial EGS

- Methods for increasing production well flow rates
- Methods of characterizing the fractured volume
- Methods of repairing short-circuits
- Methods of understanding the role of existing faults in augmenting or impeding flow
- Robust instrumentation for hi-temp down-hole environment
- Methods of predicting scaling and deposition
- Validation of long-term viability of commercial-scale EGS at several sites

Conclusions re: EGS

EGS potential dwarfs that of other renewable resources

EGS potential is widespread

- Potentially far greater siting flexibility than other renewables
- More diffuse, may add to the cost and environmental impact of development

EGS remains commercially unproven

Commercial EGS is likely a decade or more in the future

- Numerous issues need to be resolved through R&D
- Commercial demonstration projects will require several years to be up and running
- Several years of operation likely to be needed to confirm the long-term viability of EGS reservoirs

EGS costs likely to be higher than conventional geothermal

- Deeper wells
- Cost of establishing and maintaining fracture system
- Hot, high pressure environment

NORTHWEST 6th POWER PLAN

21

Northwest Power and Conservation Council

Possible Sixth Plan action items

EGS pilot projects at areas of special interest unique to the Northwest

- Snake River plain
- Oregon Cascades

Participation in Basin & Range EGS pilot project

NORTHWEST 6th POWER PLAN

22

Northwest Power and Conservation Council