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January 7, 2008

MEMORANDUM

TO: Council Members

FROM: Jeff King, Senior Resource Analyst

SUBJECT: Review of generating resource options for the Sixth Power Plan

Over the past year, staff has been engaged in assessments of future generating resource options for the Northwest. Topics addressed include resource availability (in terms of both commercial status and quantity), technical performance, and capital and operating costs. Issues that might facilitate or constrain development of these resources have also been assessed. Assessments have been completed on the major commercially-available sources of generation including wind power from in-region and out-of-region sources, solar thermal and photovoltaic power plants from in-region and out-of-region sources, natural gas combined-cycle plants, gas turbine generators, reciprocating engine generators, steam-electric coal-fired power plants and advanced nuclear plants. Results of these assessments have been discussed with the Council's Generating Resources Advisory Committee and the Power Committee. Staff is now compiling quantitative data from this assessment for use in the Council's price forecasting, portfolio risk, and reliability models.

Staff will summarize the results of these assessments for the Council and will provide an initial sense of the potential role of these resources in the Northwest power system. Further understanding of the potential role of these resources will be gained as needs and risk assessment work proceeds. Remaining to be completed are assessments of coal gasification technology and of several commercially available but quantity-limited renewable resources including geothermal, woody biomass, biogas and hydro additions. The latter are characterized by limited data, diverse applications, and wide variation in cost. Also remaining to be assessed are resources which have not yet achieved full commercial availability, including wave and tidal current energy, offshore wind power suitable for Northwest sites, and carbon dioxide separation and sequestration facilities for fossil power plants.

Presentation materials will be provided prior to the meeting.

Sixth Northwest Conservation & Electric Power Plan

Future Generating Resource Options for the Pacific Northwest

Jeff King

Northwest Power and Conservation Council

Portland, OR January 13, 2008



"reliable and available within the time it is needed..."

* Commercial and near-commercial technologies.

Available*

Natural gas combined-cycle Natural gas gas turbine generators Natural gas reciprocating engines On-shore wind turbine generators Pulverized coal steam-electric Coal gasification-combined-cycle New hydropower Advanced light water reactors Solar photovoltaics Parabolic trough concentrating solar Solid biomass steam-electric Biogas generation Conventional geothermal Waste heat recovery cogen

Not yet available

CO2 separation and sequestration Engineered geothermal Wave energy Tidal current energy Deep water offshore wind Dedicated electric energy crops Solar power tower Solar Stirling dish Space power satellites Nuclear fusion



How much potential in context of likely Northwest needs (300 – 500 aMW/yr)?

Lots (thousands of aMW)

Coal Natural gas Wind Uranium Solar radiation Forest management residue>>?? Wave ??

Limited (tens to hundreds of aMW) << Geothermal?? Woody biomass (other than forest management residue) Hydropower •New •Upgrades **Biogas** •Landfill •Wastewater treatment •Animal waste Tidal current Waste heat recovery cogen



High technical potential generating resources





Applications

Energy production

- **Dispatchable** can be turned on, up, down or off as needed.
- Variable (a.k.a intermittent) produces energy as the resource is available
- **Cogeneration** (CHP) coproduction of electricity and useful thermal energy
- **Polygeneration** coproduction of electricity and chemical fuels

Capacity

- **Peaking capacity** available to meet seasonal or daily peak loads
- **Flexible capacity** "rapid-response (sub-hourly)" capacity for regulation, and following load, wind and other variable energy resources.
- **Storage capacity** Consumes energy, but can provide peaking and/or flexible capacity, multiday energy shifting.



Generating technology applications

	Energy	Variable Energy	Cogen- eration	Flexible Capacity	Peaking Capacity
Natural gas	CC		GT, IC, CC	GT, IC, CC	GT, IC, CC
Coal	PC, IGCC				PC, IG, CC
Wind		WTG			
Nuclear	LWR				LWR
Solar	CSP, PV	CSP, PV			CSP
Biomass	ST, BG		ST, BG		ST, BG
Hydro	RoR, Res			Res	RoR, Res
Geothermal					
Hydrokinetic		Wave, Tidal Current			
Storage	- aMW	- aMW		Х	Х



Primer on power plant costs

Capital: Cost of project development, construction and financing (\$/kW)

- **Fixed Operations & Maintenance (O&M):** Non-fuel operating costs incurred whether or not the plant is dispatched (e.g., overhead, labor, property taxes, insurance, maintenance) (\$/kW/yr)
- Variable O&M: Non-fuel operating costs incurred in proportion to energy production (e.g., water, lube oil, royalties) (\$/MWh)
- **Fixed Fuel:** Fixed cost of fuel supply (e.g., gas pipeline capacity, railcars) (\$/kW/yr)
- Variable Fuel: Fuel commodity cost (\$/MMBtu)
- Emissions: Cost of emission allowances (e.g., NOx, SOx, CO2) (\$/ton > \$/MWh)
- System Integration: Regulation and load-following services required to integrate wind and other variable output resources (\$/MWh)
- **Transmission & Losses:** Transmission services (except integration) + value of losses incurred between plant and point of delivery (\$/kW/yr)



Cost elements: Energy production





Cost elements: Capacity





Resource options Early 2020s

Transmission cost & losses to point of LSE wholesale delivery No federal investment or production tax credits Baseload operation (CC - 85%CF, Nuc 85% CF, SCPC 85%) Medium NG and coal price forecast (Proposed 6th Plan) Bingaman/Specter safety valve CO2 cost



Risk and Uncertainty

Expected costs are only part of the story

Generating resources are subject to important risk & uncertainty

- Fuel price uncertainty
- CO2 allowance cost/carbon tax
- Investment risk

These and others are assessed in the portfolio risk modeling but a look at the implications of the first two follows



Resource options, early 2020s: Doubling of fuel commodity prices



Resource options, early 2020s: \$45/ton CO2 cost



Additional resource assessment work

Refined assessment of flexible capacity resources

- Where lies the top end of integration cost curve?
- Woody biomass

A potentially big source - commercial forest management mechanical thinning residue Geothermal costs

Coal gasification costs

CO2 separation & sequestration prospects & costs

- New & retrofit
- Wind remote resource development vs. local build-out
 - Transmission/capacity factor/system integration

Overview of potential resources

- Offshore wind
- Engineered geothermal
- Wave, tidal current, other hydrokinetic

