Assessment of Natural Gas Single Cycle Turbine, Reciprocating Engines, and Wind Resources for Draft Seventh Plan

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Power Committee (Webinar)

Purpose of Today's Webinar

- Communicate results from the work Council staff (with aid from the GRAC) has been doing recently around two key supply-side resource technologies
  1. Natural Gas Peakers (Single Cycle Turbines and Reciprocating Engines)
  2. On-shore, Utility-scale Wind
- This includes cost and performance estimates, along with definition of new resource reference plants for use in the Regional Portfolio Model

Reminder: Reviewed with P4 for Input in RPM for Draft 7th Plan

- ✓ Utility-scale Solar PV
- ✓ Natural Gas - Combined Cycle Combustion Turbines
- ❑ Utility-scale Wind
- ❑ Natural Gas – Peakers (Single Cycle Turbines and Reciprocating Engines)
- ❑ RPS Analysis for input to RPM

GRAC Meetings To Date

GRAC Meeting	Solar PV	CCCT	Gas Peakers	Wind	Hydro Scoping	Offshore Wind	Storage	SMR	EGS
1) Jun 20 2013	1								
2) Oct 16 2013	2	1			1				
3) Feb 27 2014		2	1						
4) May 28 2014	3	3	2	1	2	1			
5) Oct 2 2014			3	2	3				
6) Nov 7 2014	4								
7) Nov 21 2014					4				
8) Dec 18 2014			4	3			1		
9) Jan 27 2015							2	1	1

SMR = Small Modular Reactors, EGS = Enhanced Geothermal (as opposed to conventional geothermal)

Reference Plant Basics

- Potential technology and configuration
- Likely location
- Capacity (MW)
- Normalized overnight capital cost ($/kW)
- O&M costs fixed ($/kW-yr) and variable ($/MWh)
- Levelized cost fixed ($/kW-yr) and full ($/MWh)– annualized cost of capital and operation across the lifecycle
- Heat rate if applicable
- Note: all $ in 2012 dollars

Reference Plants, Cost Estimates

NATURAL GAS SINGLE CYCLE AND RECIPROCATING ENGINES

4 Key Points for Gas Peakers

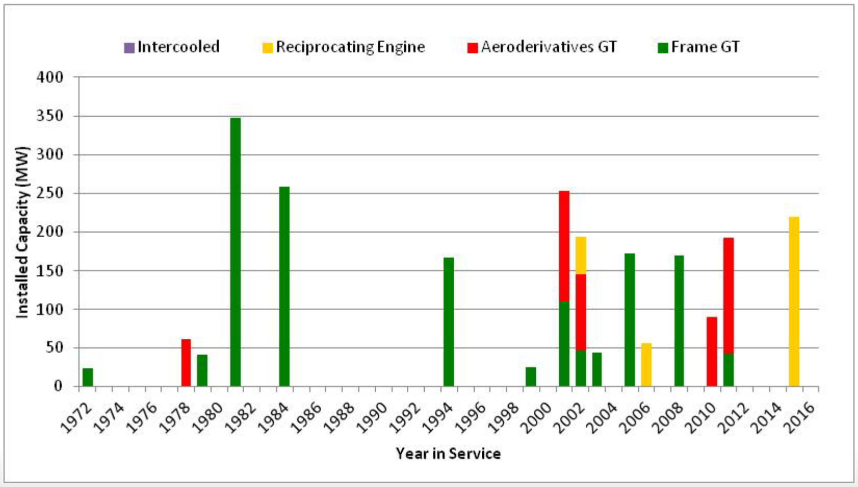
1. Technology	Mature technology, with continued improvements and adaptations resulting in greater efficiency and performance – resulting in better use of natural gas and more flexibility
2. In the Northwest	Increasing presence in the region. Primary use has changed over the last several decades, but may provide valuable integration for regional variable energy resource generation. Plentiful natural gas supply from diverse sources and robust gas infrastructure.
3. Cost and Uncertainty	Stable capital cost estimates, but the levelized cost over 20 year planning horizon is uncertain – depends on future natural gas supply, price
4. Emissions	Emits CO_2 when generating, and related methane emissions from natural gas production and transportation - but are within proposed EPA regulations for CO_2 emissions from new plants

Peaking Power Plant Characteristics

Draft 7th Power Plan Reference Plants ($2012)

Unit Size (MW)	Capital Cost ($/kW)	Heat Rate (Btu/kWh)	Ramp Rate (Minutes)
Biggest	Most expensive	Least Efficient	Slowest
Frame 1x216	Recip 1,300	Frame SCCT 9801	Frame SCCT >10
Intercooled 2x100	Aero SCCT 1,100	Aero SCCT 9048	Intercooled <10
Aero SCCT 4x47	Intercooled 1,000	Intercooled 8541	Aero SCCT <10
Recip 12x18	Frame SCCT 800	Recip 8370	Recip <10
Smallest	Least Expensive	Most Efficient	Fastest

Historical Peaking Plant Additions in the Region (MW)



Note: There are currently no intercooled/aero hybrid plants in the PNW

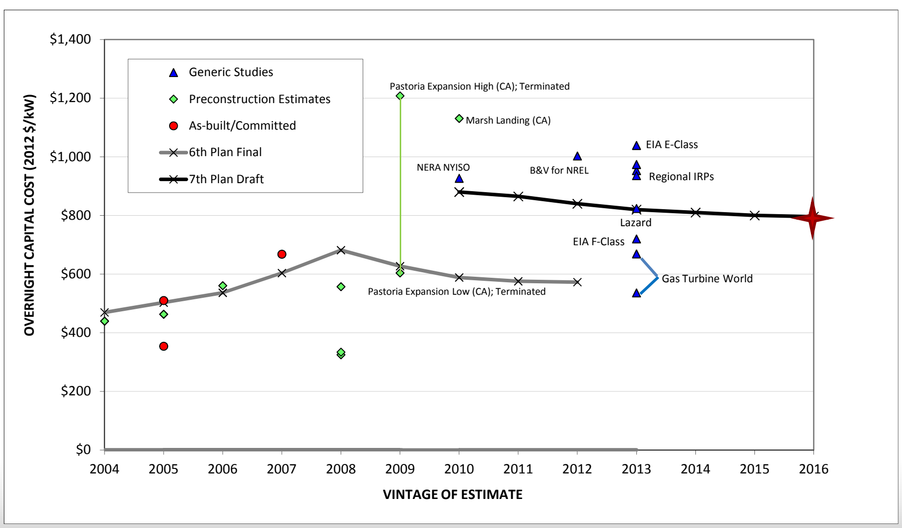
Discussion Points at GRAC

- Which technologies should be represented in the RPM?
  - Very similar costs and attributes, RPM won't be able to differentiate between operating characteristics, like ramp rates
  - Modeling too many resources in the RPM increases run time
  - Choose one or two and view them as a proxy for any of the peaking technologies?

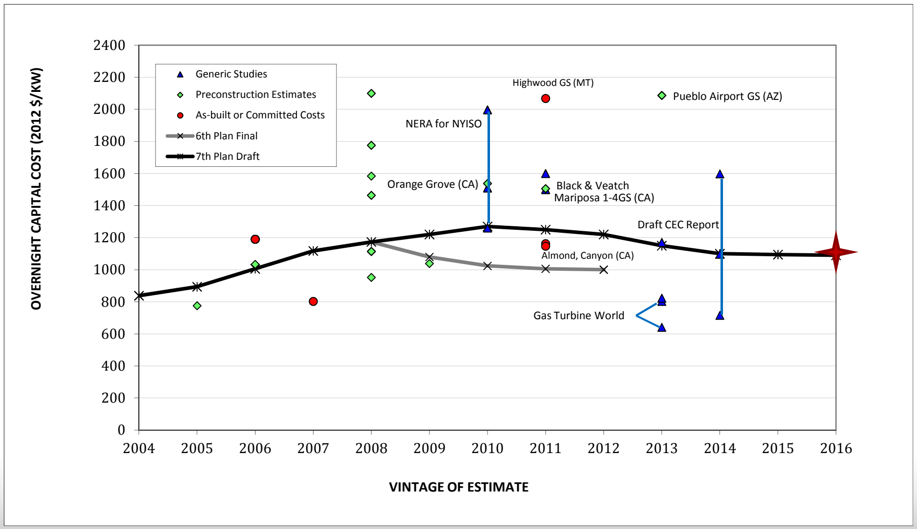
Reference Plants

	Frame GE 7F 5-Series (1) X 216 MW	Aero GE LM6000 PF SP (4) X 47 MW	Intercooled GE LMS100 PB (2) X 100 MW	Recip Engine Wärtsilä (12) X 18 MW
Location	PNW West	PNW West	PNW West	PNW West
Earliest In –Service	2018	2018	2018	2018
Development time (yrs) (siting, licensing, construction)	2.75	2.75	2.75	2.75
Economic Life Years	30	30	30	30
Capacity MW	216	190	200	220
Capital Cost $/kW	$800	$1,100	$1,000	$1,300
Fuel	Natural Gas	Natural Gas	Natural Gas	Natural Gas
Heat Rate btu/kWh	9801	9048	8541	8370
Capacity Factor % (for presentation purposes)	25	25	25	25
Inv. Tax Credit	-	-	-	-
O&M Fixed ($/kW-yr), Variable ($/MWh)	$7.00, $10.00	$25.00, $5.00	$11.00, $7.00	$10.00, $9.00

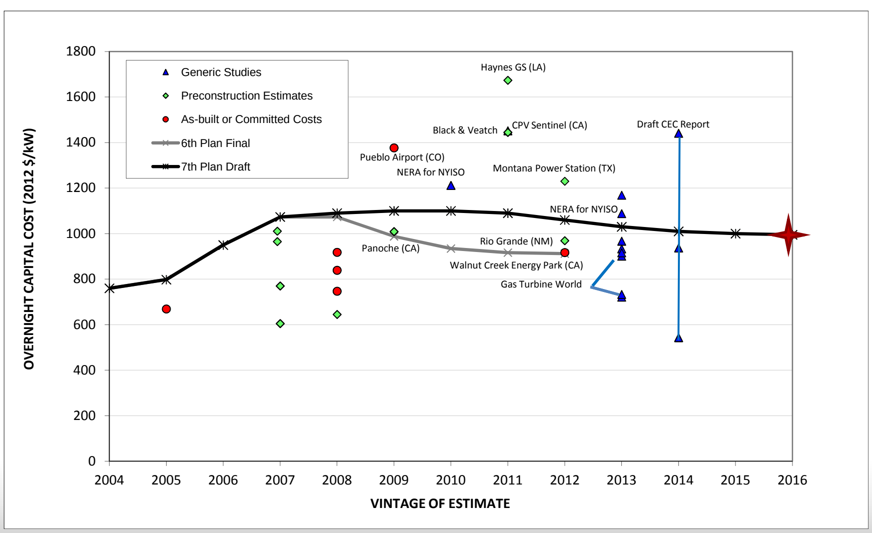
Preliminary Draft 7P Capital Cost Estimate for Frame GT

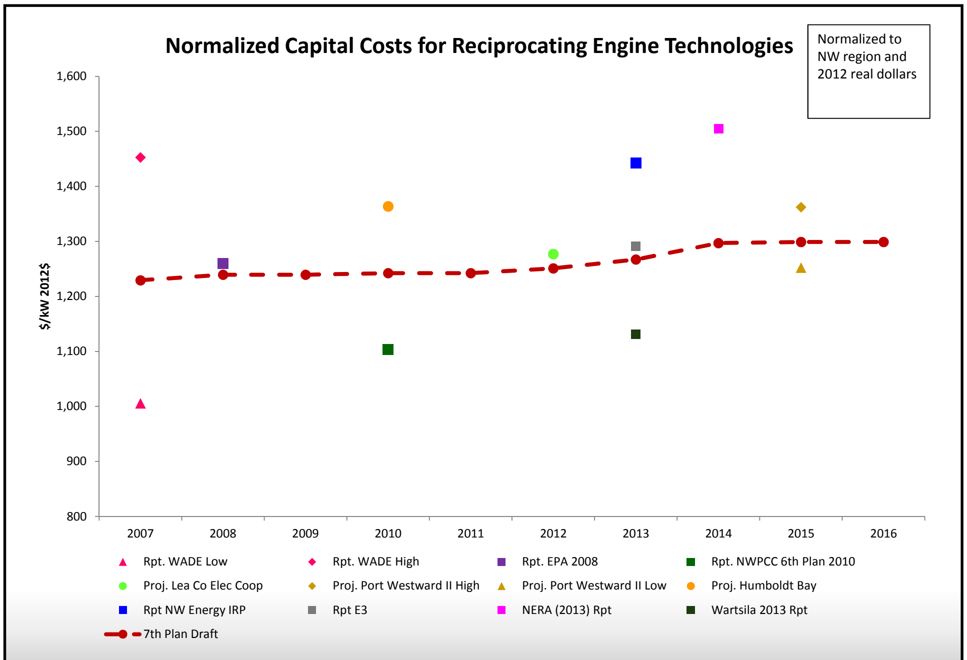


Preliminary Draft 7P Capital Cost Estimate for Aeroderivative GT

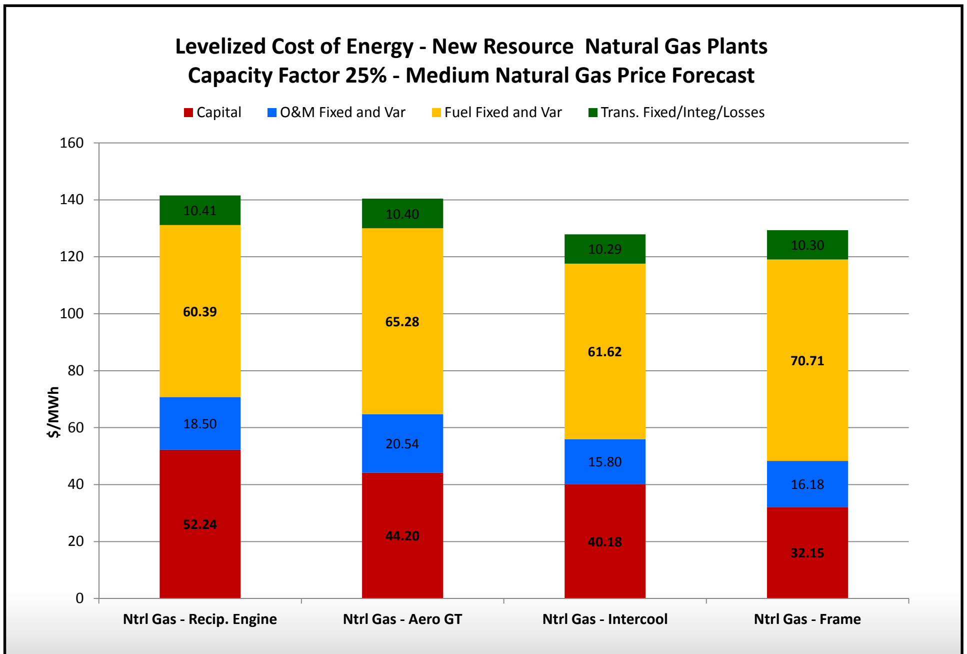


Preliminary Draft 7P Capital Cost Estimate for Intercooled GT

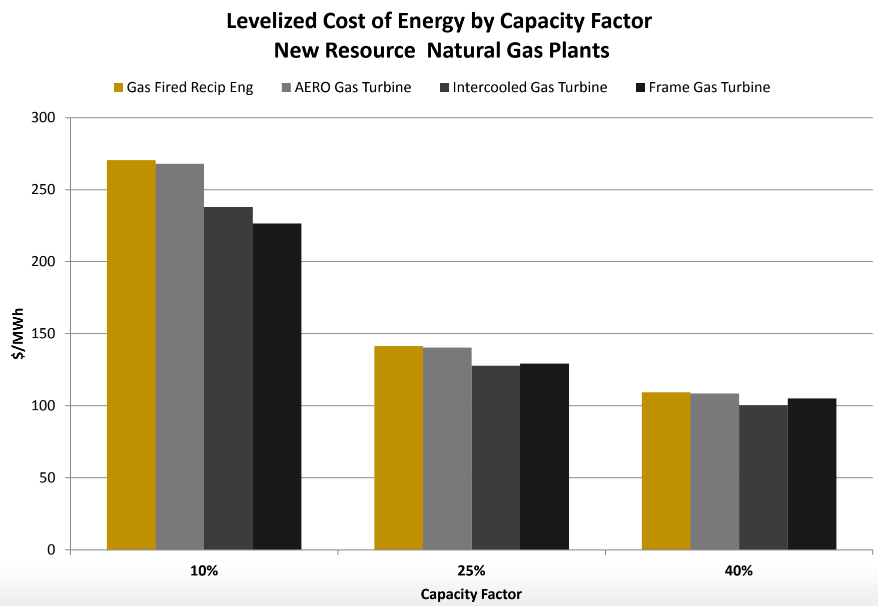




Northwest Power and Conservation Council 15 SEVENTH NORTHWEST POWER PLAN



Northwest Power and Conservation Council 16 SEVENTH NORTHWEST POWER PLAN



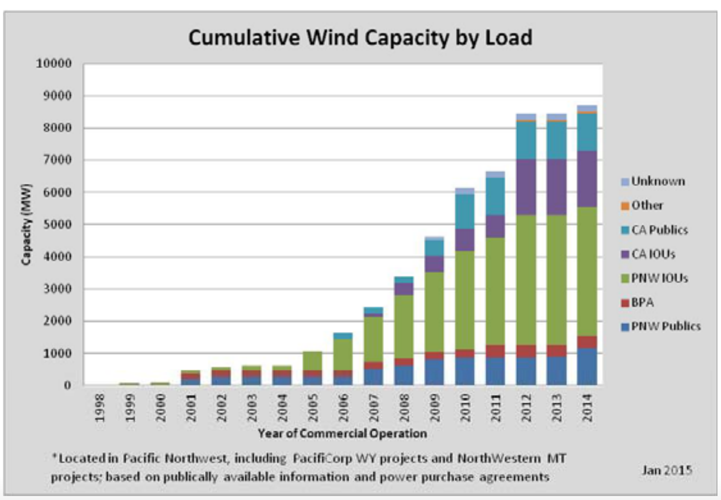
Reference Plants, Cost Estimates

UTILITY-SCALE WIND

4 Key Points for Wind

1. Technology	Mature technology, with continued improvements in efficiency and performance – resulting in higher capacity factors and ability to capture more wind in less desirable wind resource areas
2. In the Northwest	Significant presence in the region. Since 2000, about 7,500 MW wind capacity installed in the Pacific Northwest. Additional ~1,000 MW in Wyoming (PacifiCorp projects) serving PNW load.
3. Cost and Uncertainty	Slightly decreasing capital cost estimates since peak in 2009/10
4. Emissions	Does not emit CO_2

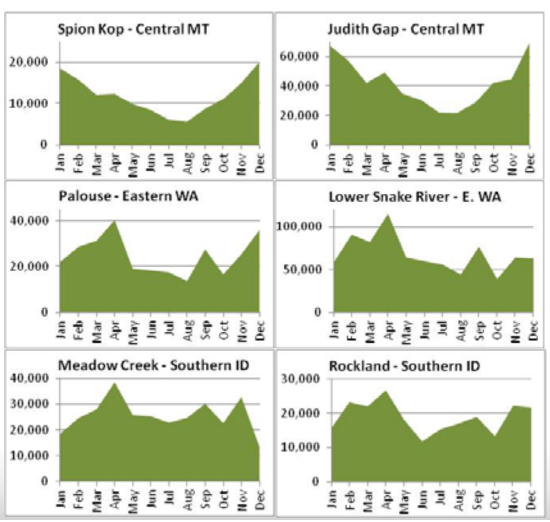
Wind Development in the PNW



Discussion Points at GRAC

- Capacity factors
  - Improving technologies are capturing more energy.
  - How does it effect assumed future capacity factors?
- Role of Montana wind to serve Western load centers
  - Transmission – existing and potential new upgrades/builds
  - Winter-peaking resource matches up closer with demand

Comparison of Regional 2013 Generation Shapes (MWh)

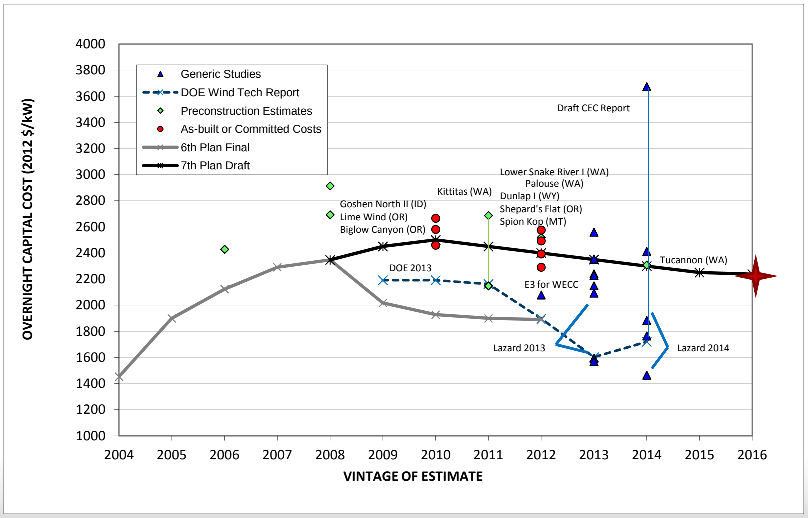


Central MT – Peak in Dec/Jan
Capacity Factor – 40% (6P = 38%)

Columbia Basin – Peak in Mar/April, Sept/Oct
Capacity Factor – 32% (6P = 32%)

Southern ID – Peak in Mar/April, Sept/Oct
Capacity Factor – 32% (6P = 30%)

Preliminary Capital Cost of Wind



Financial Incentives

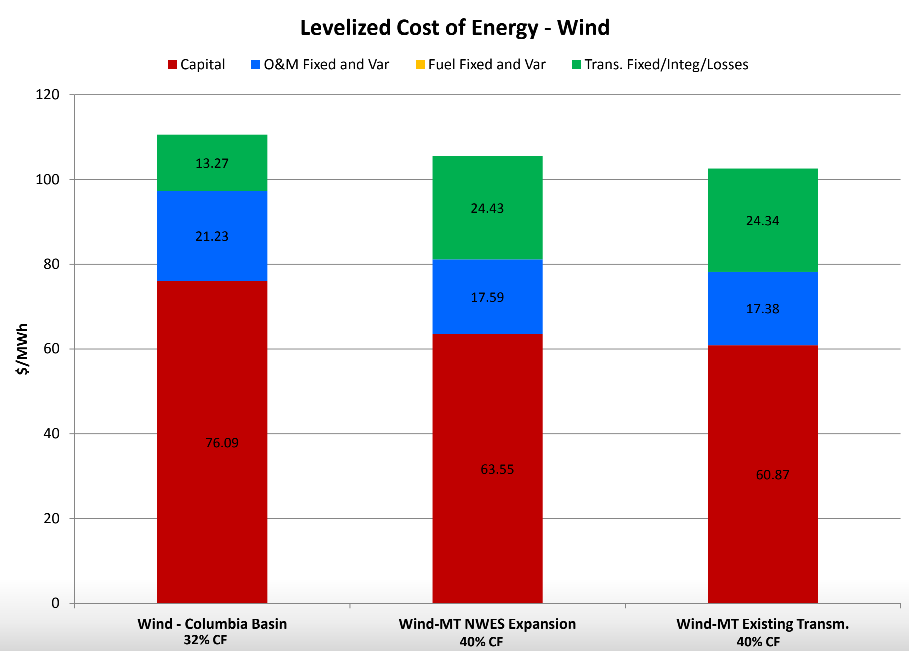
- Production Tax Credit (PTC) expired in 2013, was renewed by Congress in December through 2014
  - Projects that began construction before end of 2014 eligible
  - Extension doesn't do much for wind development – too late and not long enough (there was a possibility of extending through 2015)
- Investment Tax Credit (ITC)
  - Ability to take 30% ITC in lieu of PTC now expired

Draft Seventh Plan Proposal:

- No financial incentives included in levelized costs for wind power

Reference Plants

	On-Shore Wind (40) X 2.5 MW	On-Shore Wind (40) X 2.5 MW
Location	Columbia Gorge	Central Montana, delivered to BPA system
Earliest In –Service	2019	2019
Development time (yrs) (siting, licensing, construction)	4	4
Economic Life Years	25	25
Capacity MW	100	100
Capital Cost $/kW	$2,240	$2,240
Fuel	--	--
Heat Rate btu/kWh	--	--
Max Capacity Factor %	**32%**	**40%**
Inv. Tax Credit/ Production Tax Credit	--	--
O&M Fixed ($/kW-yr), Variable ($/MWh)	$35.00, $2.00	$35.00, $2.00



What's Coming Next

- Feb Power Committee & March Council Meetings –
  - Draft Seventh Plan generating characteristics for use in the Regional Portfolio Model
  - Solar PV, CCCT, SCCT, Recips, Wind
- Feb or March Power Committee (tbd)
  - Regional RPS analysis

BACK-UP SLIDES

Properties of Peaking Technologies

Frame (80MW – 250 MW units)	Aeroderivative (15 – 60 MW units)
• Stationary device, weight not an issue • Strengths - longevity and durability • Weaknesses – slower response time; higher heat rate; higher exhaust temperatures/difficult air quality control • Typical use – on for several days, then shut down • PNW – several frame units built in 1970's – 1990's for hydro back-up (firming)	• Designed from aircraft engine; lighter, more delicate than frame • Strengths – rapid response time; lower heat rate than frame; easy maintenance; smaller unit size • Typical use – meeting short-term peak loads and variable resource integration • PNW – several Pratt and Whitney and a few LM6000 plants
Intercooled (100 MW units)	**Reciprocating Engine (2 - 20 MW units)**
• Hybrid of frame and aeroderivative – intercooled equipment required • Strengths – rapid response; lowest GT heat rate. Especially useful in summer peaking • Weaknesses - requires continuous source of cooling water • Typical use –short-term peak loads and variable resource integration • PNW – none currently planned or in operation; numerous in WECC, esp. California	• Largest gas engines in world – 4 stroke • Strengths – highly modular; very rapid response, low heat rate, duel fuel capability, not sensitive to temps and elevation • Typical use – short-term peak loads and variable resource integration • PNW – PGE built first large plant in region (Port Westward II); several smaller units in operation • Note: aside from NG peaking, used for small biogas and cogen applications, back-up gen

Categorization of Resources for the Draft Seventh Power Plan (1)

Prioritization based on a resource's commercial availability, constructability, cost-effectiveness, and quantity of developable resource.

Primary; Significant: Resources that look to play a major role in the future PNW power system
Assessment : In-depth, quantitative characterization to support system integration and risk analysis modeling. Will be modeled in RPM

Secondary; Commercial w/ Limited Availability: Resources that are fully commercial but that don't have a lot of developmental potential in the PNW
Assessment : Quantitative characterization sufficient to estimate levelized costs. Will *not* be modeled in RPM.

Long-term Potential: Resources that have long term potential in the PNW but may not be commercially available yet
Assessment: Qualitative discussion of status & PNW potential, quantify key numbers as available. Will *not* be modeled in RPM.

Categorization of Resources for the Draft Seventh Power Plan (2)

Primary; Significant	Secondary; Commercial w/ Limited Availability	Long-Term Potential
Natural Gas Combined Cycle	Biogas Technologies (landfill, wastewater treatment, animal waste, etc.)	Engineered Geothermal
Wind	Biomass - Woody residues	Offshore Wind
Solar PV	Conventional hydrothermal Geothermal	Modular Nuclear Units
Natural Gas Simple Cycle, Reciprocating Engine	New Hydropower	Wave Energy
	Hydropower Upgrades	Tidal Energy
	Waste heat recovery and CHP	Coal Technologies w/ CO_2 Separation
	Storage Technologies*	CO_2 Sequestration
		Storage Technologies*

* Various storage technologies may fall under different categories

Northwest Power and Conservation Council

SEVENTH NORTHWEST POWER PLAN