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

February 3, 2015

MEMORANDUM

TO: **Power Committee**

FROM: **Gillian Charles, Energy Policy Analyst**
Steve Simmons, Energy Analyst

SUBJECT: **Draft Seventh Plan Generating Resource Characteristics for use in the Regional Portfolio Model**

BACKGROUND:

Presenter: Gillian Charles and Steve Simmons

Summary: Staff will present a high level summary of the proposed draft Seventh Plan generating resource characteristics that will be inputs to the modeling analysis performed in the Regional Portfolio Model (RPM). These resources include: natural gas combined cycle combustion turbines, natural gas single cycle combustion turbines, reciprocating engines, utility-scale solar photovoltaic, and utility-scale on-shore wind. In addition to presenting the resource reference plants and cost estimates, staff will also compare the draft assumptions with the final assumptions used in the Sixth Power Plan.

Relevance: Staff anticipates that it will begin conducting scenario analysis using the updated RPM in mid-March. Draft generating resource characteristics are being presented to the Power Committee in February. Committee member feedback and comments will be incorporated into a revised set of characteristics to be presented to the full Council in March for acceptance to use as the generating resource assumptions in the RPM analysis for the draft Seventh plan.

Work plan: 1.D. Prepare for Seventh Power Plan and maintain analytical capability – generating resource characterization

Background: Staff previously presented generating resource characteristics information during detailed Power Committee webinars on November 18th and January 29th. The Council's Generating Resources Advisory Committee (GRAC) has also reviewed and vetted over multiple meetings the assumptions being proposed.

More Info: For detailed information on the work that has been presented to the GRAC, see the GRAC past meetings webpage - http://www.nwcouncil.org/energy/grac/meetings/. In addition, the presentation materials from the previous Power Committee webinars are available on the Council website - http://www.nwcouncil.org/news/meetings/.

Draft Seventh Plan Generating Resource Characteristics for use in Regional Portfolio Model

Gillian Charles, Steve Simmons

2/10/15

Power Committee

Purpose of Today's Presentation

- High level summary of proposed draft Seventh Plan generating resource characteristics*
  - Technology overviews
  - Reference plants and cost assumptions
  - Comparison to final Sixth Plan assumptions – what changed and why?
- Looking for P4 consensus to present to full Council in March → input to RPM for draft plan analysis

*These characteristics were previously presented at Power Committee webinars and reviewed at multiple Generating Resource Advisory Committee meetings.

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

November 18, 2014 - P4 Webinar
- ✓ Utility-scale Solar PV
- ✓ Natural Gas - Combined Cycle Combustion Turbines

January 29, 2015 – P4 Webinar
- ✓ Utility-scale Wind
- ✓ Natural Gas – Peakers (Single Cycle Turbines and Reciprocating Engines)

March 2015 – P4
- ❑ 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)

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 **Power Plan Narratives**
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
RPM Input Resources	Storage Technologies*	CO_2 Sequestration
	Power Plan Narratives	Storage Technologies*

* Various storage technologies may fall under different categories

Photo credit: Kiewit

Reference Plant

COMBINED CYCLE COMBUSTION TURBINE

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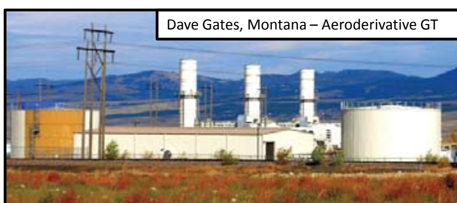
SEVENTH NORTHWEST POWER PLAN

Overview of Technology

Description of Technology: Combined Cycle Combustion Turbine - consists of one or more gas turbine generators combined with one or more heat recovery steam generators (HRSG). ▪ Extremely efficient for baseload power, becoming more flexible, lowest CO_2 emitting of fossil-fuel based generators ▪ Can be augmented with duct firing – boosts power output as needed at the expense of a higher heat rate ▪ Wet or dry cooling configurations: For sites with water constraints, dry cooling configuration results in significantly less water usage but with higher capital costs ▪ Emits CO_2 – but within proposed EPA regulations for new plants. Also related methane emissions from natural gas production and transportation.
Importance/Relevance to PNW: Plays a significant role in the region as a dispatchable baseload power source. The technology benefits from a robust natural gas infrastructure in the region which can tap a diverse set of supply sources from both the US and Canada (BC, Alberta)
Main GRAC issues: Discussion included ▪ Expected plant size consistent a 1x1 configuration (1 gas-turbine coupled with 1 HRSG) ▪ Requested configurations for both Wet-Cooled, and Dry-Cooled
Role in future power system: provide efficient baseload power along with some flexibility
Changes since Sixth Plan analysis: Slightly higher capital and O&M cost in Seventh Plan, but with improved technology and efficiency

Reference Plant(s)

	CCCT 1	CCCT 2
Location	PNW East	PNW East
Capacity (MW)	**370** (390)	425
Economic Life (years)	30	30
Earliest In –Service	2018	2020
Development time (years)	5	5
Capital Cost ($/kW) In-service year 2016	**1,147** (1,046)	1,287
Fuel	Natural Gas – East	Natural Gas – East
Heat Rate (btu/kWh)	**6,770** (6,930)	6,704
Capacity Factor % (for presentation purposes)	60	60
Inv. /Prod. Tax Credit	-	-
O&M Fixed ($/kW-yr), Variable ($/MWh)	**$15.37, $3.27** **$14.00, $1.70**	15.37/3.27


Dave Gates, Montana – Aeroderivative GT
Photo credit: PowerMag.com


Danskin, Idaho – Frame GT
Photo credit: Tim Bondy


Port Westward II – Recip
Photo credit: PGE flickr


Port Westward II – Recip
Photo credit: PGE flickr

Reference Plants

GAS PEAKERS – SINGLE CYCLE AND RECIPROCATING ENGINES

Overview of Technology

Description of Technology:

- Single Cycle – One or more combustion gas turbines driving an electric generator. Compact, modular plants used for meeting short-duration peak loads. Rapid response start-up and load following capability.
- Reciprocating Engine – One or more compression spark or spark-ignition reciprocating engine generators driving an electric generator. Very modular. Used for emergency back-up and isolated systems; more recently for peaking and load following services.

Importance/Relevance to PNW: Historically used for hydro shaping; now with continued improvements in technology resulting in more flexible and efficient equipment, primary role changing towards variable energy integration, contribution to peak load

Main GRAC issues: Main discussion focused on which technologies to include in the Council's RPM analysis. Proposal was to consider whatever technology is selected by the model as a "proxy" for any of the others.

Role in future power system: With increased variable energy resources (wind, solar) on the system, role of gas peakers to help with integration is becoming increasingly important.

Changes since Sixth Plan analysis: The recovery from the 2008 recession did not occur as quickly as forecast, so instead of costs decreasing, they continued to increase until about 2010 and are not decreasing as fast as forecast. Seems to be a shift in WECC towards aeros, intercooled, and recips, and not much development of frame units.

Reference Plant(s)

	Frame GE 7F 5-Series 1 X 216 MW	Aero GE LM6000 PF 4 X 47 MW	Intercooled GE LMS 100 PB 2 X 100 MW	Recip Engine Wärtsilä 12 X 18 MW
Location	PNW West	PNW West	PNW West	PNW West
Capacity (MW)	**216** (85)	**190** (92)	**200** (100)	**220**
Economic Life (years)	30	30	30	30
Earliest In –Service	2018	2018	2018	2018
Development time (years)	2.75	2.75	2.75	2.75
Capital Cost ($/kW) In-service year 2016	**$800** ($561)	**$1,100** ($980)	**$1,000** ($1,052)	**$1,300** ($1,082)
Fuel	Natural gas	Natural gas	Natural gas	Natural gas
Heat Rate (btu/kWh)	**9801** (11960)	**9048** (9370)	**8541** (8870)	**8370** (8850)
Capacity Factor % (for presentation purposes)	25%	25%	25%	25%
Inv. Tax Credit	--	--	--	--
O&M Fixed ($/kW-yr), Variable ($/MWh)	**$7.00, $10.00** ($12.30, $1.20)	**$25.00, $5.00** ($14.50, $4.50)	**$11.00, $7.00** ($9.00, $5.60)	**$10.00, $9.00** ($14.50, $11.20)

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All costs represented in 2012 $

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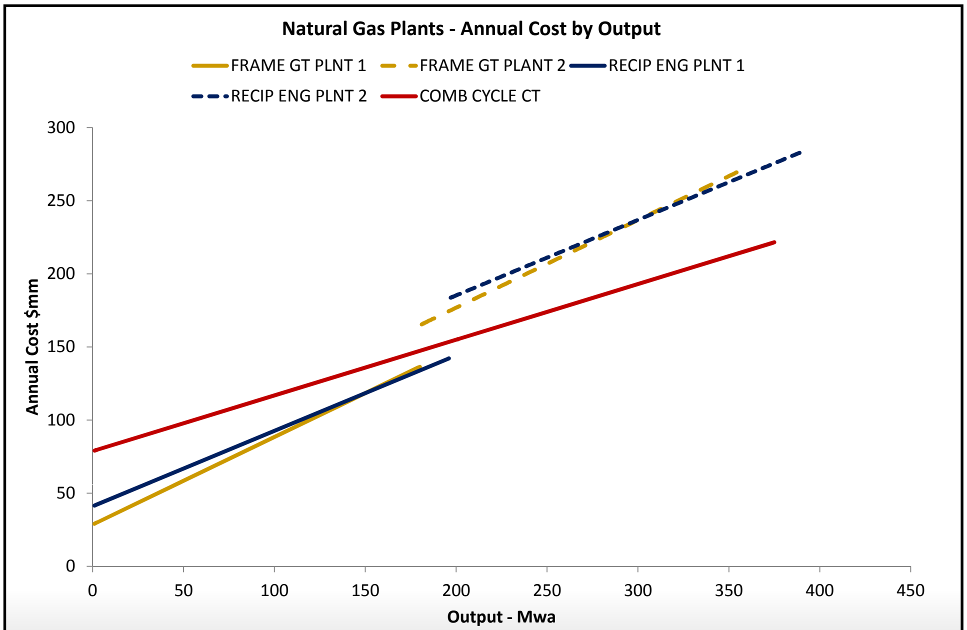
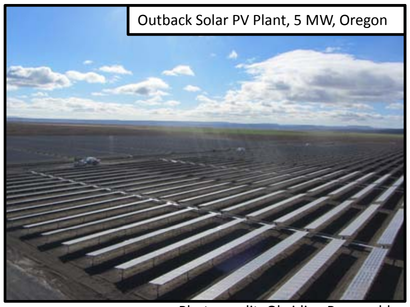
Black = Draft 7th Plan Assumption
Red = Final 6th Plan Assumption

SEVENTH NORTHWEST POWER PLAN

Discussion

- Which resource(s) to include in RPM analysis?
  - Can one be considered a proxy for all?
- If purpose/use of resource trumps cost (in the case of gas peakers), does it matter which one we select?





Outback Solar PV Plant, 5 MW, Oregon

Photo credit: Obsidian Renewables

Copper Mountain Solar facility, 48 MW, Arizona

Photo credit: Sempra Energy

Sandhill Solar Farm, 19 MW, Colorado

Photo credit: Solar Professional

Reference Plants

UTILITY-SCALE SOLAR PV

Overview of Technology

Description of Technology: Solar PV systems convert sunlight directly into electricity. These systems are comprised of 3 primary components:

1) PV Modules: typically silicon based, or thin film materials
2) Power Electronics: including DC to AC inverters, and control electronics
3) Balance of System: including foundations, mounts - fixed or tracking systems, land permitting

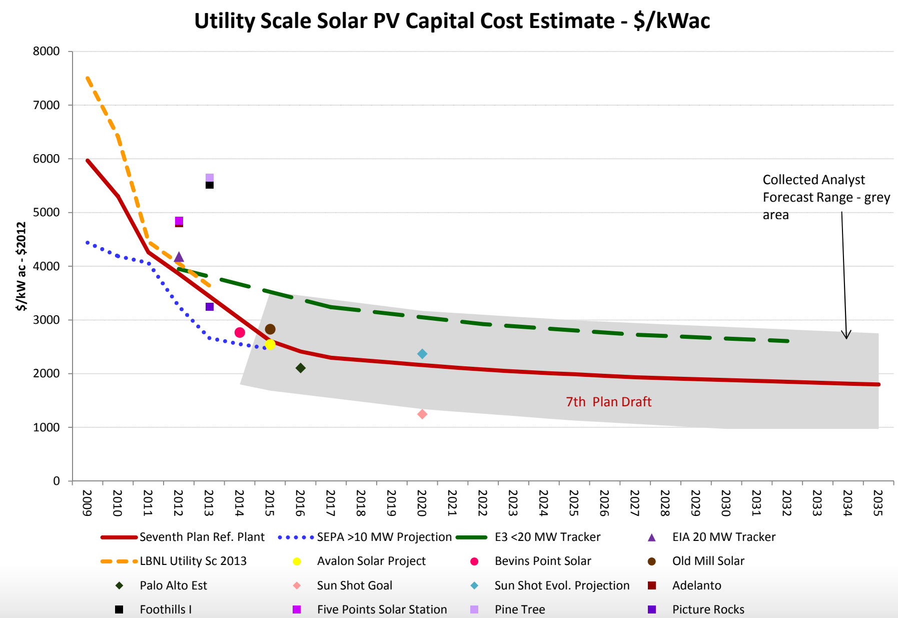
Rapidly evolving technology – improving in both efficiency and cost

Importance/Relevance to PNW: Although there is a limited presence in the region, activity has recently picked up in Southern Idaho – which is probably the best solar resource region for the Northwest.

Main GRAC issues: Much discussion over the declining solar costs. Several iterations of capital cost forecasts for the next 20 years. Also important and unique financing arrangements in order to best capture value of the ITC.

Role in future power system: Non-dispatchable variable resource – output varies seasonally. If costs continue to decline, could become important renewable resource in the region

Changes since Sixth Plan analysis: Significant improvements in technology and cost – have resulted in solar PV being an input to the RPM model for Seventh Plan.



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SEVENTH NORTHWEST POWER PLAN

Reference Plant(s)

	Solar PV Utility Scale
Location	S. ID
Capacity (MW)	**20 (20)**
Economic Life (years)	30
Earliest In –Service	2016
Development time (years)	3
Capital Cost ($/kWac) In-service year 2016	**2,413 (5,919)**
Fuel	-
Heat Rate (btu/kWh)	-
Capacity Factor % (for presentation purposes)	26.2
Inv. /Prod. Tax Credit	ITC 30%/10%
O&M Fixed ($/kW-yr), Variable ($/MWh)	**$16.63 ($36.00)**

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All costs represented in 2012 $

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Black = Draft 7th Plan Assumption
Red = Final 6th Plan Assumption

SEVENTH NORTHWEST POWER PLAN


Tucannon River Wind Farm, 267 MW, 2014

Photo credit: PGE flickr

Reference Plant

ONSHORE-WIND

Overview of Technology

Description of Technology: Wind turbine blades are propelled by air flow, which causes the shaft to spin the rotor, which in turn spins the generator to create electricity.

Importance/Relevance to PNW: Wind has played a significant role in the region over the past decade. With the Renewable Portfolio Standards (RPS) enacted by OR, WA, MT and others in WECC spurring development in the PNW, the region has installed ~7,500 MW capacity since 2000 (~8,500 MW when PAC WY projects are included).

Main GRAC issues:

- Capacity factors – With improvements in technology increasing the capacity factors of wind projects, how will the Council account for this? Proposal – institute a capacity factor improvement curve in the RPM, similar to the treatment of increased thermal efficiencies
- Montana wind – MT is a high wind resource potential state, and the generation shape is winter peaking (as opposed to spring/fall peaks in the Col. Gorge). Upgrading/building transmission to get the wind to western load centers has been a central discussion.

Role in future power system: There has been a significant lull in wind development since the boom in 2012 (when ~2,000 MW were developed) due in part to uncertainty over Federal tax incentives, but more likely due to utilities reaching their near-term RPS goals. As the next round of goals approaches in 2020, we are likely to see another pick-up in development of renewable resources – including wind.

Changes since Sixth Plan analysis: The recovery from the 2008 recession did not occur as quickly as forecast, so instead of costs decreasing, they continued to increase until about 2010 and are not decreasing as fast as forecast. The resource potential in the region has declined since the Sixth Plan, to account for the major development in 2010-2012. MT wind is looking more cost-effective than it was in the previous plan.

Reference Plant(s)

	On-Shore Wind 40 X 2.5MW	On-Shore Wind 40 X 2.5MW
Location	Columbia Basin	Central Montana, delivered to BPA system
Capacity (MW)	100	100
Economic Life (years)	**25** (20)	**25** (20)
Earliest In –Service	2019	2019
Development time (years)	**4** (4.5)	**4** (4.5)
Capital Cost ($/kW) In-service year 2016	**$2,240** ($1,850)	**$2,240** ($1,850)
Fuel	--	--
Heat Rate (btu/kWh)	--	--
Capacity Factor % (for presentation purposes)	32%	**40%** (38%)
Inv. /Prod. Tax Credit	--	--
O&M Fixed ($/kW-yr), Variable ($/MWh)	**$35.00, $2.00** ($44.70, $2.20)	**$35.00, $2.00** ($44.70, $2.20)

MT Wind Resource Blocks

Name	Description	Capacity MW	Available starting in
MT Wind – Existing Transmission	Wind delivered to BPA system via NWES, IM14	130	2016
MT Wind – NorthWestern Transmission Expansion	Wind delivered to BPA system via new 230kV line, NWES	330-400	2017
MT Wind M2W	Wind delivered to BPA system via M2W update on BPA & Colstrip systems	550	2020
MT Wind w/Colstrip 1&2 Retirement	Wind	700	Depends on scenario

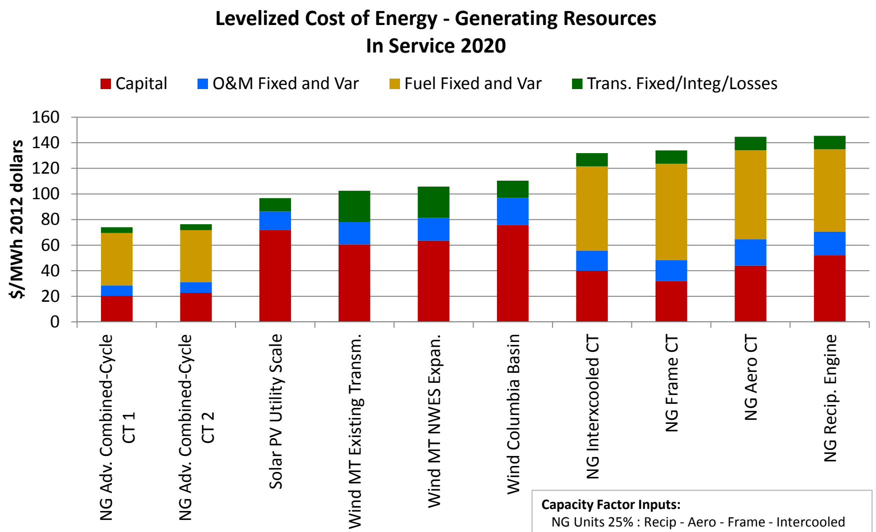
Fixed ($/kW-yr) and full ($/MWh)– annualized cost of capital and operation across the lifecycle

LEVELIZED COST OF ENERGY

Levelized Cost

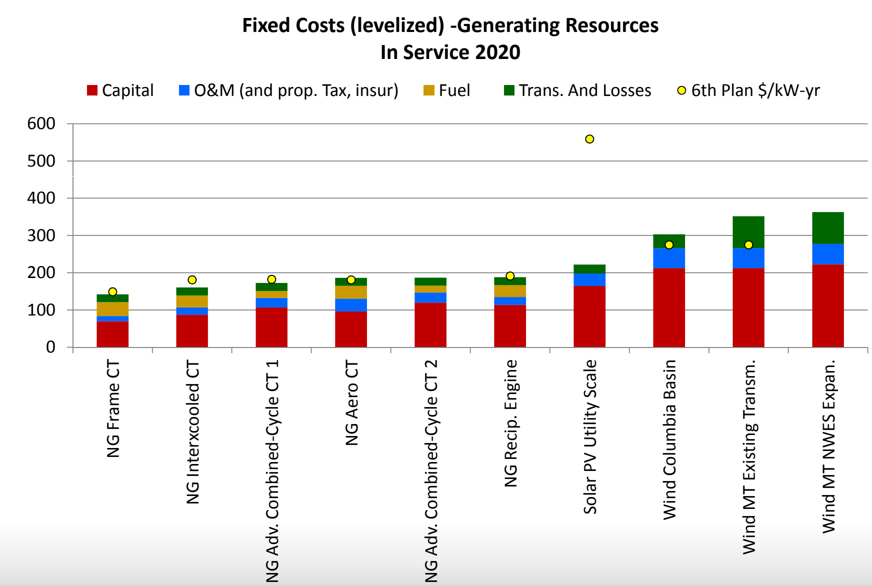
MicroFin - revenue requirements financial model

- 1. Calculates annual cash flows over the plant lifetime that satisfy revenue requirements
- Annual cash flows are compressed into a single year dollar value – Net Present Value (NPV)
- NPV is levelized - converted into an even, annualized payment (like a mortgage)
- When divided by annual energy production – it becomes the Levelized Cost of Energy $/MWh
- Levelized Cost of Energy can be used to compare the average lifecycle costs of different types of resources
- The estimated Fixed Levelized Cost ($/kW-year) is input to RPM for each resource



Capacity Factor Inputs:
NG Units 25% : Recip - Aero - Frame - Intercooled
NG CCCT units 60%
MT Wind 40 %
Col. Basin Wind 32 %
Solar PV 26.2%

Fuel Price: Medium Natural Gas Price Forecast



Next Steps

- Incorporate Power Committee feedback from today
- Presentation to full Council in March re: generating resource characteristics for use in draft RPM analysis
- RPS Analysis
  - GRAC – webinar in late February
  - Power Committee – March meeting

BACKGROUND MATERIAL

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