Northwest Power and Conservation Council

March 5, 2013

MEMORANDUM

TO: Council Members

FROM: Charlie Black, Power Planning Division Director

SUBJECT: Primer and Briefing on Generating Resources

During the discussion about power system capacity at the February Council meeting, Members asked for more specific information about how generating resources are used to meet the region's energy, capacity and flexibility needs. In particular, more detail about different types of natural gas-fired generation was requested.

In response to the Council's request, staff has prepared another in a series of primers designed to build up a framework for understanding power planning issues. The topic of capacity and flexibility planning was highlighted in the Council's recent mid-term assessment of the sixth power plan. To address power system capacity and flexibility, a solid knowledge of generating resources and their characteristics is needed.

This primer begins with an updated version of the table presented at the February meeting that identifies how and to what extent different generating resources provide energy, capacity and flexibility. The primer then provides more detail about each resource and finishes with a more in-depth look at natural gas-fired generation.

This briefing will be at a similar level of detail as the previously briefings on greenhouse gas emissions, power system flexibility and capacity.

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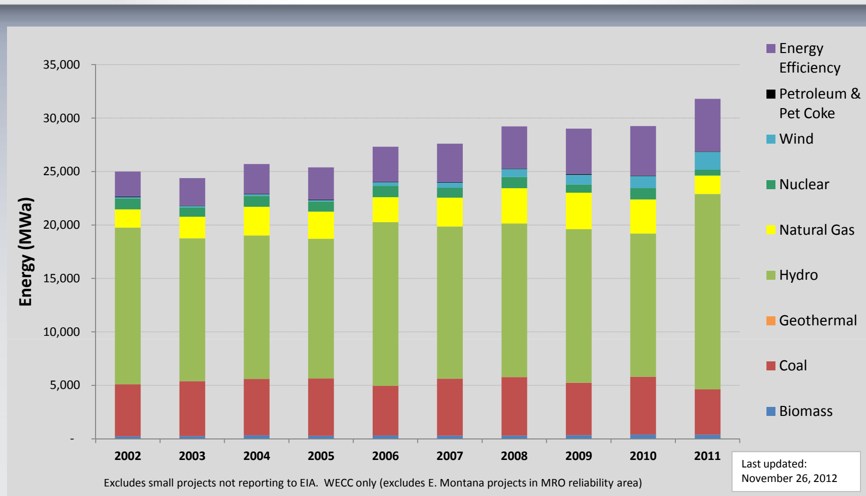
Electric Generating Resources

Review of Resource Characteristics

Brief Introduction to Natural-Gas Fired Generation

March 13, 2013

Power Resources in the Pacific Northwest 2002-2011



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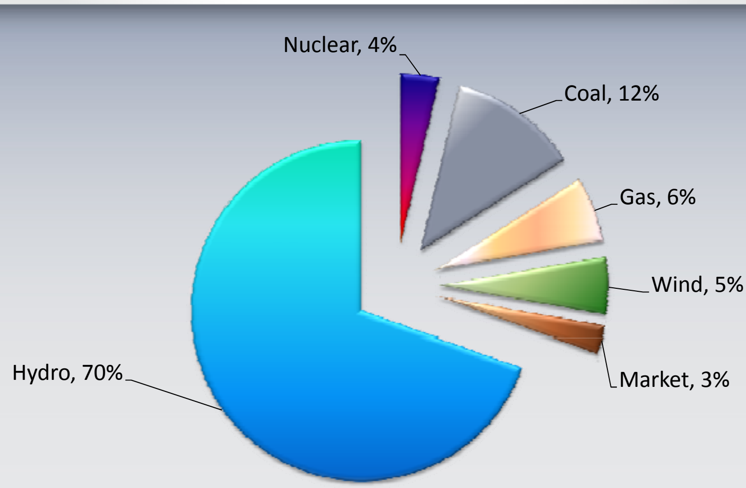
Average Annual Generation Dispatch*



*Simulated results from GENESYS over all water, temperature, forced outage and wind conditions.

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Typical Uses of Northwest Generating Resources Energy – Capacity – Flexibility

Resource Type	Can be Dispatched	Energy	Capacity	Flexibility
Hydro	Yes	Yes	Yes	Yes
Coal	Yes	Yes	No	No
Natural Gas - Combined Cycle	Yes	Yes	Yes	Yes
Natural Gas - Peaking (Simple Cycle, Reciprocating)	Yes	No	Yes	Yes
Nuclear	Yes	Yes	No	No
Wind	No	Yes	No	No
Solar – Photovoltaic	No	Yes	No	No
Solar – Thermal	Yes (limited)	Yes	Yes (limited)	No
Storage (e.g., battery)	Yes	No	Yes	Yes
Energy Efficiency	No	Yes *	No*	No *
Demand Response Interruptible Load (e.g., air conditioners)	Yes (shut off only)	No	Yes	No
Demand Response Dispatchable Load (e.g., water heaters)	Yes	No	Yes	Yes

* Note – energy efficiency contributes to capacity and flexibility needs by reducing the need for other resources but cannot be directly controlled to offset unexpected increases in hourly demands, whereas demand response measures are specifically designed for that purpose.

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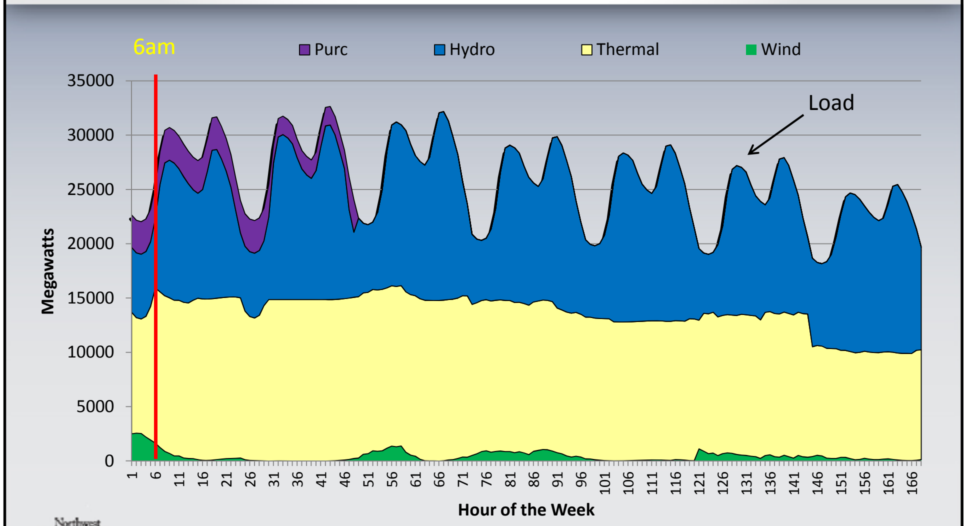
Simulated Hourly Dispatch
(typical January week)



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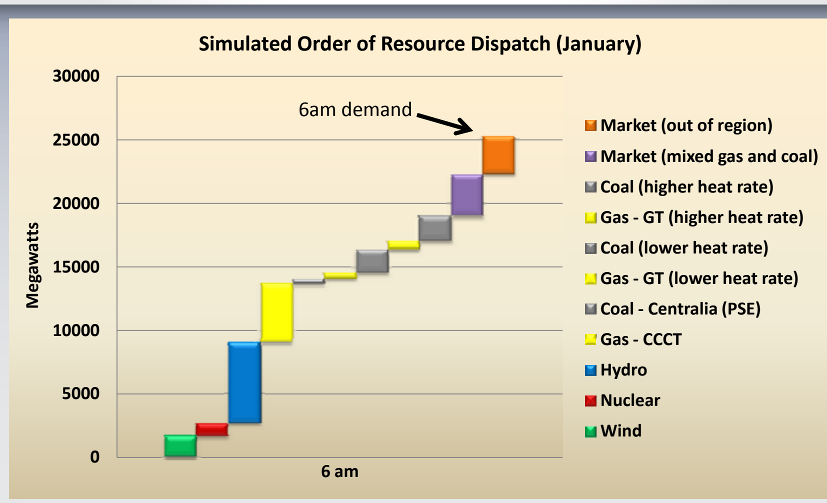
Simulated Dispatch Order
(6am January weekday)



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U.S. Energy Information Administration

2013 Annual Energy Outlook Cost and Performance Characteristics

Technology	Size (MW)	Heat Rate (Btu/kWh)	Lead Time (Yrs)	Overnight Cost in 2012 (2011 $/kW)	Variable O&M (2011 $/kW)	Fixed O&M (2011 $/kW)	Levelized Cost (2011 $/MWh) in service 2018
Scrubbed Coal New	1300	8,800	4	2,833	4.39	30.64	100.1
Int. Coal-Gas. Comb-Cycle (IGCC)	1200	8,700	4	3,718	7.09	50.49	123.0
Pulverized Coal with carbon seq.	650	12,000	4	5,138	4.37	65.31	135.5
Conv Gas/Oil Comb-Cycle	620	7,050	3	901	3.54	12.94	67.1
Adv Gas/Oil Comb-Cycle (CC)	400	6,430	3	1,006	3.21	15.10	65.6
Conv. Combustion Turbine	85	10,850	2	956	15.18	7.21	130.3
Advanced Combustion Turbine	210	9,750	2	664	10.19	6.92	104.6
Advanced Nuclear	2236	10,452	6	5,429	2.10	91.65	108.4
Biomass	50	13,500	4	4,041	5.17	103.79	111.0
Geothermal	50		4	2,567	0.00	110.94	89.6
Conv Hydro	500		4	2,397	2.60	14.57	90.3
Wind	100		3	2,175	0.00	38.86	86.6
Solar Thermal	100		3	4,979	0.00	66.09	261.5
Solar PV	150		2	3,805	0.00	21.37	144.3

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Power Plant Fuel Efficiency Terminology and Metrics

The energy content in one kilowatt-hour (kWh) of electricity is 3,412 British thermal units (Btu)

Heat rate is a common measure of power plant fuel efficiency. It is defined as units of fuel energy consumed per unit of electricity produced – often expressed as Btu per kWh

Thermal efficiency is a more general term used to indicate how efficiently a power plant converts the potential energy from a fuel into electricity – it is expressed as a percentage

The lower the heat rate for a plant, the higher its thermal efficiency

Thus, a power plant with a heat rate of 6,824 Btu/kWh has a fuel efficiency of 50 percent (3,412/6,824)

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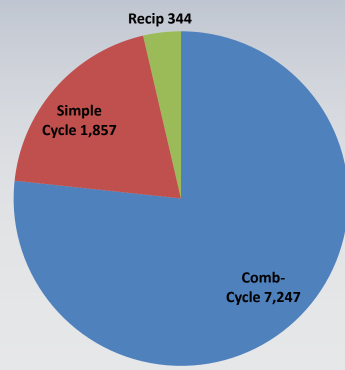
Major Types of Natural Gas-Fired Generating Facilities

- Single-cycle combustion turbine (SCCT)
- Combined-cycle combustion turbine (CCCT)
- Reciprocating engine

Installed Capacity in the Region in megawatts as of 2012



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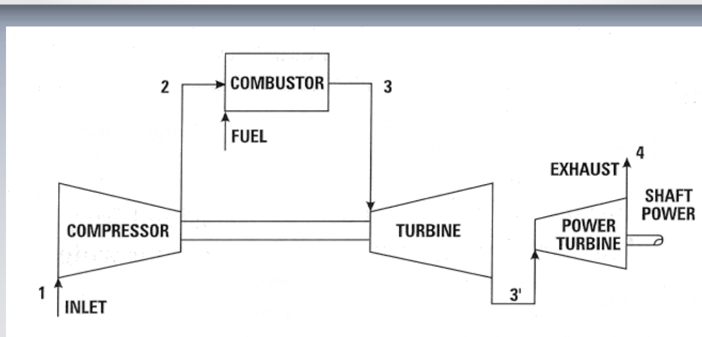
Single-Cycle Combustion Turbine



1. Outside air is brought in at the inlet and compressed to high pressure
2. Fuel (natural gas or oil) is combusted, heating the pressurized air
3. Hot compressed gas expands to low pressure across turbine blades
4. The gas turbine drives the compressor and an electric generator. Low pressure hot gas is exhausted out the stack

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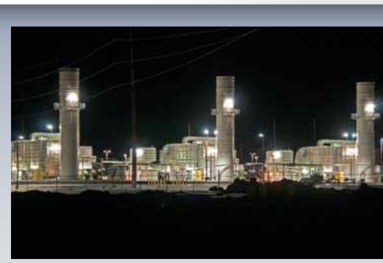
Aeroderivative SCCTs

- Based on aircraft jet engines
- Compact, light weight, highly modular
- Low capital costs, short design and construction times
- Rapid start-up times
- Used for peaking capacity and flexibility, typically not economical for base load
- GE LMS100 with intercooling is a popular technology (hybrid)
- Example: GE Flex Aero LM6000PH™
  - Available with intercooling
  - 48 MW base load output
  - 8390 heat rate (Btu/kWh) – 41 % fuel efficiency.
  - Startup to full output in under 10 minutes, potentially under 5



- Dave Gates Generating Station at Mill Creek
- NorthWestern Energy
- 150 MW capacity from 6 Aero Turbines (Pratt & Whitney SWIFTPAC50 GT)
- Began commercial operation in 2011

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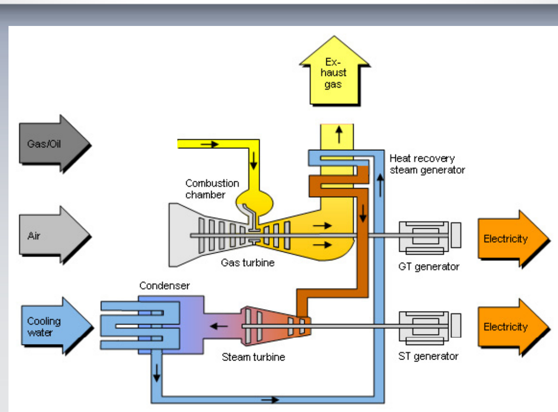
Combined-Cycle Combustion Turbines



1. Combustion turbine is in the middle of the diagram
2. Exhaust heat from the combustion turbine is used to make steam for a steam turbine, resulting in greater fuel efficiency

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Combined-Cycle Combustion Turbines

- One or more gas turbine generators with exhaust heat recovery steam generators
- Typically larger units than single-cycle, with higher capital costs and longer lead times
- Much more efficient, often the choice for new base load power
- State of the art example: Siemens SGT5-8000H™
  - 570 MW output
  - 60 % thermal efficiency
  - Faster start up times, potentially 15 minutes

- Langley Gulch Power Plant
- Idaho Power Co
- 300 MW capacity using Siemens SGT6-5000F™
- Began commercial operation in 2012

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Reciprocating Engines

- Reciprocating internal combustion engines which drive a generator
- Provide rapid start up and response times – most useful for peaking and flexibility
- Typically multiple small units lined in a “farm”
- A recip farm may be more efficient at part-load operation than a single gas turbine of equivalent size due to the versatility of operating multiple units
- PGE’s proposed Port Westward 2 gas plant – powered by Wärtsilä recips providing 200 MW of capacity in 2015

- Plains End Power Plant
-Cogentrix IPP for Xcel/Public Service Co of Colorado
- 20 Wärtsilä 18V3456 Recip Engines providing 111 MW of peaking power
- In operation 2002

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Gas-Fired Power Plant Characteristics

6th Power Plan

Unit Size (MW)	Capital Cost ($/kW)	Heat Rate (Btu/kWh)	Ramp Rate (Minutes)
Biggest	Most expensive	Least Efficient	Slowest
CCCT 1x395	Recip 1,150	Frame SCCT 11,870	CCCT >>10
Frame SCCT 1x85	CCCT 1,120	Aero SCCT 9,300	Frame SCCT >10
Aero SCCT 2x47	Aero SCCT 1,050	Recip 8,800	Aero SCCT <10
Recip 12x8	Frame SCCT 610	CCCT 6,790	Recip <10
Smallest	Least Expensive	Most Efficient	Fastest

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