Natural Gas Combined Cycle Combustion Turbines

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Natural Gas Combined Cycle Combustion Turbines

- Dispatchable baseload power
- Can provide flexibility – ability to ramp up and down, supplemental peaking capacity, complements renewable development
- Highly efficient and lowest per-MW CO_2 production of fossil fuel resources
- Plentiful natural gas supplies and low prices
- Relatively easy to site and permit
- Recent CCCT addition in Idaho (Langley Gulch) and announced in Oregon (Carty)

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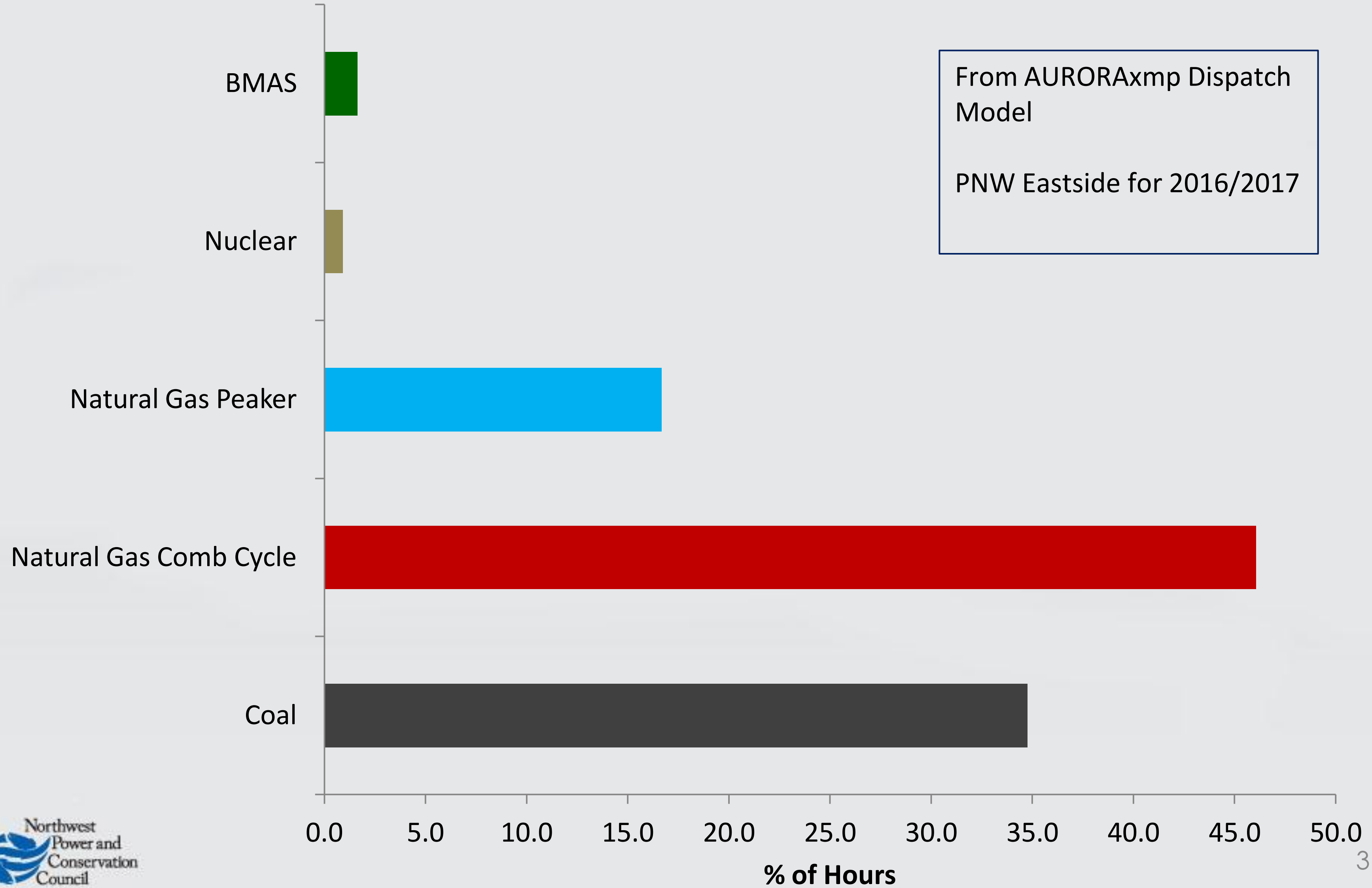
Combined Cycle Dispatch
Percentage of Hours on the Margin by Resource Type
Winter Months



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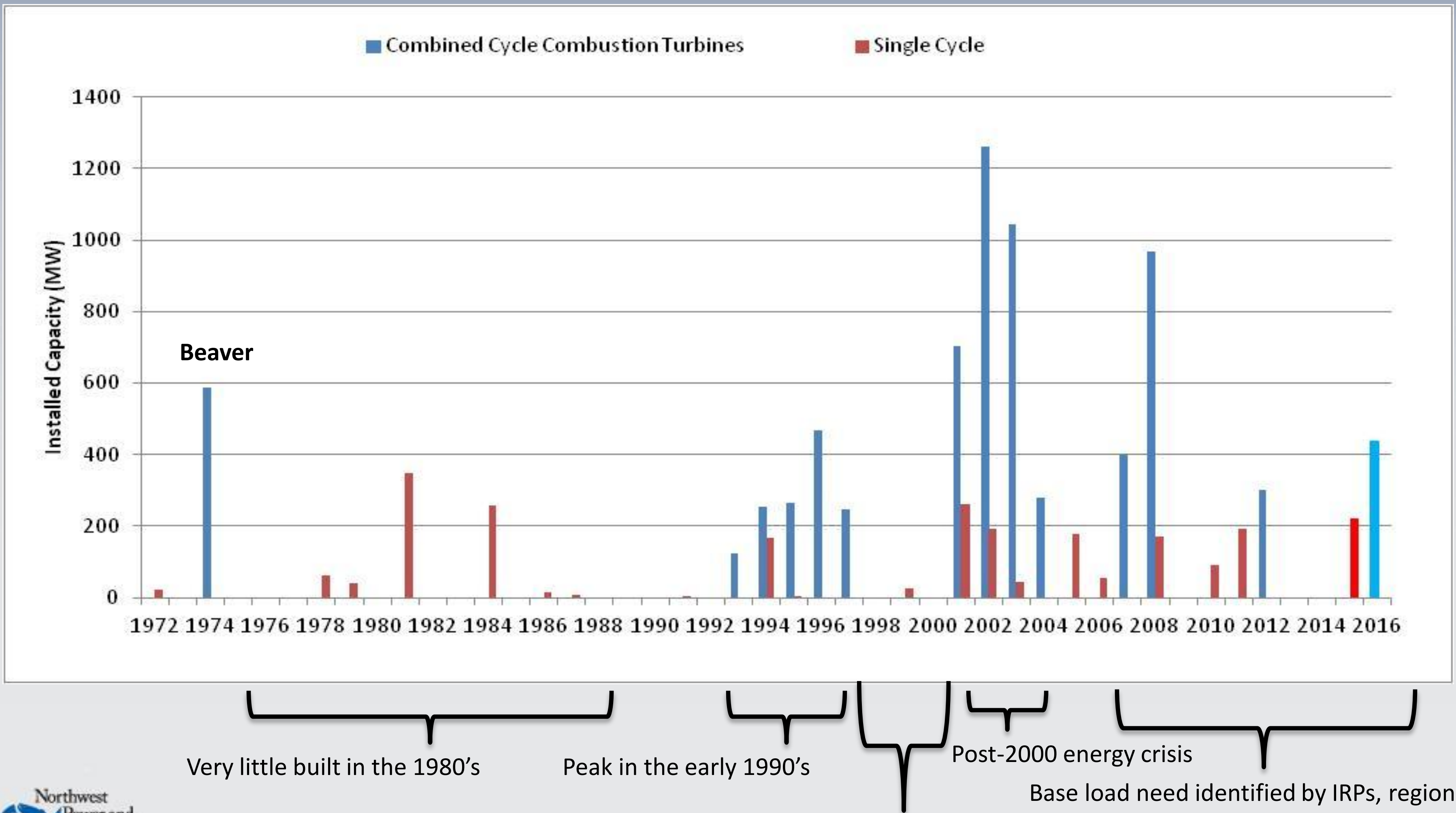
CCCTs in the Region

Capacity Factor assumptions for CCCT levelized cost of energy calculations are often around 85%

Here in the Northwest, actual Capacity Factors for CCCTs are much lower

- Average around 43%
- Range from 12% to 80%

Development of CCCTs in PNW



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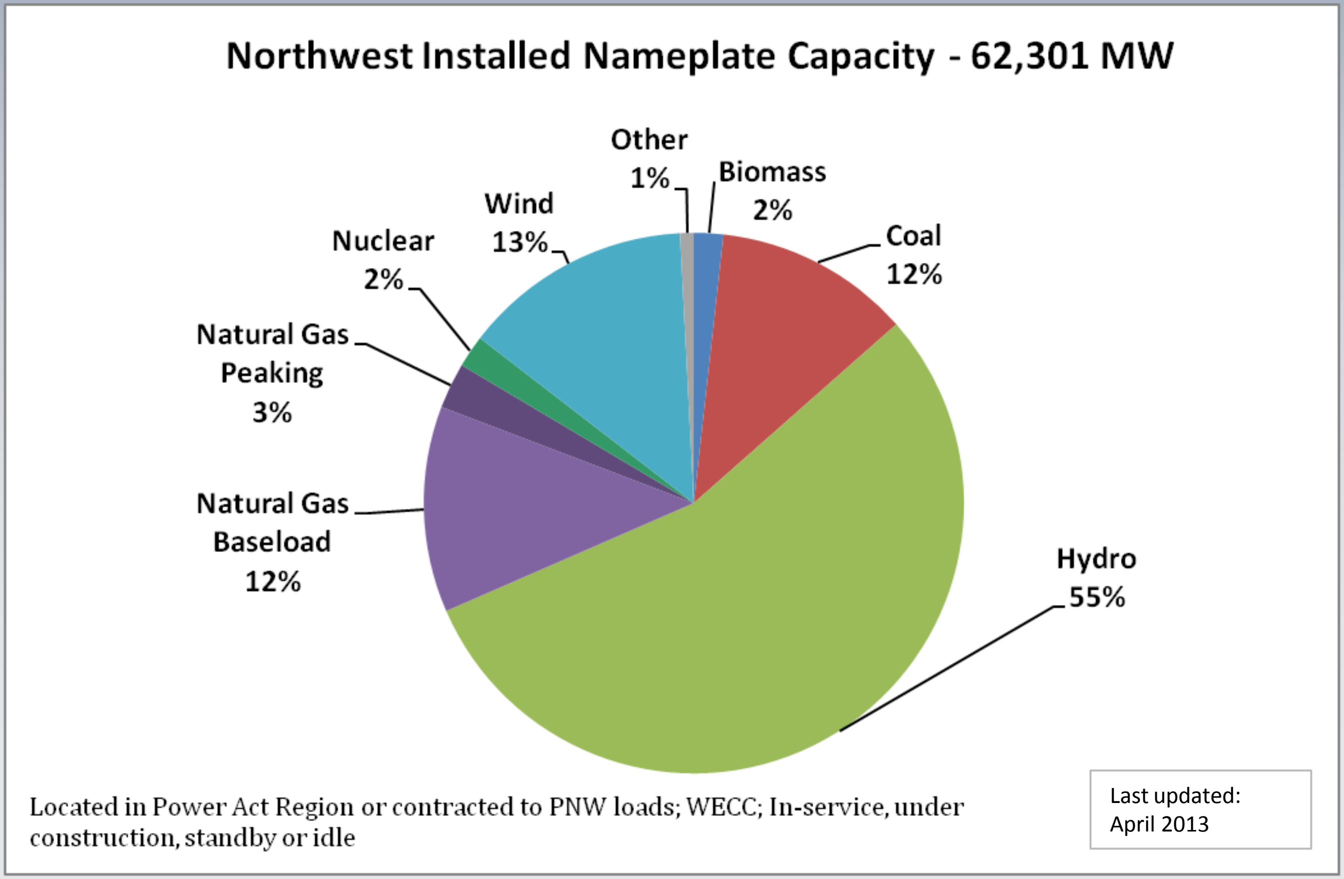
Natural Gas Baseload is 12% of the Region's Installed Capacity



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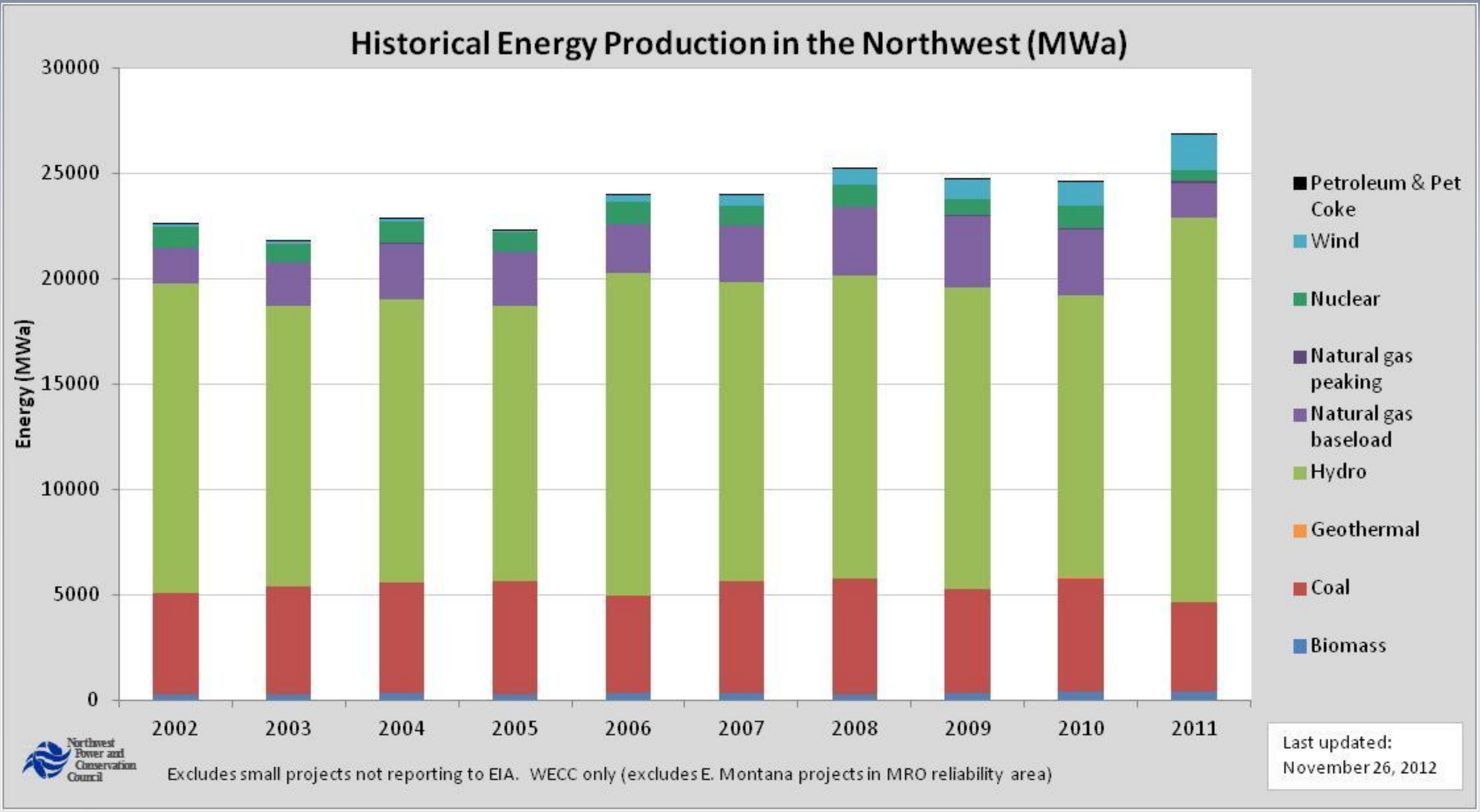
CCCT production dependent upon hydro year



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Existing CCCT plants in Region

20 Projects

- Average Capacity = 345 MW
- Average Heat Rate = 7,243 Btu/kWh

Beaver Units in Clatskanie Oregon - PGE
In service 1974
586 MW Capacity
Seven GE7B GT units paired with a single ST generator
Williams NW Gas Pipeline

Langley Gulch in New Plymouth ID – ID Power
In service 2012
300 MW Capacity
1x1 Siemens SGT6-5000 F with duct firing
Williams NW Gas Pipeline

Port Westward in Clatskanie Oregon – PGE
In service 2007
399 MW Capacity
1x1 Mitsubishi 501G gas turbine
Williams NW Gas Pipeline

Coyote Springs II in Boardman OR – Avista
In service 2003
287 MW Capacity
1x1 GE 7FA GT with Alstom ST
TransCanada GTN pipeline

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Utility IRPs – Projected Future Need for Baseload Natural Gas

Utility	IRP	CCCT	Notes
Avista	2013	~ 270 MW	Est 2026; to replace expiring contract
Idaho Power	2013	0 MW	Langley Gulch (300 MW, 2012 service)
NorthWestern Energy	2011*	~ 300 MW	Potential resource identified for 2018
PacifiCorp	2013**	~ 645 MW	Lake Side 2 (est. 2014 service)
Portland General Electric	2012	440 MW	Carty Generating Station (est. 2016 service)
Puget Sound Energy	2013	0 MW	PSE found CCCTs less cost-effective than single cycle w/ oil back-up; emphasized flexibility over energy

* NorthWestern Electricity Supply Resource Procurement Plan; due to recent proposed 633 MW hydro acquisition, 2013 procurement plan may have different projection

** PacifiCorp projects additional ~2,000MW CCCT within 20-yr planning horizon in PAC EAST

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State of the Art Summary

Combined Cycle Combustion Turbine

CCCT State of the Art

Gas Turbine World Handbook - 2012

- Restructuring of the generation mix is underway to accommodate wind and solar power generation
- Technology shift toward making CCCT plants more operationally efficient at part and minimum load outputs.
- Focus on rapid start times as well as flexibility - ability to quickly ramp up and down.
- Two drivers for demand
  - grid backup to support intermittent wind and solar power
  - Replacements for coal plant retirements as well as nuclear power plant scheduled shutdowns.

CCCT State of Art

Gas Turbine World Handbook – 2012 Pricing Methodology

- Consensus of what project developers, owners and operators, consultants and OEM supplies agree as reasonable for budgeting purposes.
- Basic EPC contract prices - excludes project specific owner expenses like cost of land, project development,...
- Reference Plant: bare bones - integrated gas turbine, HRSG, Steam Turbine all optimized for net output and efficiency
- Costs do not include add-on options:
  - duel fuel combustion
  - catalytic NOx reduction
  - power augmentation like duct/HRSG firing
  - air inlet chilling
- Renewable integration will drive more costly upgrades and flexible gas and steam turbine designs.
  - fast start up and ramping
  - operational flexibility
  - part load efficiency

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Advanced CCCT	Alstom Power	GE FLEX	Mitsubishi	Siemens
Unit	KA26-1	FE50	MPCP1	SCC6-8000H 1S
Gas Turbine	1xGT26	1xFE50	1xM501J	1xSGT6-8000H
Net Output - MW	467	512	470	410
Gas Turbine Output - MW	302	330	322	275
Steam Turbine Output - MW	165	182	148	135
Heat Rate Btu/kWh	5,739	5,594	5,549	5,687
Heat Rate Adjusted *	6,612	6,445	6,393	6,552
Budget Plant Price $	249 $MM	267 $MM	254 $MM	232 $MM
Price $/kW	534	522	540	565
Adjusted Price $/kW *	897	876	906	950

Source: Gas Turbine World 2012 Handbook

* Adjustments - LHV to HHV, Inlet & Exhaust derate, Life Cycle degradation, Aux. Mech. and Elect., Elevation derate, Cost of Labor, Owners Cost

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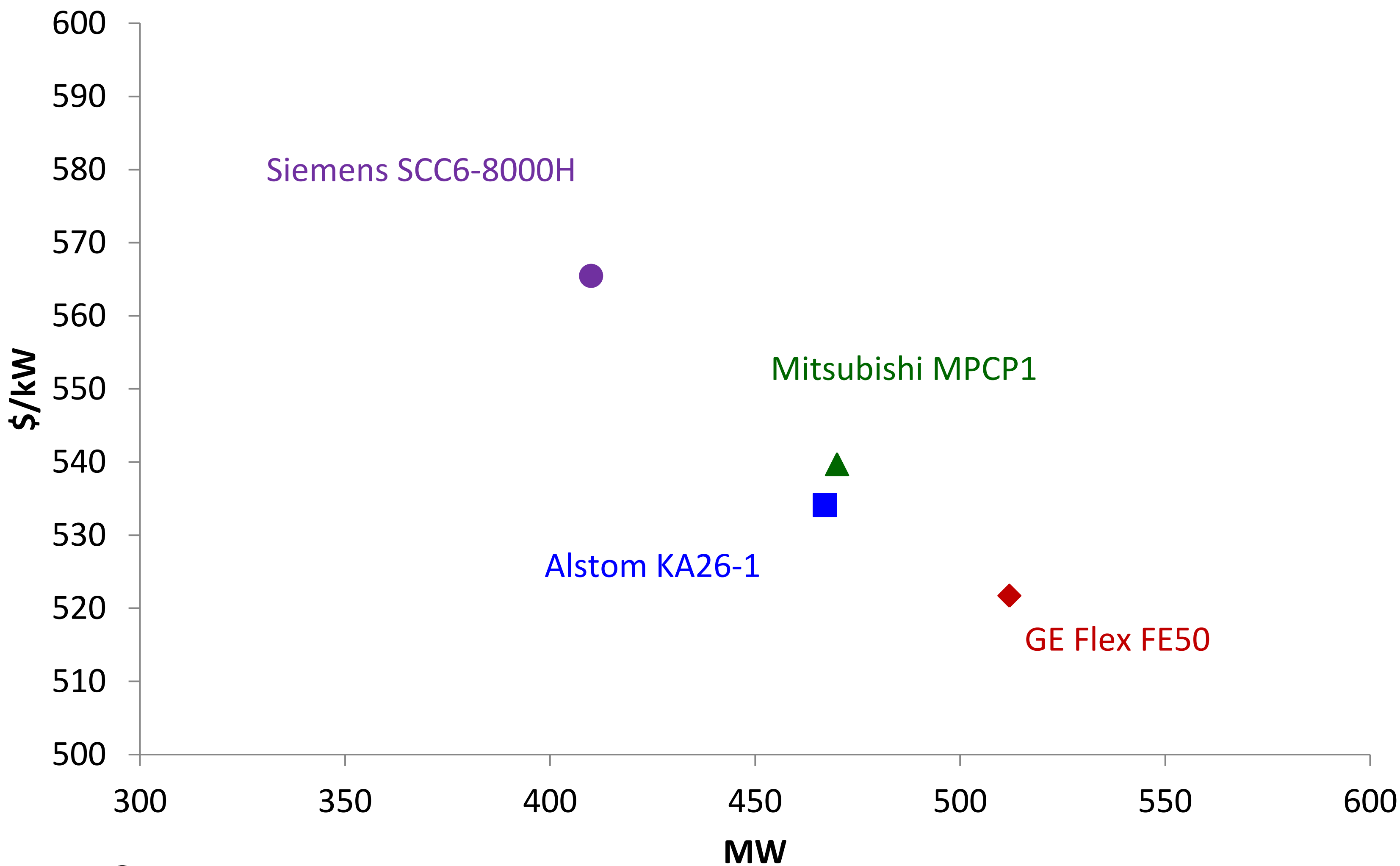
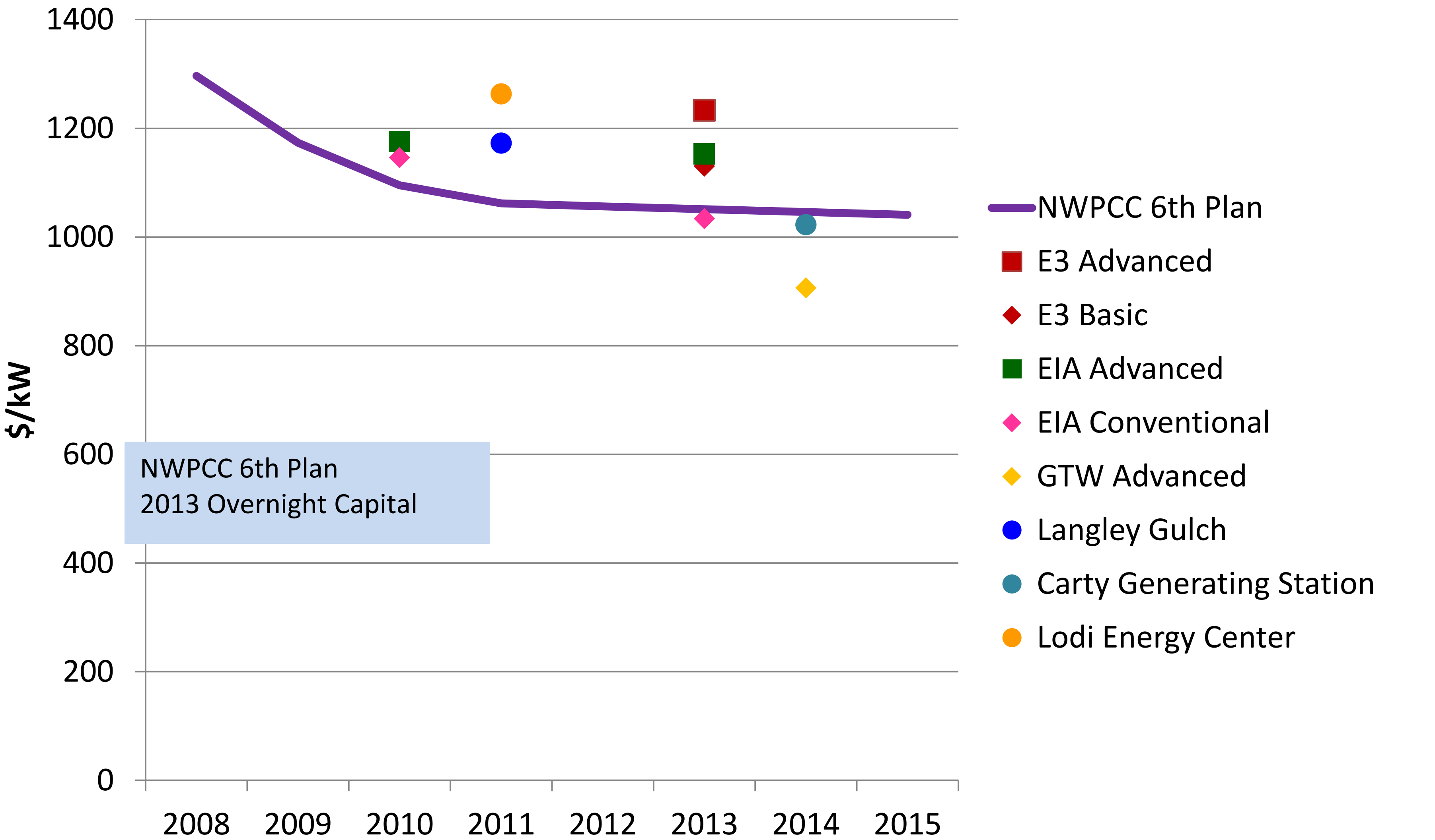
Alstom Power	GE FLEX	Mitsubishi	Siemens
1. Efficiency remains nearly constant from 100% to 80% of max output 2. Can be parked overnight and idled at low power output (100MW) with low emission levels and ramped up in the morning and consume less than shutting down	1. full launch in 2013/2014 2. can be turned down to 30% of full load output and maintain NOx and CO emission levels 3. capable of reaching full rated capacity in 28 minutes 4. ramp rate up or down at 50 MW/min 5. orders including one for wind and solar power generation	1. Cold Start Up - can reach 320MW base load in 25 to 30 minutes with the steam turbine output in another 10 minutes 2. Ramp rate down 20MW/min 3. DLE combustion - reduces emissions under 25ppm Nox and 9ppm CO without catalytic reduction	1. Cold Start Up - can reach full load in less than 30 minutes 2. Ramp rate up and down at 35 MW/min

Non-Adjusted Budget Price by Plant Size Exhibit Economy of Scale



Source: Gas Turbine World 2012 Handbook

CCCT Cost Estimates in 2012 $
By vintage - in service 2 years later
Normalized



Advanced CCCT Characteristics

Source	Class & Configuration	Cooling & Augmentation	Adjustments
E3: Cost and Performance Review of Generation Technologies October 2012	G or H Class 1x1	Wet Cooling Duct Firing	Translated from 2010 dollars and All In Costs (IDC) to 2012 dollars and Overnight Capital Cost Translated costs from average US location to Boardman OR
EIA: Updated Capital Cost Estimates for Utility Scale Generating Plants – April 2013	H Class 1x1	Wet Cooling Duct Firing	Translated costs from average US location to Boardman OR

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Recent CCCT Projects

Project	In Service	Technology	Capacity	Cost	Adjustments
Langley Gulch in New Plymouth ID	2012	1x1 Siemens SGT6-5000F	330 MW (winter)	389 $MM	Location Costs $ and Elevation
Lodi Energy Center in Lodi CA	2012	1x1 Siemens SCC6-5000 F Flex30 No duct firing	296 MW	388 $MM	Location Costs and Elevation
Carty Generating Station in Boardman OR	2016	1x1 Mitsubishi 501G	440 MW	450 $MM	

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Preliminary CCCT Reference Plant

H-Class or beyond Advanced natural gas fired CCCT – such as MHI J-Class

- 1 Gas Turbine paired with 1 Steam Turbine
- Capacity 470 MW with 25 MW duct firing capability
- DLN and Catalytic control of NOx
- Evaporative Cooling
- 6^{th} Plan Capital Cost Estimates updated to 2012 dollars – for 2013 vintage: 1,051 $/kW

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CCCT Environmental

1. Cost of emission controls (DLN, Selective Catalytic Reduction) internalized as part of the overall capital cost
2. Costs for water, wastewater and solid compliance are included in the O&M estimate

CCCT O&M Costs

Source	Fixed O&M $/kW-yr 2012$	Variable O&M $/MWh 2012$
EIA	15.37	3.27
E3	10.98	NA
NWPCC 6th Plan	14.70	1.96

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Emissions

EIA 2013 Updated Capital Costs	Lb/MMBtu
NOx	0.0075
SO2	0.001
CO2	117

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Potential Federal Legislation

- September 2013 – EPA re-proposed New Source Performance Standard
  - NG fired turbines > 250 MW would need to meet standard of **1,000 lbs of CO_2/MWh**
  - NG fired turbines 73 MW – 250 MW would need to meet standard of **1,100 lbs of CO_2/MWh**
  - Applies only to **<u>new projects</u>**; existing projects exempt from this particular standard
  - Explicit exemption for simple cycle turbines

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State Emission Performance Standards (EPS)

- Generally consistent with proposed Federal Standard
  - Oregon (2009) – 1,100 lbs of CO_2/MWh
  - Washington (2007) – 1,100 lbs of CO_2/MWh
  - Eligible facilities and exemptions dependent upon state rules

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CO_2 production of combined-cycle technologies

Case	Technology	Heat Rate (HHV, full load, net lifecycle)	CO_2 Production (lb/MWh)*
5th Plan Representative Plant	GE 207FA (2x1 F-class plant)	7030	818
6th Plan Representative Plant	Mitsubishi 501G (1x1 G-class plant) Port Westward	6750	786
State of the Art - High Efficiency	GE 107H (1x1 H-class plant) Inland Empire	6580	766
State of the Art - High Flexibility	Siemens SCC6-5000F Flex-Plant 30 Lodi Energy Center	6920	805

*Natural Gas CO_2 factor – 116 lb/MMBtu

Dispatch for Natural Gas Fired Power

When bidding into the market – how are natural gas costs accounted for?

Is dispatch based on the full natural gas cost (commodity & pipeline charges) or just on variable or commodity cost?

Next Steps

- Gather input and feedback from GRAC members on preliminary assumptions
- Finalize a reference plant – capacity, heat rate,…
- Finalize a capital cost and cash flow schedule for the reference plant as of 2012
- Finalize forecasts for capital costs, O&M costs, and Levelized Costs across the Seventh Power Plan horizon (2015 – 2035)
- Revisit at January GRAC meeting

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