Natural Gas Combined Cycle
Combustion Turbines

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GRAC
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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 CO₂ 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)
Combined Cycle Dispatch
Percentage of Hours on the Margin by Resource Type
Winter Months

- BMAS
- Nuclear
- Natural Gas Peaker
- Natural Gas Comb Cycle
- Coal

From AURORAxmp Dispatch Model
PNW Eastside for 2016/2017
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

Very little built in the 1980’s
Peak in the early 1990’s
Post-2000 energy crisis
Base load need identified by IRPs, region
Late 1990’s succession of good water years
Natural Gas Baseload is 12% of the Region’s Installed Capacity.

Northwest Installed Nameplate Capacity - 62,301 MW

- Hydro: 55%
- Natural Gas Baseload: 12%
- Wind: 13%
- Nuclear: 2%
- Natural Gas Peaking: 3%
- Coal: 12%
- Biomass: 2%
- Other: 1%

Located in Power Act Region or contracted to PNW loads; WECC; In-service, under construction, standby or idle

Last updated: April 2013
CCCT production dependent upon hydro year.
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
## Utility IRPs – Projected Future Need for Baseload Natural Gas

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

* 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
State of the Art Summary

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

Source: Gas Turbine World 2012 Handbook

<table>
<thead>
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<th>Alstom Power</th>
<th>GE FLEX</th>
<th>Mitsubishi</th>
<th>Siemens</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Efficiency remains nearly constant from 100% to 80% of max output</td>
<td>1. full launch in 2013/2014</td>
<td>1. Cold Start Up - can reach 320MW base load in 25 to 30 minutes with the steam turbine output in another 10 minutes</td>
<td>1. Cold Start Up - can reach full load in less than 30 minutes</td>
</tr>
<tr>
<td>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</td>
<td>2. can be turned down to 30% of full load output and maintain NOx and CO emission levels</td>
<td>2. Ramp rate down 20MW/min</td>
<td>2. Ramp rate up and down at 35 MW/min</td>
</tr>
<tr>
<td></td>
<td>3. capable of reaching full rated capacity in 28 minutes</td>
<td>3. DLE combustion - reduces emissions under 25ppm Nox and 9ppm CO without catalytic reduction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. ramp rate up or down at 50 MW/min</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. orders including one for wind and solar power generation</td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>
Non-Adjusted Budget Price by Plant Size
Exhibit Economy of Scale

Source: Gas Turbine World 2012 Handbook
## Advanced CCCT Characteristics

<table>
<thead>
<tr>
<th>Source</th>
<th>Class &amp; Configuration</th>
<th>Cooling &amp; Augmentation</th>
<th>Adjustments</th>
</tr>
</thead>
<tbody>
<tr>
<td>E3: Cost and Performance Review of Generation Technologies October 2012</td>
<td>G or H Class 1x1</td>
<td>Wet Cooling Duct Firing</td>
<td>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</td>
</tr>
<tr>
<td>EIA: Updated Capital Cost Estimates for Utility Scale Generating Plants – April 2013</td>
<td>H Class 1x1</td>
<td>Wet Cooling Duct Firing</td>
<td>Translated costs from average US location to Boardman OR</td>
</tr>
</tbody>
</table>
## Recent CCCT Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>In Service</th>
<th>Technology</th>
<th>Capacity</th>
<th>Cost</th>
<th>Adjustments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Langley Gulch in New Plymouth ID</td>
<td>2012</td>
<td>1x1 Siemens SGT6-5000F</td>
<td>330 MW (winter)</td>
<td>389 $MM</td>
<td>Location Costs $ and Elevation</td>
</tr>
<tr>
<td>Lodi Energy Center in Lodi CA</td>
<td>2012</td>
<td>1x1 Siemens SCC6-5000 F Flex30 No duct firing</td>
<td>296 MW</td>
<td>388 $MM</td>
<td>Location Costs and Elevation</td>
</tr>
<tr>
<td>Carty Generating Station in Boardman OR</td>
<td>2016</td>
<td>1x1 Mitsubishi 501G</td>
<td>440 MW</td>
<td>450 $MM</td>
<td></td>
</tr>
</tbody>
</table>
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
- 6th Plan Capital Cost Estimates updated to 2012 dollars – for 2013 vintage: 1,051 $/kW
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

<table>
<thead>
<tr>
<th>Source</th>
<th>Fixed O&amp;M $/kW-yr 2012$</th>
<th>Variable O&amp;M $/MWh 2012$</th>
</tr>
</thead>
<tbody>
<tr>
<td>EIA</td>
<td>15.37</td>
<td>3.27</td>
</tr>
<tr>
<td>E3</td>
<td>10.98</td>
<td>NA</td>
</tr>
<tr>
<td>NWPCC 6th Plan</td>
<td>14.70</td>
<td>1.96</td>
</tr>
</tbody>
</table>
## Emissions

<table>
<thead>
<tr>
<th>EIA 2013 Updated Capital Costs</th>
<th>Lb/MMBtu</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>0.0075</td>
</tr>
<tr>
<td>SO2</td>
<td>0.001</td>
</tr>
<tr>
<td>CO2</td>
<td>117</td>
</tr>
</tbody>
</table>
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 CO₂/MWh**
  - NG fired turbines 73 MW – 250 MW would need to meet standard of **1,100 lbs of CO₂/MWh**
  - Applies only to new projects; existing projects exempt from this particular standard
  - Explicit exemption for simple cycle turbines
State Emission Performance Standards (EPS)

- Generally consistent with proposed Federal Standard
  - Oregon (2009) – 1,100 lbs of CO2/MWh
  - Washington (2007) – 1,100 lbs of CO2/MWh
  - Eligible facilities and exemptions dependent upon state rules
# CO2 production of combined-cycle technologies

<table>
<thead>
<tr>
<th>Case</th>
<th>Technology</th>
<th>Heat Rate (HHV, full load, net lifecycle)</th>
<th>CO2 Production (lb/MWh)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th Plan Representative Plant</td>
<td>GE 207FA (2x1 F-class plant)</td>
<td>7030</td>
<td>818</td>
</tr>
<tr>
<td>6th Plan Representative Plant</td>
<td>Mitsubishi 501G (1x1 G-class plant) Port Westward</td>
<td>6750</td>
<td>786</td>
</tr>
<tr>
<td>State of the Art - High Efficiency</td>
<td>GE 107H (1x1 H-class plant) Inland Empire</td>
<td>6580</td>
<td>766</td>
</tr>
<tr>
<td>State of the Art - High Flexibility</td>
<td>Siemens SCC6-5000F Flex-Plant 30 Lodi Energy Center</td>
<td>6920</td>
<td>805</td>
</tr>
</tbody>
</table>

*Natural Gas CO2 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