September 30, 2014

MEMORANDUM

TO: Power Committee
FROM: Gillian Charles, Steve Simmons
SUBJECT: Generation Resource Assessment Methodology

BACKGROUND:
Presenter: Gillian Charles, Energy Policy Analyst
Steve Simmons, Energy Analyst

Summary: As the Council develops the draft Seventh Power Plan, staff will present a series of primers on Council analytical methodologies and input data and assumptions. At the October 7th Power Committee Meeting in Pendleton, staff will present the generation resource assessment methodology and describe its role in the development of the power plan.

Relevance: The results of generating resource assessment are a key set of inputs to the power plan. Resource characteristics such as capital cost, fuel conversion efficiency, regional availability and operating characteristics (e.g. flexibility) and performance for each resource play a critical role in resource selection in the Regional Portfolio Model

Workplan: 1D – Prepare for Seventh Power Plan and maintain analytical capability

Background: Council staff follows a methodology in developing its assumptions for the different generating resource characterizations. This includes reviewing (1) current and planned projects in the region and WECC, (2) manufacturer’s products and new technologies, and (3) analysis and reports from regional and national organizations. Staff develops estimates and assumptions for resources and thoroughly vets these preliminary
estimates with the Council’s Generating Resources Advisory Committee (GRAC) for feedback. Once preliminary estimates for resources are ready for inclusion in the draft plan, staff will review them with the Council for additional feedback.

More Info: The GRAC webpage has a lot of information on topics and resources covered thus far this plan cycle - http://www.nwcouncil.org/energy/grac/home/.
Generating Resources Assessment Methodology

Power Committee
October 7, 2014
Gillian Charles and Steve Simmons

Outline

- Generating Resources Assessment Methodology
  - Analysis
  - Models
  - Generating Resources Advisory Committee
- Categorization of Resources for the Draft Seventh Power Plan
- Where we are at, what is coming next
Purpose

- Council’s mission – assure the region of an Adequate, Efficient, Economical, and Reliable Power Supply (AEERPS) by selecting the least cost, least risk resource strategy over the 20 year planning horizon
- Generating resource assessment informs the resource strategy
  - Resource types and technologies
  - Assumptions – Cost, Construction Schedule, Operating Characteristics and Performance, Developable Potential

Generating Resource Assessment Process

- Staff develops preliminary resource assumptions
- Review preliminary resource assumptions with the Generating Resources Advisory Committee (GRAC)
  - Incorporate feedback and information
- Review draft plan resource assumptions with the Power Committee/Council for approval to use in draft Seventh Plan analysis
Generating Resources Assessment Methodology

**Financial Assumptions**
- Base year dollars = 2012$  
- Discount Rate = 4%  
- Inflation Rate  
- Standardized GDP Deflators

**Generating Resource Assessment**
- Reference Plant: Unit size and configuration, technology, characteristics and performance  
- Cost: Capital, O&M  
- Construction Schedule

**Regional Portfolio Model**

**AURORAxMP Electric Market Model**

**GENESYS**

**Environmental Methodology**
- TBD

**Fuel Price Forecasts**
- Natural gas, coal, oil  
- Transmission, Integration Costs

**MicroFin**
- Levelized Cost of Energy  
- Levelized Fixed Cost (annual basis)

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**Reference Plant Key Attributes (1)**

**Reference Plant** – a representative resource with a plausible configuration for development in the PNW; used in the Power Plan as possible new resource options

<table>
<thead>
<tr>
<th><strong>Configuration</strong></th>
<th>Technology, number of units, air emission controls, cooling (wet vs. dry), specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price Year</strong></td>
<td>The vintage of the technology, overnight capital cost, and operating cost</td>
</tr>
<tr>
<td><strong>Year Dollars</strong></td>
<td>Reference year for setting dollar value; used consistently throughout power plan assumptions</td>
</tr>
<tr>
<td><strong>Capacity (MW)</strong></td>
<td>The maximum power that a machine or system can produce continuously under specified conditions</td>
</tr>
<tr>
<td></td>
<td>- International Standards Organization (ISO) – rating at 59°F, 1 atmosphere air pressure, 60% relative humidity; way of setting a standard condition for performance comparison</td>
</tr>
<tr>
<td></td>
<td>- Site – adjusts for elevation at specific sites (which effects atmospheric pressure)</td>
</tr>
<tr>
<td></td>
<td>- Lifecycle – adjusts for effects of wear and tear on the equipment and restorative maintenance</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>The maximum expected potential resource operation; expressed as a percentage of full capacity.</td>
</tr>
<tr>
<td><strong>Capacity Factor</strong></td>
<td>The ratio of actual/expected output over a period of time, to potential output if operating at full capacity; expressed as a percentage of full capacity. Capped by availability.</td>
</tr>
</tbody>
</table>

**Dispatchable resources** (combined cycle, single cycle, coal) – determined by economics  
**Non-dispatchable resources** (wind, solar PV, landfill gas) – determined by environmental conditions, availability of primary energy resource
Reference Plant Key Attributes (2)

Heat Rate (Btu/kWh) – the amount of fuel required to produce 1 kilowatt hour of electrical output; denotes fuel conversion efficiency. Can be expressed as heat rate (energy input vs kilowatt hour out) or as conversion efficiency (percentage)
Example: GE LMS 100 intercooled single cycle turbine
• The heat rate is 8540 Btu/kWh
• The fuel conversion efficiency is 40%
The lower the heat rate, the more efficient the plant is at converting fuel to electricity

Construction Lead Time (months) - amount of time it takes from conception to commissioning; Two phases for purposes of current Regional Portfolio Model (RPM):
• Planning and Development – Identification of need (e.g. IRP) to establishment of EPC contract (includes all siting and licensing, environmental assessments, preliminary engineering)
• Construction – From Notice to Proceed to complete construction and commissioning

Economic Life – assumed useful operating life (in years)

* Btu – British Thermal Unit – standard measure of energy content; 3413 Btu per kilowatt hour.
* EPC – Engineering, Procurement, and Construction contractor (final engineering, procurement of materials and equipment, and construction and commissioning)

Draft 7th Plan Example:
Aeroderivative Gas Turbine Reference Plant (1)

<table>
<thead>
<tr>
<th>Year</th>
<th>Dollars</th>
<th>2012 $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price Year</td>
<td></td>
<td>2015</td>
</tr>
</tbody>
</table>

Technology & Configuration base | (4) GE LM6000 PF SPRINT
---|---
Capacity Plant Total (MW) | 180 MW lifecycle capacity
Fuel | Natural Gas
Heat Rate (btu/kWh) | 9050
Availability (annual) | 91%
Economic Life (Years) | 30

Construction Lead Time (Months) | 18 planning & development (33 total)
| 15 construction (33 total)
Reference Plant Key Cost Estimates

**Overnight Capital Cost ($/kW)** – Sum of engineering, procurement, and construction (EPC) costs plus owner’s cost (costs incurred by the project developer – permits, licenses, land, project development costs, infrastructure, taxes, regulatory compliance costs, etc.)
- Will include a high/low cost band to capture uncertainty around estimates

**Fixed Operation and Maintenance (O&M)** – Costs that include operating and maintenance, labor and materials, and administrative overhead. For purposes of the Council’s modeling, major maintenance, capital replacement, and decommissioning costs are also included. Expressed in $/kW-Yr.

**Variable O&M** – Costs that are a function of the amount of power produced; includes consumables such as water, chemicals, lubricants, and catalysts, waste disposal, regulatory compliance costs (emission allowances/offsets, CO2 costs); expressed in $/MWh.

**Levelized Cost of Energy** – the estimated cost of energy for a specific resource over its productive life, expressed in $/MWh.

Estimating Capital Cost Assumptions and Normalizations

**Normalization** – Establishing comparable estimates by adjusting source data to common year dollars, vintage/price years, plant configuration, etc.

1. Reference sources – reported plant data, generic reports
2. Objective - normalize to draft Seventh Plan reference plant design
   - Overnight capital costs in $2012
   - Site-specific adjustments to capacity and heat rate
   - Site-specific labor costs
   - Typical configuration for PNW
3. Look for outliers, trends; forecast future 20 year trend line
List of Reference Sources

- Project-specific publically available reported info
- Technical data from manufacturer
- Regional utility IRPs
- Gas Turbine World (2013 Handbook)
- Black & Veatch analysis
- NERA analysis for NYISO
- EIA Capital Cost, EIA Annual Energy Outlook
- National Energy Technology Laboratory (NETL)
- National Renewable Energy Laboratory (NREL)
- California Energy Commission
- Generating Resources Advisory Committee (GRAC)
- Department of Energy annual market reports, technology-specific reports

Preliminary Draft 7th Plan Capital Cost Estimate for Aeroderivative

![Graph showing capital cost estimates over vintage of estimate.](image)

DRAFT- For presentation purposes only.
Draft 7th Plan Example:
Aeroderivative Gas Turbine
Reference Plant (2)

<table>
<thead>
<tr>
<th>Year</th>
<th>Dollars</th>
<th>2012 $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price Year</td>
<td></td>
<td>2015</td>
</tr>
<tr>
<td>Overnight Capital Cost ($/kW)</td>
<td></td>
<td>$1,095</td>
</tr>
<tr>
<td>Capital Cost Band (Hi/Low %)</td>
<td></td>
<td>TBD</td>
</tr>
<tr>
<td>Fixed O&amp;M ($/kW-Yr)</td>
<td></td>
<td>$12.00</td>
</tr>
<tr>
<td>Variable O&amp;M ($/MWh)</td>
<td></td>
<td>$4.50</td>
</tr>
<tr>
<td>Levelized Cost of Energy</td>
<td></td>
<td>TBD</td>
</tr>
</tbody>
</table>

Generating Resources
Assessment Methodology

- **Financial Assumptions**
  - Base year dollars – 2012$
  - Discount Rate – 4%
  - Inflation Rate
  - Standardized GDP Deflators

- **Environmental Methodology**
  - TBD

- **Fuel Price Forecasts**
  - Natural gas, coal, oil
  - Transmission, Integration Costs

- **Generating Resource Assessment**
  - Reference Plant: Unit size and configuration, technology, characteristics and performance
  - Cost: Capital, O&M
  - Construction Schedule

- **MicroFin**
  - Levelized Cost of Energy
  - Levelized Fixed Cost (annual basis)

- **Regional Portfolio Model**
- **AURORA Model**
- **Electric Market Model**
- **GENESYS**
MicroFin – How it Works

Excel-based, revenue requirements financial model

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

Three financial sponsor options
1. Muni/PUD
2. IOU
3. IPP

Key assumption differences among the sponsor types
1. Tax rates
2. Debt rates and service periods
3. Equity return rates and service periods

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MicroFin Financials

<table>
<thead>
<tr>
<th>Key Assumptions</th>
<th>Municipal/PUD</th>
<th>Investor Owned Utility</th>
<th>Indep. Power Producer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal Tax - %</td>
<td>0</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>State Tax - %</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Fed Tax Inv Credit - %</td>
<td>0</td>
<td>30/10¹</td>
<td>30/10¹</td>
</tr>
<tr>
<td>Property Tax - %</td>
<td>0</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Insurance - %</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Debt Fraction - %</td>
<td>100</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>Debt Interest Rate (not tax adjusted)</td>
<td>5.24</td>
<td>6.69</td>
<td>6.69</td>
</tr>
<tr>
<td>Debt payment Period</td>
<td>25²</td>
<td>25²</td>
<td>20²</td>
</tr>
<tr>
<td>Return on Equity</td>
<td>0</td>
<td>10</td>
<td>13.7</td>
</tr>
<tr>
<td>Equity Payment Period</td>
<td>25²</td>
<td>25²</td>
<td>20²</td>
</tr>
<tr>
<td>Discount Rate</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Inflation Rate</td>
<td>1.64</td>
<td>1.64</td>
<td>1.64</td>
</tr>
</tbody>
</table>

¹Solar only – Fed ITC 30% thru 2016, 10% following
² Gas 30/30/15
LCOE Example - Combined Cycle Combustion Turbine

ADV CCCT 2
- **Input**
  - Capacity 425 MW
  - Capital Cost $1,217/kW
  - Capacity factor 0.6

ADV CCCT 2
- **Output**
  - NPV $3.1 billion
  - Level. Cost of Energy $71/MWh

**Levelized Cost of Energy Example**

**Advanced Combined Cycle Combustion Turbine & Utility Scale Solar PV**

1. In service 2020
2. CCCT Cap Factors: 0.85 – 0.60 – 0.35
4. Solar PV Cap Factor: 0.26
In Addition to Resource Assessment...

- Wholesale Electric Price Forecast
- Renewable Portfolio Standards – WECC-wide forecast of future need
- Generating Resources Database – existing and planned projects in the PNW

Generating Resources Advisory Committee (GRAC)

- One of several advisory committees to the Council to assist in the development of the power plan
- Serves in advisory capacity only
  - No votes are taken
  - Role is to review information, vet assumptions, provide feedback
- Members from IOUs, public utilities, BPA, state commissions, public interest groups, national labs, independent contractors
Progress so far...

- Staff has reviewed the following preliminary resource assumptions with the GRAC:
  - Utility-scale Solar PV
  - Combined Cycle Combustion Turbine technologies
  - Single Cycle Combustion Turbine Technologies (gas peakers)
  - Reciprocating Engine Technologies (gas peaker)
  - Utility-scale Wind
- Staff is supervising the Council’s Regional Hydropower Potential Scoping Study

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)

<table>
<thead>
<tr>
<th>Primary; Significant</th>
<th>Secondary; Commercial w/ Limited Availability</th>
<th>Long-Term Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas Combined Cycle</td>
<td>Biogas Technologies (landfill, wastewater treatment, animal waste, etc.)</td>
<td>Engineered Geothermal</td>
</tr>
<tr>
<td>Wind</td>
<td>Biomass - Woody residues</td>
<td>Offshore Wind</td>
</tr>
<tr>
<td>Solar PV</td>
<td>Conventional hydrothermal Geothermal</td>
<td>Modular Nuclear Units</td>
</tr>
<tr>
<td>Natural Gas Simple Cycle, Reciprocating Engine</td>
<td>New Hydropower</td>
<td>Wave Energy</td>
</tr>
<tr>
<td>Hydropower Upgrades*</td>
<td>Waste heat recovery and CHP</td>
<td>Tidal Energy</td>
</tr>
<tr>
<td></td>
<td>Hydropower Upgrades*</td>
<td>Coal Technologies w/ CO₂ Separation</td>
</tr>
<tr>
<td></td>
<td>Storage Technologies**</td>
<td>CO₂ Sequestration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Storage Technologies**</td>
</tr>
</tbody>
</table>

* Depending on results from hydropower potential assessment, hydropower upgrades to existing facilities may change categories
** Various storage technologies may fall under different categories

Tentative Schedule

- **Now → February**: Finalize draft resource assessments on primary resources for input into the RPM
  - Presentations to GRAC, Power Committee
- **March → July**: Perform resource assessment for secondary resources for inclusion in the draft Power Plan
  - Presentations to GRAC, Power Committee
- **July → September**: Discuss long-term potential resources for inclusion in draft Power Plan, Action Plan
What’s coming to you over the next few months?*

**November**
- Rooftop Solar, Utility-scale Solar PV – draft 7P resource assessments
- Combined Cycle Combustion Turbine – draft 7P resource assessment
- Hydropower potential scoping study – results, analysis, next steps
- Wholesale Electricity Price Forecast

**December**
- Environmental Methodology

**January**
- Single Cycle and Reciprocating Engine Technologies, Utility-scale Wind – draft 7P resource assessment

* Schedule is tentative and subject to change

Questions?

Photo Credits: Slide 1. Bonneville Dam (NWPPCC), Langley Gulch (NWPPCC), Outback Solar (Obsidian Renewables), Lower Snake River Wind Farm (Puget Sound Energy), Boardman (OPB), Reciprocating Engines (Wärtsilä)
Slide 26. Lower Granite (NWPPCC)