Resource Technology Comparisons

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Resource Technology Comparisons
Outline

- Resource Planning Analysis Process
- Resource Choices
- Average Delivered Cost Analysis
  - Assumptions
  - Baseline Results
  - Risk Variables (Stress)
- Value Adjustment to Delivered Costs
- Summary
Resource Planning Analysis Process

Customer Load Forecast → Planning Assumptions → Screening Analysis → Transmission Deliverability → Economic Analysis, Risk Analysis → Plan(s) Selection → Continuous Process → Resource Commitments → Procurement Process
Resource Choices

- Demand Side Programs
  - Energy Efficiency
  - Demand Response
- Renewable
  - Wind
  - Geothermal
  - Biomass / Biogas
  - Solar Thermal and Photovoltaic
  - Distributed Sources
- Conventional
  - Pulverized Coal
  - IGCC Coal
  - Gas Combined Cycle
  - Gas Combustion Turbine
  - Nuclear

Considerations

Reliability
Environmental Impacts
Potential Carbon Cost
Capital Cost
Average Delivered Cost
Economic Value
Availability
Fuel Price Volatility
Technology Risk
Permit/License Process
Construction Period
Development Risks
Customer Response
Water Usage
Average Delivered Cost Analysis

• Lifetime levelized cost of a resource at an assumed capacity factor
• Used as a screening tool only
• Generally based on utility financing assumptions
  – Goal is to keep technologies on a level playing field
  – Not meant to specify procurement method
• Most effectively used to compare similar duty cycle resources (i.e., base to base, peaking to peaking, etc.)
• Limitations of test
  – Doesn’t capture interaction with existing generation or transmission systems
  – Quantifies cost only, not value
  – Doesn’t capture reliability impacts
  – Doesn’t effectively compare diverse resource types
• Value Adjusted Supply Analysis developed to mitigate the above limitations
## Resource Technologies

### Cost and Performance Assumptions

<table>
<thead>
<tr>
<th>Resource</th>
<th>Capital Cost ($/kw)</th>
<th>–Heat Rate (BTU/kWh)</th>
<th>Capacity Factor</th>
<th>Transmission (Miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Efficiency</td>
<td>N/A</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Solar Thermal</td>
<td>3,500-4,500</td>
<td></td>
<td>42%</td>
<td>20 - 60</td>
</tr>
<tr>
<td>Solar Photovoltaic (utility scale)</td>
<td>4,500-5,500</td>
<td></td>
<td>22%</td>
<td>20 - 60</td>
</tr>
<tr>
<td>Wind</td>
<td>1,600-1,800</td>
<td></td>
<td>30%</td>
<td>5 - 155</td>
</tr>
<tr>
<td>Geothermal</td>
<td>3,000-3,500</td>
<td></td>
<td>90%</td>
<td>10 - 135</td>
</tr>
<tr>
<td>Biomass/ Biogas</td>
<td>1,700-2,100</td>
<td></td>
<td>85%</td>
<td>0 - 155</td>
</tr>
<tr>
<td>Gas Combustion Turbine</td>
<td>600-800</td>
<td>9,400 – 10,650</td>
<td>10%</td>
<td>20</td>
</tr>
<tr>
<td>Gas Combined Cycle</td>
<td>900-1,000</td>
<td>7,100</td>
<td>75%</td>
<td>20</td>
</tr>
<tr>
<td>Nuclear</td>
<td>2,500-3,200</td>
<td>10,650</td>
<td>75%</td>
<td>90</td>
</tr>
<tr>
<td>Pulverized Coal</td>
<td>2,000-2,500</td>
<td>9,000</td>
<td>75%</td>
<td>155</td>
</tr>
<tr>
<td>IGCC Coal</td>
<td>3,500-4,000</td>
<td>9,200</td>
<td>75%</td>
<td>155</td>
</tr>
</tbody>
</table>

Notes: 1. Capital cost is in 2007 dollars and includes AFUDC
Fuel Price Forecast

- Natural Gas
- Coal
- Nuclear

$/MMBtu

Delivered Cost of New Resources
Lifetime Levelized w/ 2007 In Service Date

$/MWH

Capacity Factor

90%  30%  42%  75%  75%  75%  75%  75%

Energy Efficiency  Geothermal  Wind  Solar Thermal  Nuclear  Coal  CC  IGCC

Transmission  O&M  Fuel  Capital / PPA
Delivered Cost of New Generation
Lifetime Levelized w/ 2007 In Service Date
With Stressed Variables

- Loss of Tax Credits
- Higher Capital Cost 40%
- CO2 @ 25$/ton
- Higher Gas 3$/MMBtu
- Higher Capital Cost 25%

$/MWH:
- Energy Efficiency
- Geothermal
- Wind
- Solar Thermal
- Nuclear
- Coal
- CC
- IGCC
“Value” Adjustment to Delivered Cost

• Adjustment captures differing value (i.e., avoided cost) that technologies bring to the system
• This analysis more closely replicates anticipated results from full-blown portfolio level economic analysis
• Delivered cost of generation is put on a capacity and energy equivalent basis to enable fair comparison of resources with different capacity factors
• Incorporates APS system factors
  – Capacity value – contribution to meeting APS peak load, supplemented with CT capacity
  – Energy value (summer on peak delivery versus average delivery) – solar benefit assumed to be 2,000 Btu/kWh times gas price
  – System Integration costs – wind 3.25 $/MWH
Wind Generation on APS Peak Load Day - 2007

Graph showing the relationship between APS System Load, Wind Output, and Aragonne Output (MW) over a 24-hour period. The graph highlights the peak load on APS on a specific day in 2007.
Solar Production Profiles & Typical Summer Load Profile

Solar Production Data from Forecast for July 6, 2015
Summer On-Peak Capacity Factors

Notes:
1. Summer On-Peak defined as June – September, hours ending 13 to 20.
2. Wind is based on a Northern Arizona site with 30% annual capacity factor. Data provided by NREL.
3. Solar is based on trough technology with 6 hours storage, consistent with Solana.
Value Adjustment Example

Operational Credit & Capacity Credit

Delivered Cost

Value Adjusted

Integration Cost & Capacity Cost

Combined Cycle
Solar Thermal
Wind - Exist Trans
IGCC
Wind - New Trans

Levelized Cost ($/MWH)
<table>
<thead>
<tr>
<th>Resource Type</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Efficiency</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>Lowest cost resource, Dependent on customer acceptance and participation</td>
</tr>
<tr>
<td>Geothermal</td>
<td>✓</td>
<td></td>
<td></td>
<td>Limited availability due to competition in S. Calif. Market, Dependent on PTC</td>
</tr>
<tr>
<td>Solar</td>
<td>✓</td>
<td></td>
<td></td>
<td>Dependent on ITC</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>✓</td>
<td></td>
<td></td>
<td>Lowest capital cost, Some carbon risk, Fuel price risk</td>
</tr>
<tr>
<td>Wind – Exist Transm</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>Limited availability</td>
</tr>
<tr>
<td>– New Transm</td>
<td></td>
<td></td>
<td>✓</td>
<td>Long line transm not cost effective</td>
</tr>
<tr>
<td>Nuclear</td>
<td>✓</td>
<td></td>
<td></td>
<td>Lack of recent nuclear construction, Cost uncertainty</td>
</tr>
<tr>
<td>Pulverized Coal</td>
<td>?</td>
<td></td>
<td>✓</td>
<td>Fuel price and abundance, Carbon risk</td>
</tr>
<tr>
<td>IGCC</td>
<td></td>
<td></td>
<td>✓</td>
<td>High investment cost even w/o CCS</td>
</tr>
</tbody>
</table>