King County
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Afternoon Hydropower Session
Exploring the Options
Combined Heat & Power

Presented by
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U.S. Energy Flow – 1999
Net Primary Resource Consumption 97 Quads

Source: Production and end-use data from Energy Information Administration, Annual Energy Review 1999
*Biomass/other includes wood and waste, geothermal, solar, and wind.
U.S. ENERGY USE & EFFICIENCY BY SECTOR

<table>
<thead>
<tr>
<th>Energy Sector</th>
<th>Energy Input (a)</th>
<th>Useful Energy (a)</th>
<th>Percentage Useful Energy</th>
<th>Percentage Wasted Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>22.3</td>
<td>17.9</td>
<td>80.3</td>
<td>19.7</td>
</tr>
<tr>
<td>Commercial/Residential</td>
<td>18.3</td>
<td>13.7</td>
<td>74.5</td>
<td>25.5</td>
</tr>
<tr>
<td>Electricity Generation</td>
<td>34.4</td>
<td>11.0</td>
<td>32.0</td>
<td>68.0</td>
</tr>
<tr>
<td>Transportation</td>
<td>25.9</td>
<td>5.2</td>
<td>20.0</td>
<td>80.0</td>
</tr>
</tbody>
</table>

(a) Energy expressed in Quads
(b) One Quad = 1 quadtrillion Btu = 10^{18} Btus
U.S. POWER GENERATION EFFICIENCY

Thermal power plants generate 91% of electricity
Average thermal efficiency ~ 32%
Average heat rate ~ 10,700 Btu/kWh
Combined-cycle heat rates ~ 7,000 Btu/kWh*
High efficiency CHP heat rate ~ 5,500 Btu/kWh*
Heat Recovery CHP ~ 0 Btu/kWh

* Based on natural gas fuel higher heating value
TYPICAL POWER PLANT

- Thermal Power Plant
- Electrical Power: 25% to 40%
- Waste Energy: 60% to 75%
- Fuel: 100%

COGENERATION PLANT

- Thermal Power Plant
- Fuel: 100%
- Thermal Energy: 60% to 75%
- Electrical Power: 25% to 40%
- Heat Recovery Unit
- Useful Thermal Energy: 40% to 50%
- Waste Energy: 25% to 35%

Waste Energy: 25% to 40%
COGENERATION vs THERMAL ELECTRIC GENERATION

- **Electrical Energy**: 25% to 40%
- **Rejected Waste Heat**: 60% to 75%

- **Electrical Energy**: 25% to 40%
- **Useful Thermal Energy**: 40% to 50%
- **Rejected Waste Heat**: 25% to 35%
Electric Power Savings
Case 1
10 aMW Electrical Conservation

Fuel

Thermal Power Plant
Heat Rate = 7,000Btu/kWh

Electrical Transmission
6% Transmission Losses

Industry/Institutional
10 aMW Conservation

Net Power Savings = 10.63 MW
Net Fuel Savings = 74.4 MMBtu/hr
NO\textsubscript{x} Reduction = 2.87 Tons/year*
CO Reduction = 3.5 Tons/year*
CO\textsubscript{2} Reduction = 36,830 Tons/year
* Based on NO\textsubscript{x} and CO Emissions of 2.5 ppmv
Electric Power Savings

Case 2
10 aMW CHP/Cogeneration

Thermal Power Plant
Heat Rate = 7,000 Btu/kWh
Fuel Saved = 74.4 MMBtu/hr

Industry/Institutional
10 aMW CHP
Heat Rate = 5,500 Btu/kWh
Fuel Used = 55.0 MMBtu/hr

Net Power Savings = 10.63 MW
Net Fuel Savings = 19.4 MMBtu/hr
NOx Reduction = 25.4 Tons/year*
CO Reduction = 10.2 Tons/year*
CO2 Reduction = 8,973 Tons/year

* Based on NOx and CO Emissions of 2.5 ppmv and EPA boiler emission factors.
Electric Power Savings
Case 3
10 aMW Heat Recovery CHP

Net Power Savings = 10.63 MW
Net Fuel Savings = 74.4 MMBtu/hr
NO\textsubscript{x} Reduction = 2.87 Tons/year\textsuperscript{*}
CO Reduction = 3.50 Tons/year\textsuperscript{*}
CO\textsubscript{2} Reduction = 36,830 Tons/year

\textsuperscript{*} Based on NO\textsubscript{x} and CO Emissions of 2.5 ppmv
## Electric Power Savings Summary

<table>
<thead>
<tr>
<th></th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>10 aMW</td>
<td>10 aMW</td>
<td>10 aMW</td>
</tr>
<tr>
<td>Conservation</td>
<td></td>
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<td></td>
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<tr>
<td>Power Savings</td>
<td>10.63 MW</td>
<td>10.63 MW</td>
<td>10.63 MW</td>
</tr>
<tr>
<td>Fuel Savings</td>
<td>74.4 MMBtu/hr</td>
<td>19.4 MMBtu/hr</td>
<td>74.4 MMBtu/hr</td>
</tr>
<tr>
<td>NO\textsubscript{X} Reduction</td>
<td>2.87 Tons/year*</td>
<td>25.4 Tons/year*</td>
<td>2.87 Tons/year*</td>
</tr>
<tr>
<td>CO Reduction</td>
<td>3.5 Tons/year*</td>
<td>10.2 Tons/year*</td>
<td>3.50 Tons/year*</td>
</tr>
<tr>
<td>CO\textsubscript{2} Reduction</td>
<td>36,830 Tons/year</td>
<td>8,973 Tons/year</td>
<td>36,830 Tons/year</td>
</tr>
</tbody>
</table>

Case 1 - * Based on NO\textsubscript{X} and CO Emissions of 2.5 ppmv
Case 2 - * Based on NO\textsubscript{X} and CO Emissions of 2.5 ppmv and EPA boiler emission factors
Case 3 - * Based on NO\textsubscript{X} and CO Emissions of 2.5 ppmv
## Emission Comparison
**Combined Cycle and Combined Heat & Power Facilities**

<table>
<thead>
<tr>
<th>Emission</th>
<th>Combined Cycle FA Technology</th>
<th>Cogeneration LM 6000</th>
<th>Cogeneration Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO(_x) Emissions</td>
<td>574 lb/yr/MW</td>
<td>-4,499 lb/yr/MW</td>
<td>-5,073 lb/yr/MW A Net Emission Reduction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Net Reduction</td>
<td></td>
</tr>
<tr>
<td>CO Emissions</td>
<td>701 lb/yr/MW</td>
<td>-1,338 lb/yr/MW</td>
<td>-2,039 lb/yr/MW Net Reduction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Net Reduction</td>
<td></td>
</tr>
<tr>
<td>CO(_2) Emissions</td>
<td>3,683 tons/yr/MW</td>
<td>2,790 tons/yr/MW</td>
<td>-893 Tons/yr/MW 24 %Less</td>
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</table>
CHP/Cogeneration Advantages

• More Cost Effective
  - Delivered Power Cost 30% less

• More Energy Efficient Power
  - Requires 25% to 100% Less Fuel

• Lower Variable Costs

• Lower Air Emissions
  - Net Reduction of $\text{NO}_x$ & CO Emissions
  - Reduced $\text{CO}_2$ Emissions
Key CHP Obstacles

- High Capital Cost
- High Investment Return Requirements
- Credit Issues
- Non-Alignment of Utility Interests
- High Standby Rates (Non-Cost Based)
- Low Avoided Cost Rates
- Limited Access to Wholesale Markets
Solutions

• Allow utilities to “Markup” purchased CHP power.
• Allow utilities to invest and rate base CHP.
• Cost-based standby/ancillary services.
• Avoided costs based on capital & energy costs of most recent utility owned plant.
Solutions

• Establish Energy Trust/Climate Trust to invest in energy conservation and greenhouse gas mitigation.

• State-backed financing for energy conservation/greenhouse gas mitigation.