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Potential Markets for Fuel Cell/Gas Turbine Cycles

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Market Issues

Fuel Cell/Gas Turbine System Strategic Issues

Complexity: How do the mechanical/thermal/control complexities of gas turbine cycle impact on the practical minimum capacity of this system?

Market: How does the above issue (minimum capacity) impact on selection of target market segments?

Efficiency: What “value” will the market place on higher efficiency associated with the integrated cycle?
Market Issues

Complexity/cost/performance characteristics favor larger capacity/high duty cycle systems.

- Probable range of minimum capacities: ~2-3 MW.
  - Gas turbine equipment availability, cost, performance
  - Control complexity

- Estimated system efficiency: 55%-65% (HHV).

- Siting constraints: Similar to those associated with small gas turbines.
Fuel cells face different challenges in each market sector.

<table>
<thead>
<tr>
<th>Key Markets</th>
<th>Commercial Buildings</th>
<th>Industrial Cogeneration</th>
<th>Distributed Power</th>
<th>Traditional Utility</th>
</tr>
</thead>
</table>
| Fuel Cell Market Drivers | • Highest allowable costs  
• Leverages many attractive fuel cell attributes | • Baseload power  
• Good technical fit  
• High reliability  
• High value for waste heat | • Modularity  
• High efficiency  
• Low emissions  
• Remote dispatch/fully automated | • Large market opportunity |
| Fuel Cell Market Barriers | • Non-traditional power market  
• Short payback requirements by building owners | • Low electric rates reduce allowable costs  
• Competition from other technologies (e.g. GTCC) | • Market has yet to emerge  
• Utilities need to quantify distributed benefits  
• Strongly affected by regulatory changes | • Project scale is large relative to fuel cell module sizes  
• Low allowable costs due to competing technology (GTCC) |
Market Assessment

Market niches accessible to fuel cells are expected to have “allowable” entry costs as high as $2,000/kW*

<table>
<thead>
<tr>
<th>Market Segment</th>
<th>Typical Capacity</th>
<th>Typical Load Factor</th>
<th>Typical Competing Technology</th>
<th>Allowable Cost Targets2 ($/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Entry</td>
</tr>
<tr>
<td>Commercial Building Cogeneration</td>
<td>200 kW - 2 MW</td>
<td>35 - 55%</td>
<td>Purchased Power Marketer/Broker Reciprocating Engine</td>
<td>1,500-2,000</td>
</tr>
<tr>
<td>Distributed Power</td>
<td>5 MW - 20 MW</td>
<td>45 - 55%</td>
<td>GTCC Recuperated GT Reciprocating Engine</td>
<td>1,300-1,500</td>
</tr>
<tr>
<td>Public Power Self-Generation</td>
<td>50 MW - 500 MW</td>
<td>40 - 70%</td>
<td>GTCC Purchased Power Marketer/Broker</td>
<td>1,100-1,500</td>
</tr>
<tr>
<td>Industrial Cogeneration</td>
<td>5 MW - 200 MW</td>
<td>50 - 75%</td>
<td>Gas Turbine Purchased Power Marketer/Broker</td>
<td>1,000-1,200</td>
</tr>
<tr>
<td>Central Station</td>
<td>100 MW - 500 MW</td>
<td>55 - 70%</td>
<td>Pulverized Coal CFBC GTCC</td>
<td>900-1,100</td>
</tr>
</tbody>
</table>

* Based on HHV system efficiency assumption of 40-45%.
1 Typical facility load factor shown; system can be designed for load factors of 80-95%.
2 Total installed system costs, including all owners costs; higher values reflect high value markets with limited market potential, lower values represent broader market opportunity.
## Commercial Market Breakdown

The most attractive U.S. categories have baseload power requirements in the range of 200-1,000+ kW.

<table>
<thead>
<tr>
<th>Building Categories</th>
<th>Baseload Power Requirements (kW)</th>
<th>% of US Commercial Electricity Use (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Large High-Rise Office</td>
<td>1,000+</td>
<td>20%</td>
</tr>
<tr>
<td>• Largest Hospitals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Largest Hotels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Large Shopping Mall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Hospitals (200-300 beds)</td>
<td>200–1,000</td>
<td>35%</td>
</tr>
<tr>
<td>• Large Hotels (750 rooms)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Office (200,000 sq. ft.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• School (125,000 sq. ft.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Large Retail</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Office (50,000 sq. ft.)</td>
<td>50–200</td>
<td>35%</td>
</tr>
<tr>
<td>• Average Hotel (75,000 sq. ft., 125 rm.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Multi-family (100 units)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Fast Food Restaurant (4,000 sq. ft.)</td>
<td>10–50</td>
<td>10%</td>
</tr>
<tr>
<td>• Small Office Building (10,000 sq. ft.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Multi-family (&lt;25 units)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

However, less than 10% have power requirements in the 2 MW range.
Integrated Fuel Cell/Gas Turbine Target Market

Commercial building sector on-site power/cogeneration is not a likely target market.

◆ Minimum practical capacity of integrated systems too large for a major portion of the market (~90%).

◆ Integrated system noise, vibration, complexity, O&M issues similar to those associated with gas turbine and I.C. engine equipment which has tended, in the past, to limit use at building sites.

Larger building complexes (universities, etc.), however, will remain potentially attractive markets.
Distributed power and industrial cogeneration are likely target markets.

◆ Capacity requirements in 3 MW to 50 MW power range, which is consistent with integrated cycle technology characteristics.

◆ Capacity requirements sufficiently low to avoid direct competition with GTCC.

◆ “Entry” markets available at relatively high cost ($1,300/kW) for simple-cycle fuel cells—maybe as high as $1,400/kW to $1,800/kW for high-efficiency integrated cycle.
Market Issues

What “value” will be placed on the very high efficiency of fuel cell/gas turbine cycles in the target markets?

◆ Gas prices are relatively low: recent projections indicate only modest increases over coming decade.

◆ Systems will not be ready for commercial use before the year 2000—economic analyses undertaken using standard utility models assuming gas prices at that time.

◆ “Capital charges” assumed to be 12.6% consistent with utility, IPP, and energy service company ownership (as compared to end user ownership, which would likely place a higher opportunity cost on equity portion of the financing).

◆ Assumed that busbar cost of power must be in 4¢/kWh to 7¢/kWh range to address significant portion of the market in the U.S.
The “Utility Gas” scenario assumes that the price of gas for larger users is $2.20/MMBtu in the year 2000.

**Assumptions**
- Gas price, Yr. 2000: $2.20/MMBtu (DOE/AEO 1996)
- Gas price, annual escalation: 2% (DOE/AEO 1996)
- Capacity Factor: 80%
- Start Year 2000
- 20 year life
- Capital Charge Rate 12.6%
- O&M $0.01/kWh
The “Industrial Gas” scenario assumes that the price of gas for industrial users is $2.60/MMBtu in the year 2000.

### Assumptions
- **Gas price, Yr. 2000:** $2.60/MMBtu (DOE/AEO 1996)
- **Gas price, annual escalation:** 1.5% (DOE/AEO 1996)
- **Capacity Factor:** 80%
- **Start Year:** 2000
- **20 year life**
- **Capital Charge Rate:** 12.6%
- **O&M $0.01/kWh**

### FC/GT System Allowable Capital Cost

<table>
<thead>
<tr>
<th>System Efficiency (HHV)</th>
<th>Allowable Capital Cost ($/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30%</td>
<td>$0.04/kWh</td>
</tr>
<tr>
<td>40%</td>
<td>$0.07/kWh</td>
</tr>
<tr>
<td>50%</td>
<td>$1,500</td>
</tr>
<tr>
<td>60%</td>
<td>$2,000</td>
</tr>
<tr>
<td>70%</td>
<td>$3,000</td>
</tr>
</tbody>
</table>

### Market Issues
The “Alternate” scenario assumes a price of gas $3.00/MMBtu in the year 2000.

**Market Issues**

**Assumptions**

- Gas price, Yr. 2000: $3.00/MMBtu (Alternate Scenario)
- Gas price, annual escalation: 1.5% (Alternate Scenario)
- Capacity Factor: 80%
- Start Year 2000
- 20 year life
- Capital Charge Rate 12.6%
- O&M $0.01/kWh
Observations

The “Value” of high efficiency:

◆ The integrated fuel cell/gas turbine system has increased “value” of $400-$800 per kW as compared to “simple” cycle fuel cells operating at efficiencies of 38% to 45%.

◆ The economics of integrated cycles provides a hedge against volatility in gas prices (most likely upwards given the low baseline escalation assumptions), thereby providing additional “value” via risk mitigation.