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Title:
Potential Markets for Fuel Cell/Gas Turbine Cycles

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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?

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.

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

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

Market Segment	Typical Capacity	Typical Load Factor[1]	Typical Competing Technology	Allowable Cost Targets[2] ($/kW)	
				Entry	Sustained
Commercial Building Cogeneration	200 kW - 2 MW	35 - 55%	Purchased Power Marketer/Broker Reciprocating Engine	1,500-2,000	800-1,300
Distributed Power	5 MW - 20 MW	45 - 55%	GTCC Recuperated GT Reciprocating Engine	1,300-1,500	800-1,300
Public Power Self-Generation	50 MW - 500 MW	40 - 70%	GTCC Purchased Power Marketer/Broker	1,100-1,500	800-1,100
Industrial Cogeneration	5 MW - 200 MW	50 - 75%	Gas Turbine Purchased Power Marketer/Broker	1,000-1,200	8,00-1,000
Central Station	100 MW - 500 MW	55 - 70%	Pulverized Coal CFBC GTCC	900-1,100	700-900

* 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.

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

However, less than 10% have power requirements in the 2 MW range.

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.

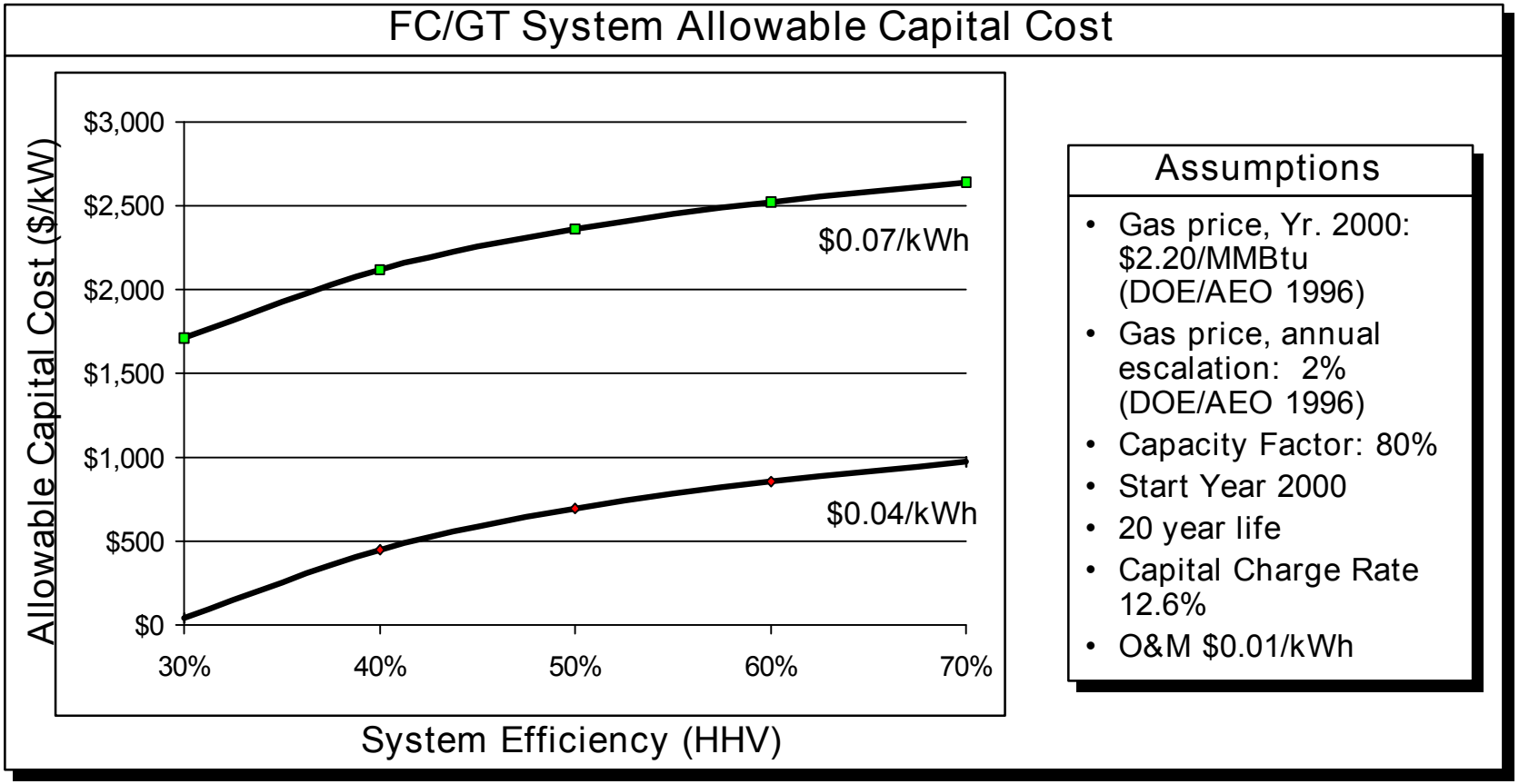
Distributed power and industrial cogeneration are likely target markets.

- 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.

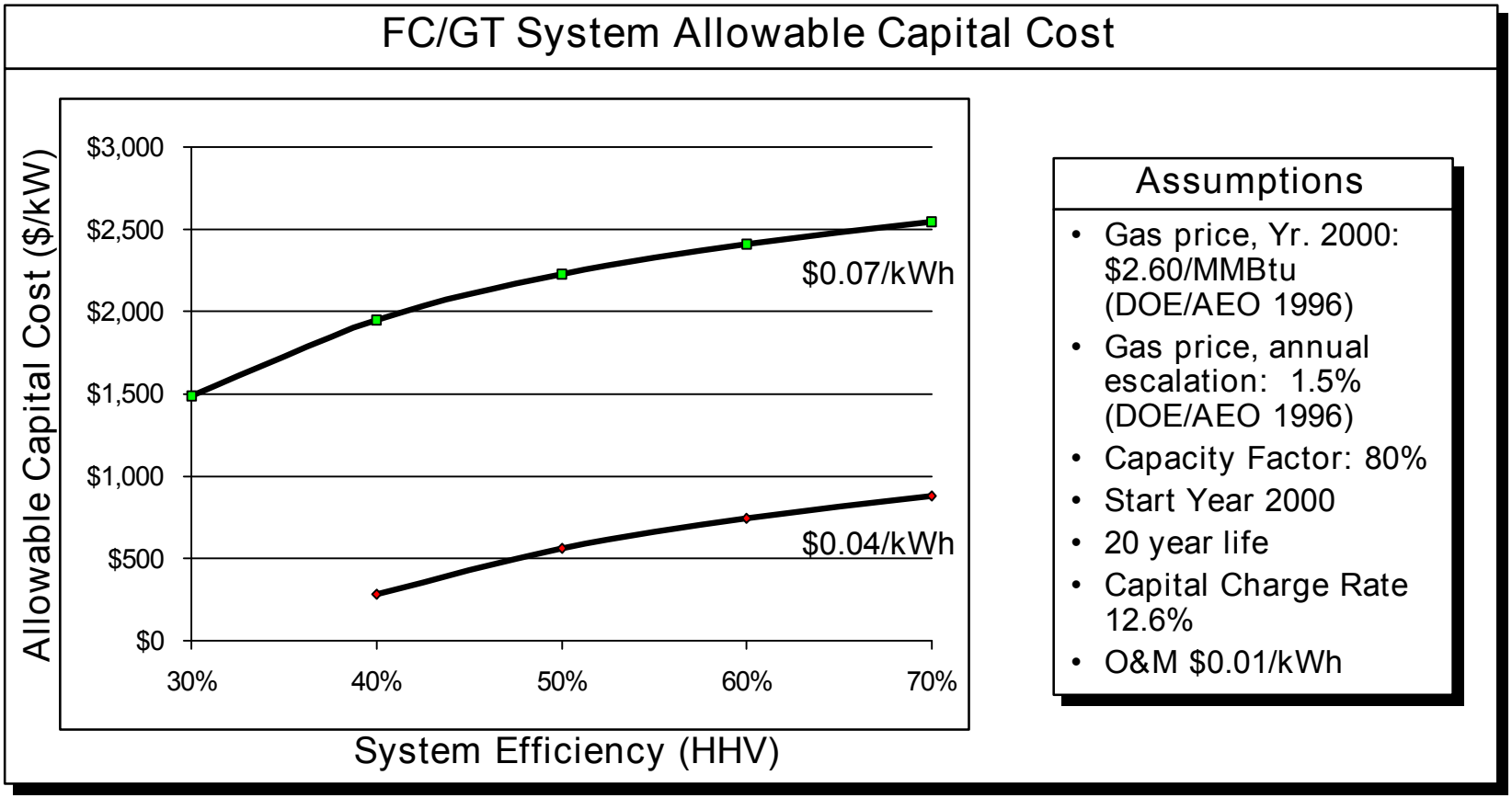
What "value" will be placed on the very high efficiency of fuel cell/gas turbine cycles in the target markets?

- 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.

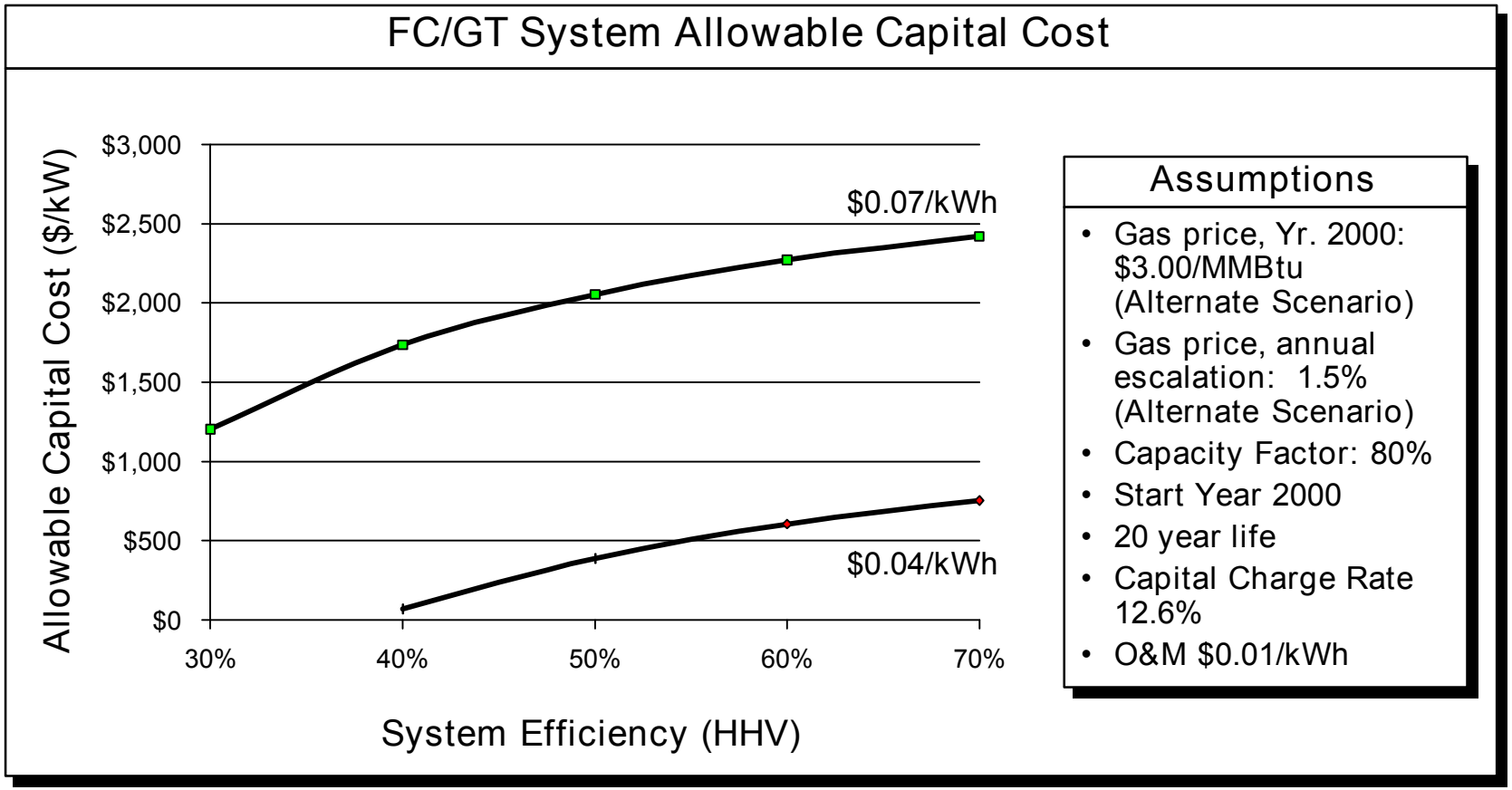
The "Utility Gas" scenario assumes that the price of gas for larger users is $2.20/MMBtu in the year 2000.



The "Industrial Gas" scenario assumes that the price of gas for industrial users is $2.60/MMBtu in the year 2000.



The "Alternate" scenario assumes a price of gas $3.00/MMBtu in the year 2000.



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.