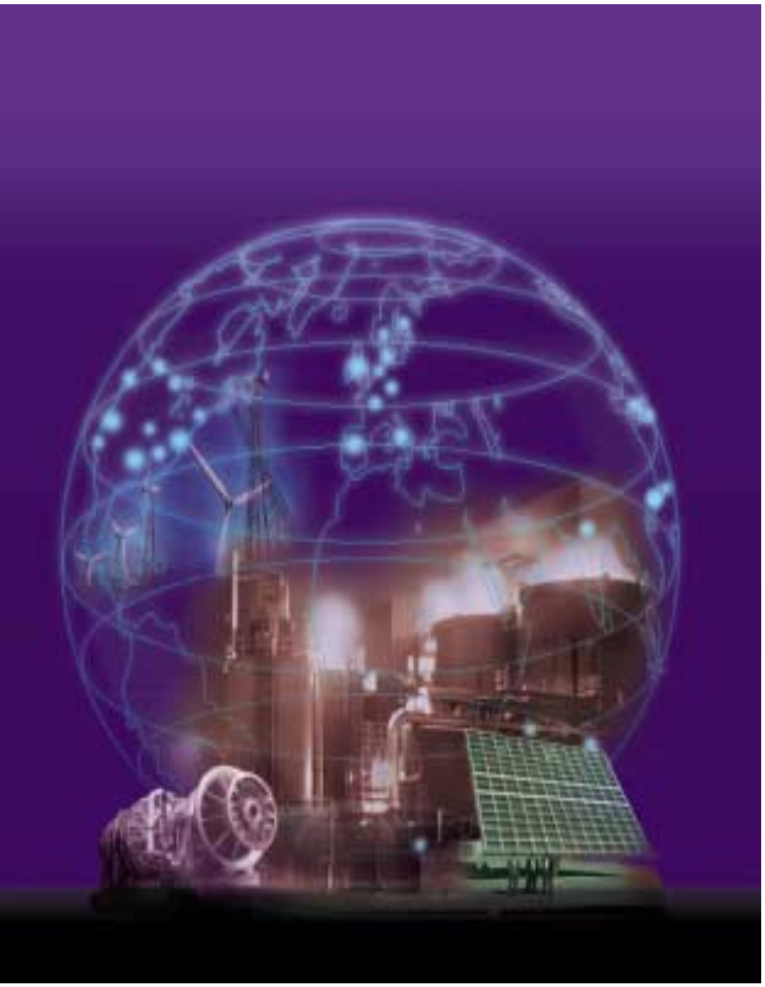

Fuel Cell Hybrid Market Assessment & Early Adopter Study

NETL Hybrid Fuel Cell Workshop
April 16-17, 2002

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- EPRI  Industry Perspectives
- Resource Dynamics  Analysis

Presentation Outline

- Executive Summary
- Methodology and Approach
- Summary of Findings
- Early Adopter Results
- Conclusions
- Recommendations

Executive Summary

Positioning of Fuel Cells into Market Needs

***Fuel Cell Hybrids Offer Best Option* for Low Cost Power**

Low-Cost Power

- SOFC-CT
- MCFC-CT
- SOFC
- MCFC

Premium Power

- SOFC
- PEMFC
- MCFC
- PAFC

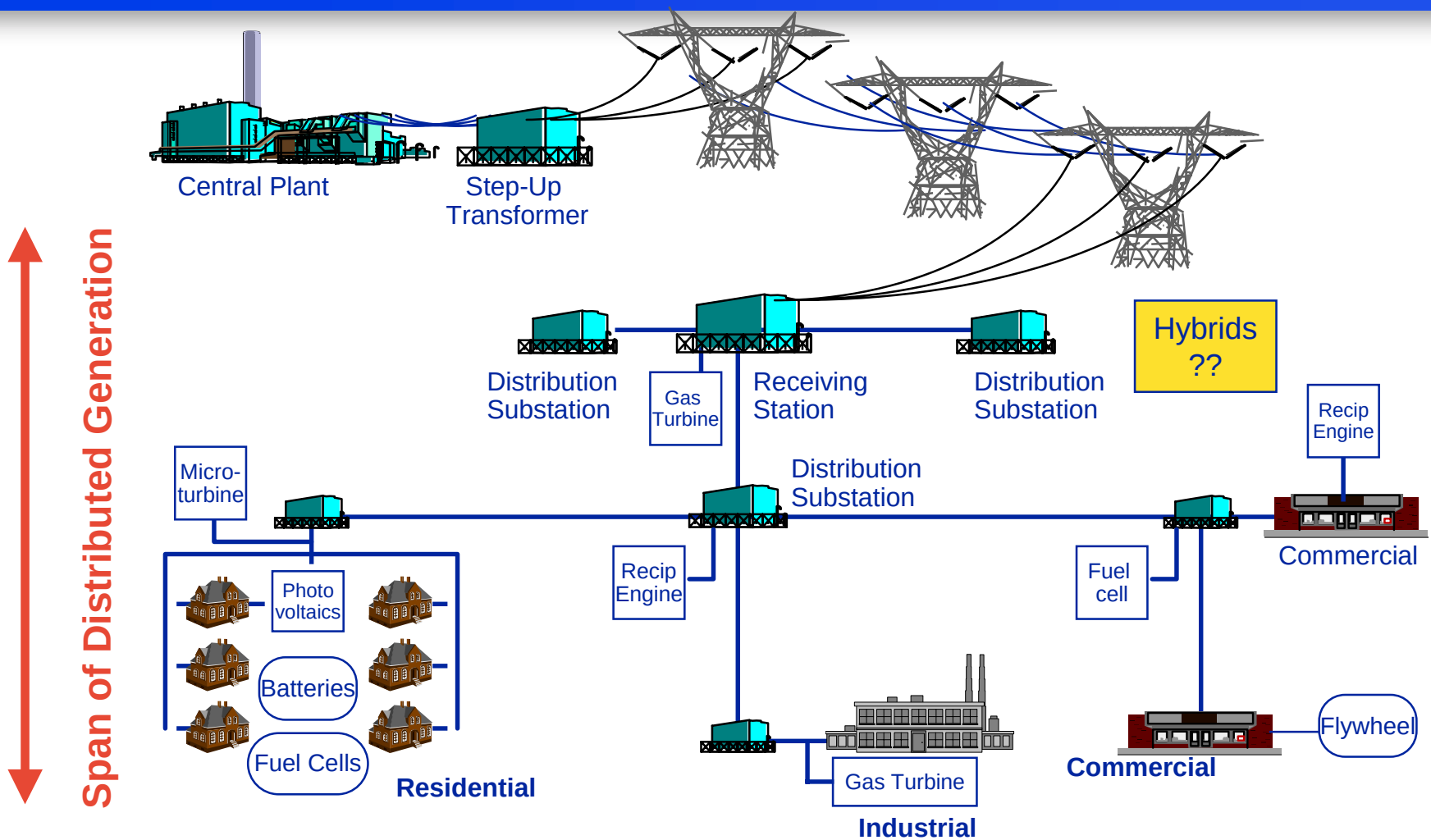
CHP

- SOFC
- MCFC

Peak Shaving
Load Mgmt

- PEMFC

Executive Summary: Objective assess the market for fuel cell hybrids in the evolving electric enterprise



Executive Summary
Project Objectives

- Estimate market potential for high efficiency fuel cell hybrids in the U.S.
- Segment market size by commercial; industrial and aggregator applications
- Identify and evaluate potential early adopters
- Use results to prioritize future R&D investments and development efforts

Executive Summary:
Input Hybrid Performance and Cost Parameters
Established by Vendors and DOE

Parameter	A	B	C
Power output MW	0.3	1.5	25
Electric efficiency %^	63	66	70
Efficiency @ 50% load	63	62	65
NOx lbs/MWH		<0.0004	
Installed Cost $/kW			
Current (2005)^	1,600	1,400	1,100
Future (2010+) *	1,100	940	660
Long-Term (2015+) *	780	700	575
O&M cost mills/kWH	7	6	6
Availability %	95	95	95

^provided by vendors; * provided by NETL/ DOE

Executive Summary
Potential Applications for Fuel Cell Hybrids

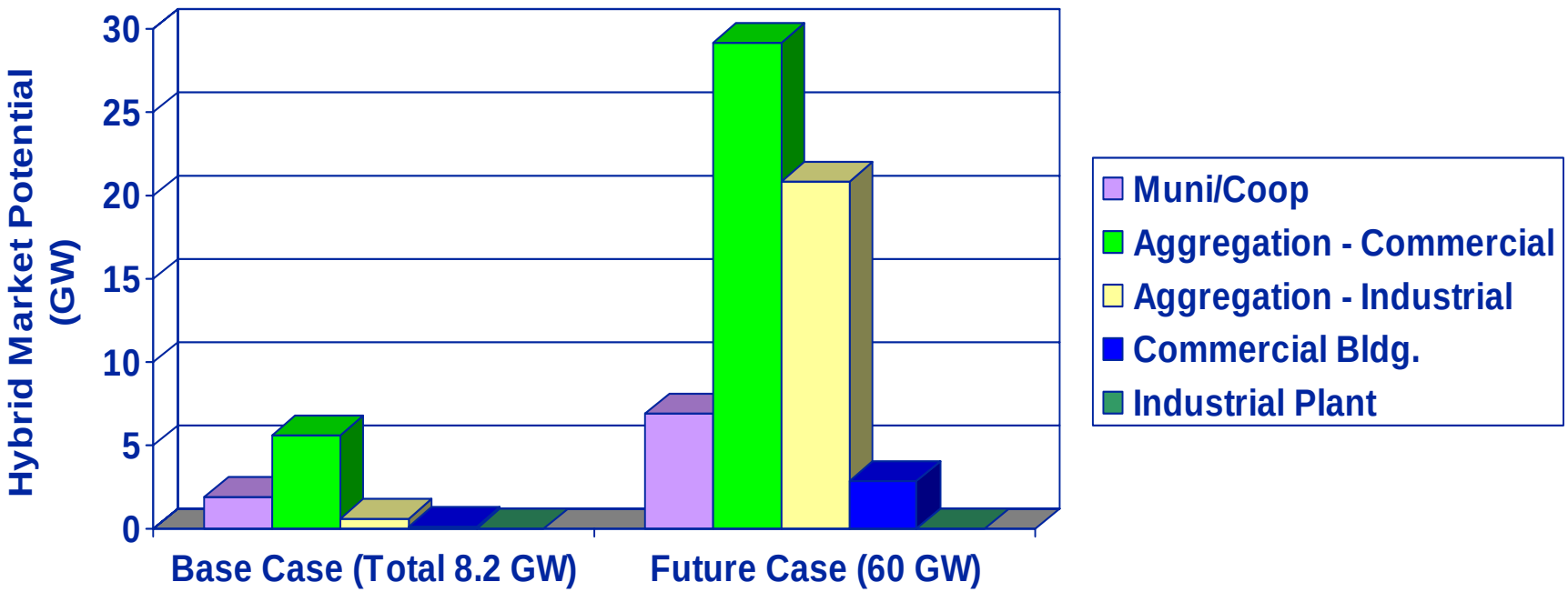
Application	Business Cases
Dispersed Power	Community Power (C/I Aggregation)
C&I	On-Site All Electric On-Site Cogeneration
Mass Markets*	Community Power (Residential Aggregation)

* Not in scope of study

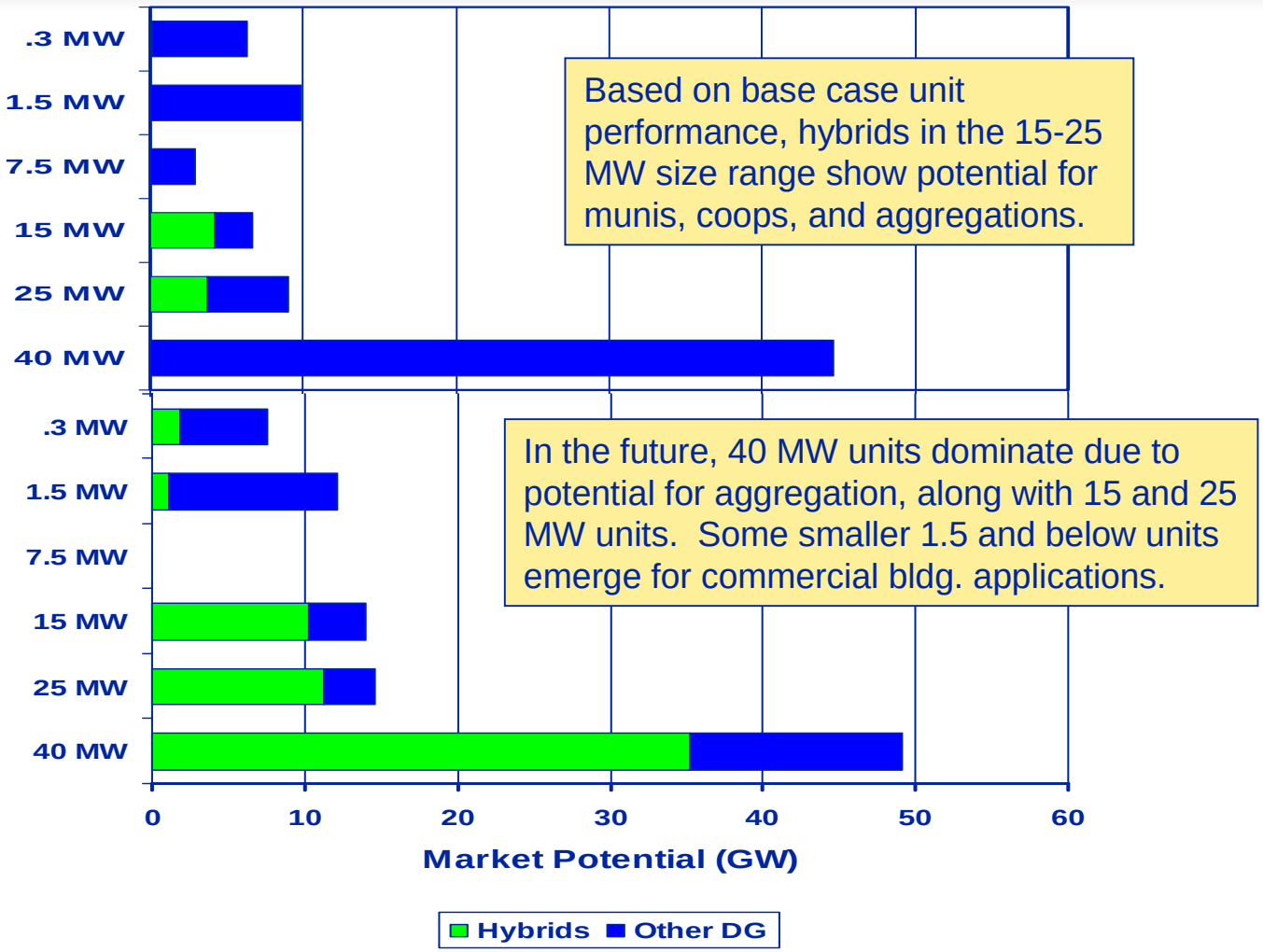
Summary of Results

Current and Future Hybrid Markets Favor Aggregation

Base case: hybrids at $1,100-1,600/kW (2005)
Future case: hybrids at $600-1,100/kW (2010+).

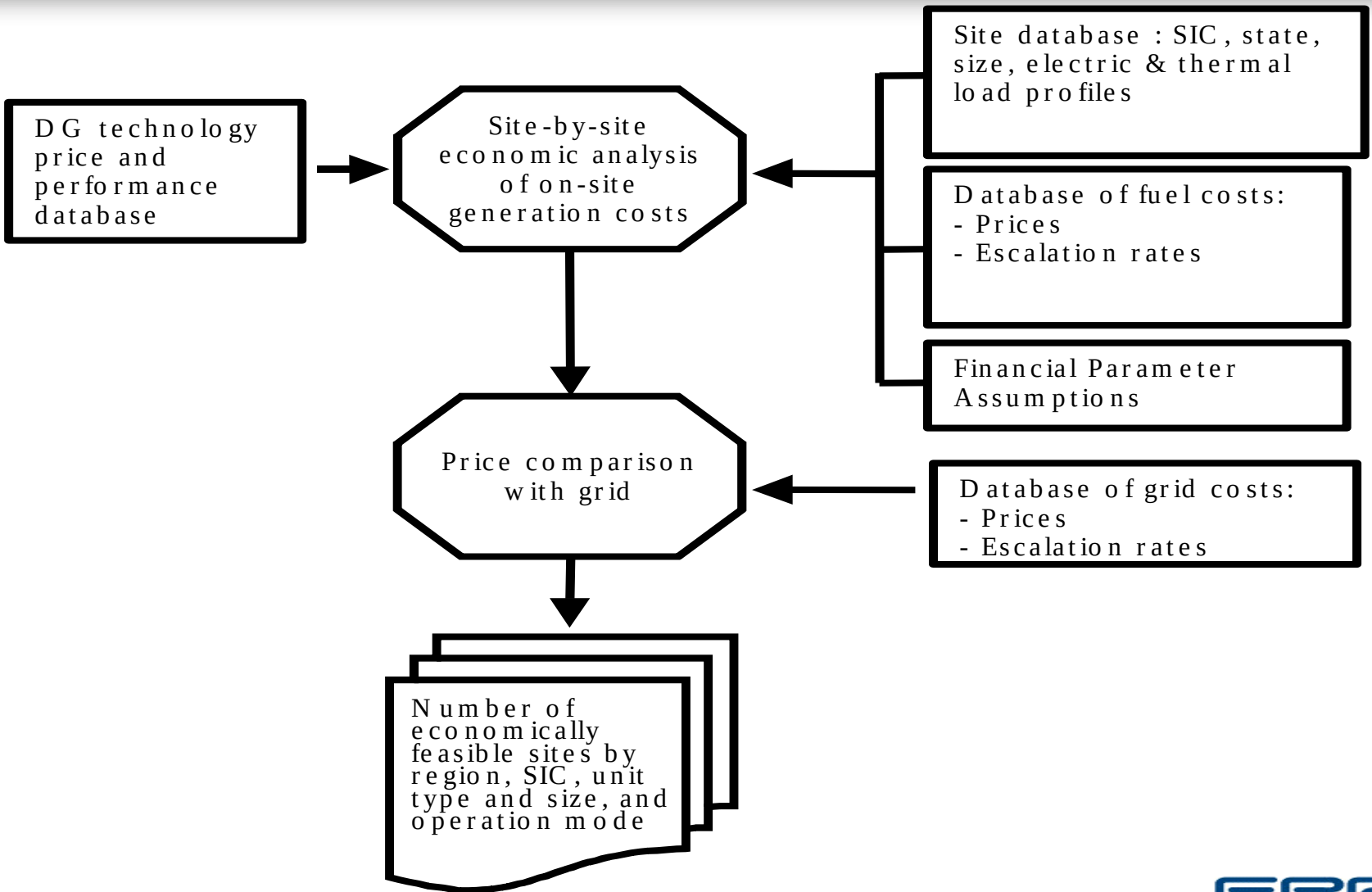


Summary of Results: Current and Future Fuel Cell Hybrids Favor Larger Sizes



Market Assessment Methodology

Developed and Validated in Prior EPRI and RDC Studies



Methodology and Approach

Conservative Financial Parameters Mirror Market Conditions

- Project life is 10 years
- Typical taxes and insurance are included
- Units sized to meet 50% of electric load for industrial; at average demand for commercial
- Electricity is not sold back to the grid
- Grid backup power is required, and included in energy bill
- Credit is given for avoided interruptions

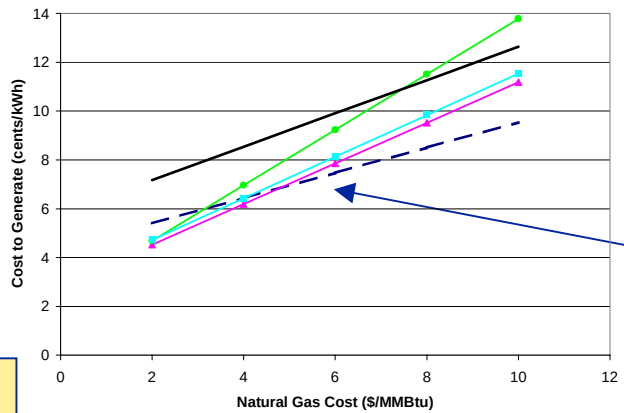
Fuel Cell Hybrids Win With Higher Energy Prices

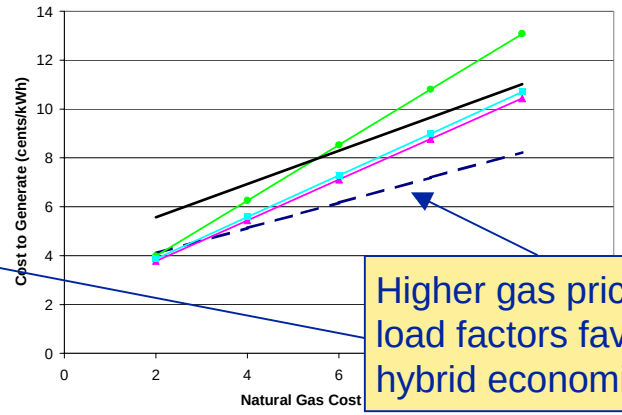
65% Load Factor

100% Load Factor

Baseload

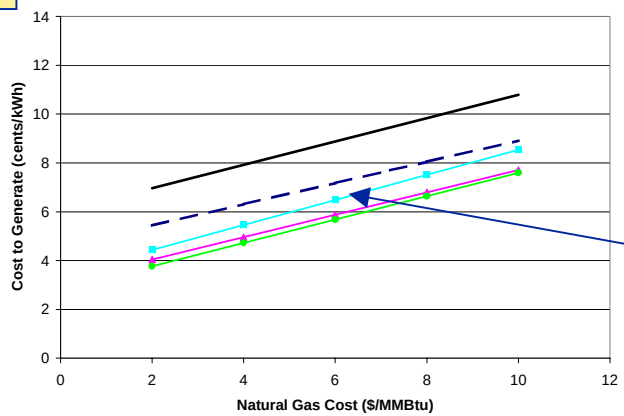
Cogeneration

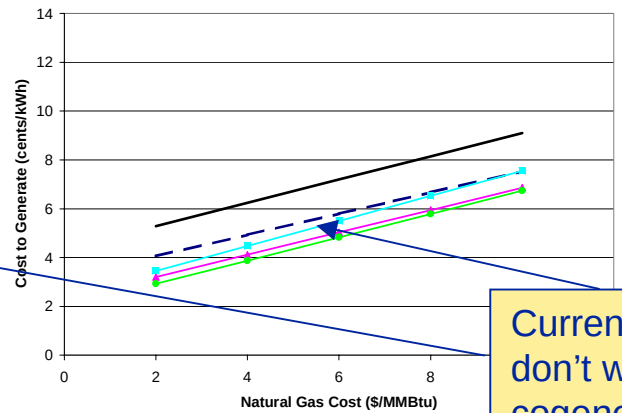




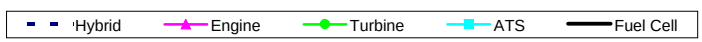
Note: Current 1-5 MW Unit

Higher gas prices and load factors favor current hybrid economics





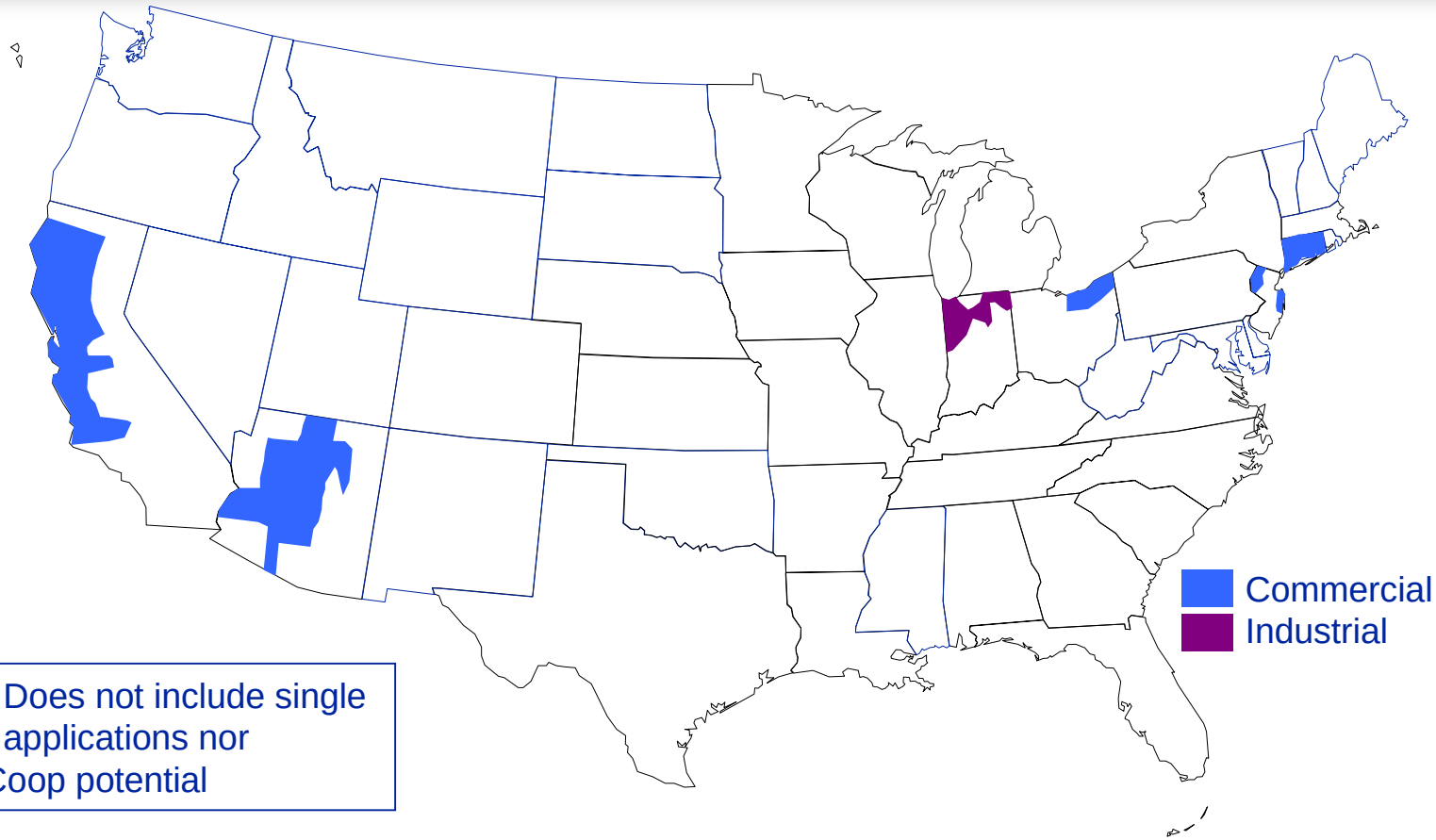
Current hybrids don't win with cogeneration



Methodology and Approach
Modified to Examine Potential for Aggregation

- **Aggregation offers improved economics**
  - Displaces more expensive electricity (small sites pay more for the same amount of electricity than large sites)
  - Few sites large enough to warrant larger hybrids; much more potential to aggregate numerous small/medium sites
- **Key Assumptions and Methodology**
  - Assumed aggregations of 100 sites (commercial) and 10 sites (industrial)
  - Representative blend of buildings to approximate aggregate load curve and applied diversity factor
  - Assumed no cogeneration
  - Incorporated typical unbundled distribution rates with no transmission charges
  - Applied 3 percent electric distribution losses

Results
Limited Areas Favor Aggregation*
Based on Current Fuel Cell Hybrid Targets



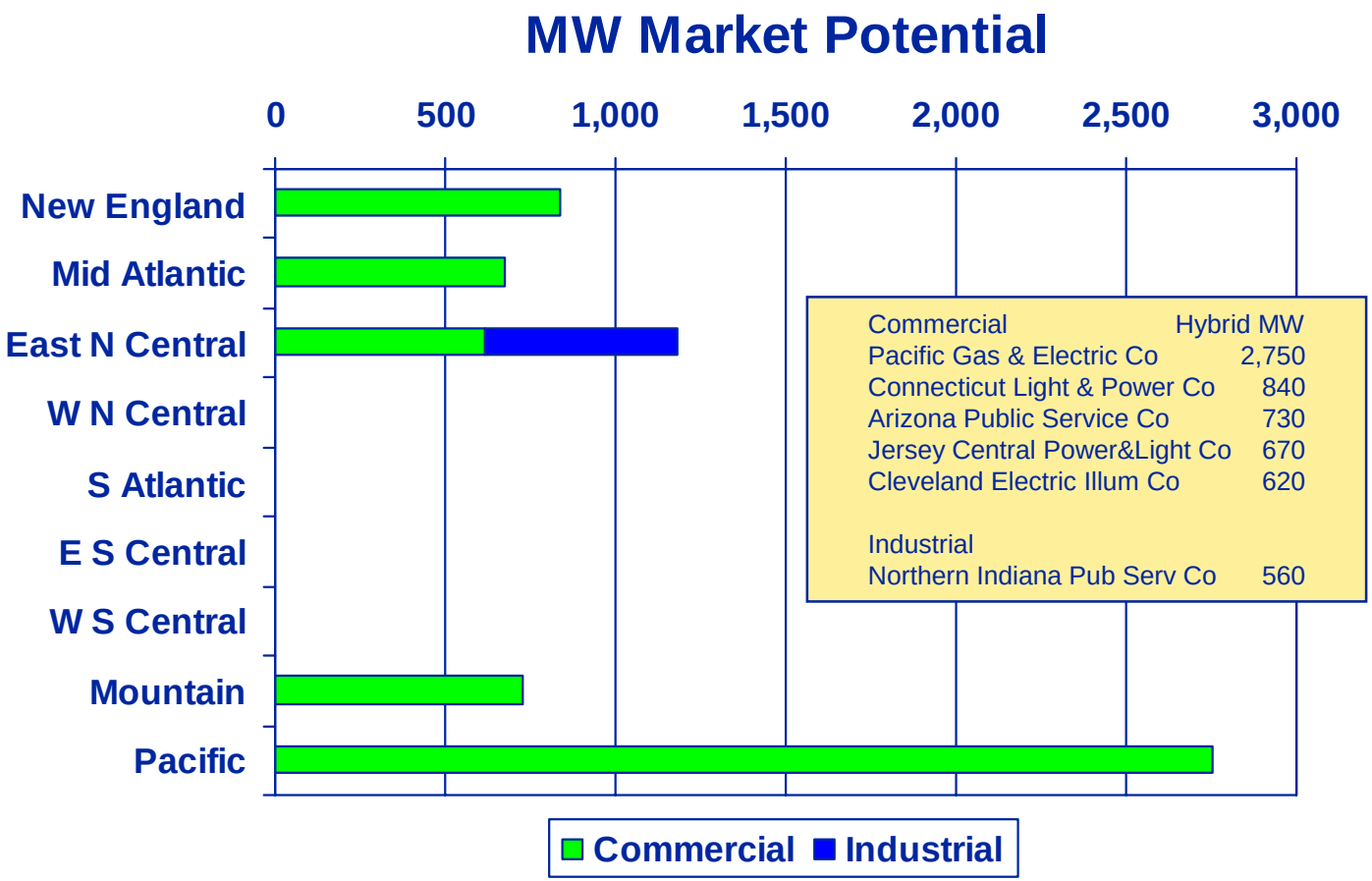
*Note: Does not include single facility applications nor Muni/Coop potential

Results

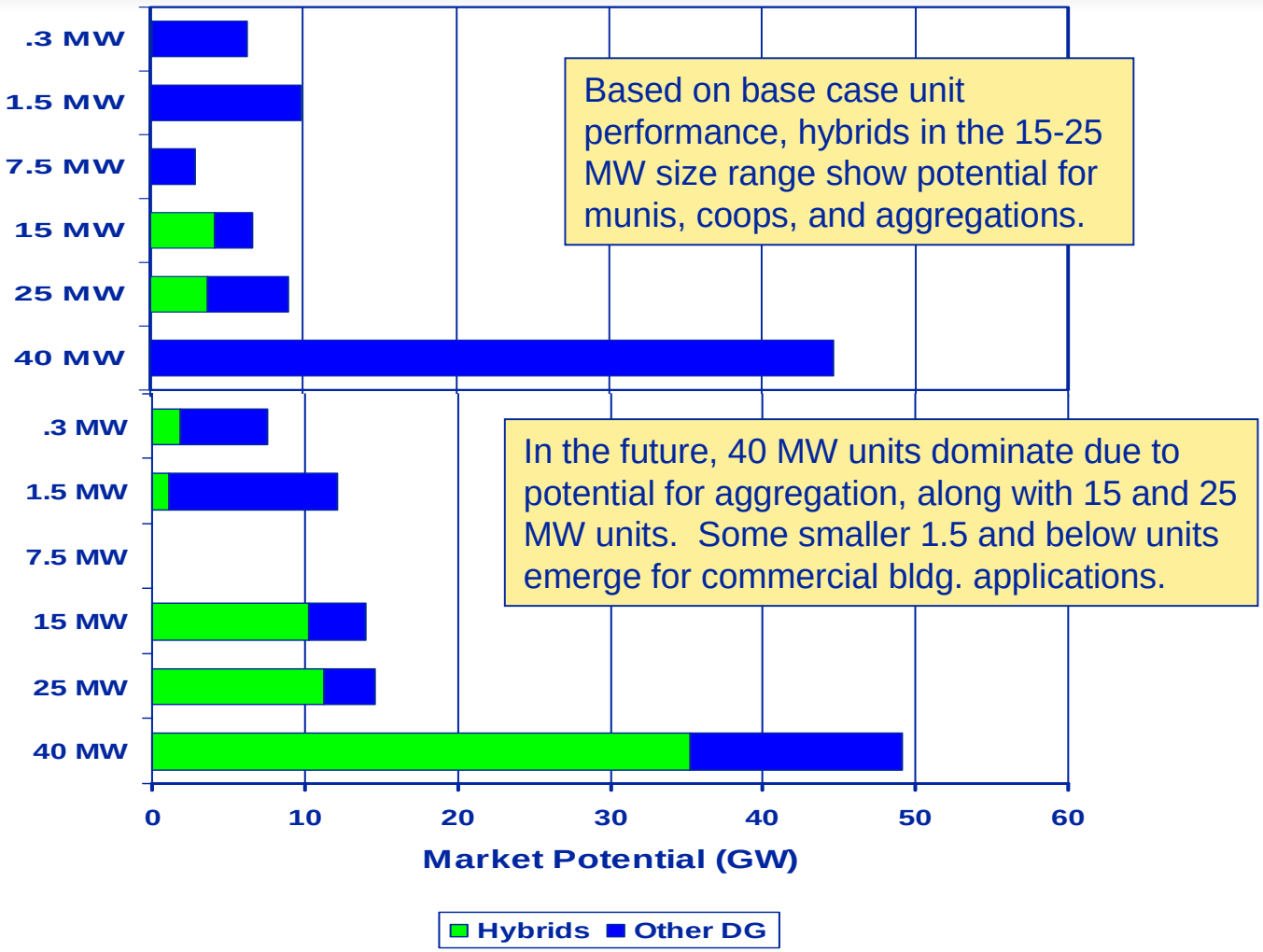
Markets for *Near-Term Fuel Cell Hybrids Could Serve Concentrated Regions*

Aggregations Focused on Commercial Sector

Note: Does not include single facility applications nor Muni/Coop potential

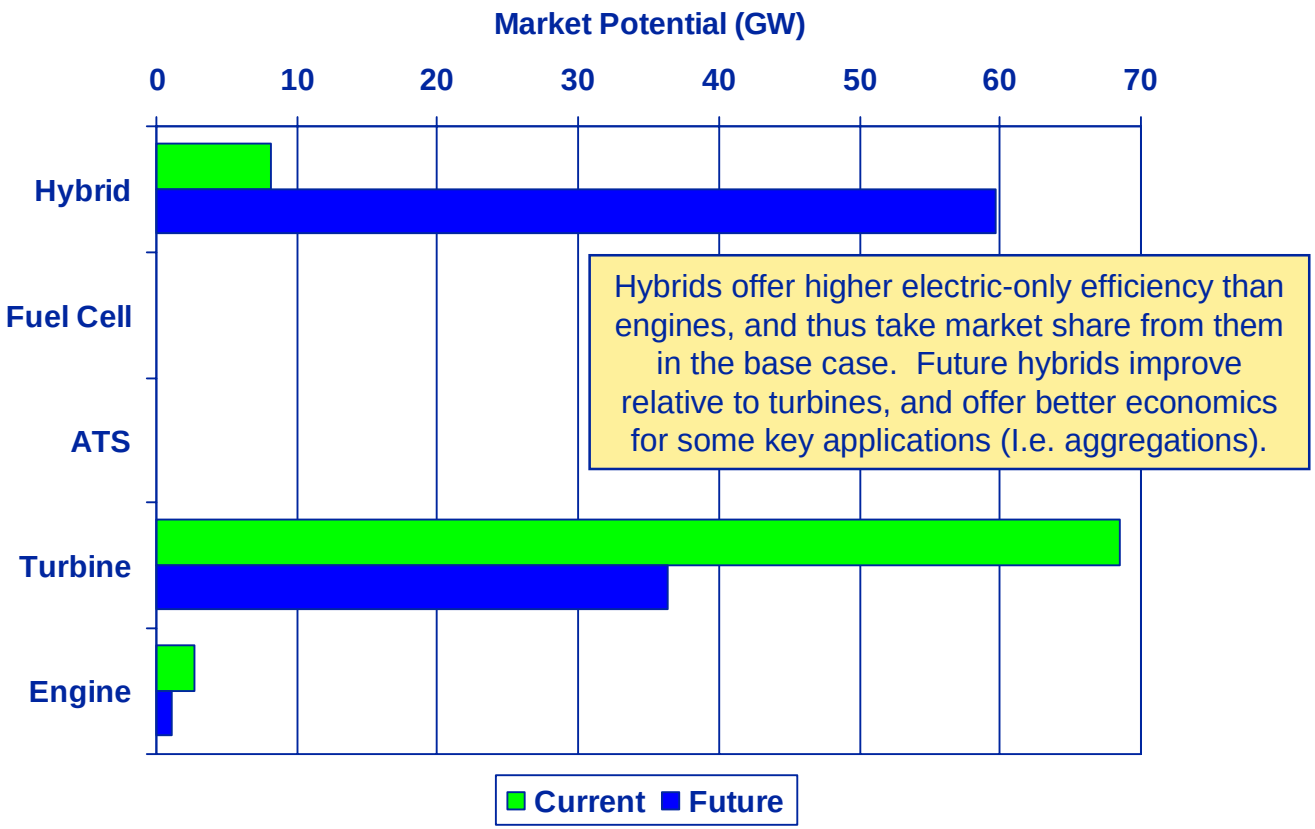


Results: Current and Future Fuel Cell Hybrids Favor Larger Sizes



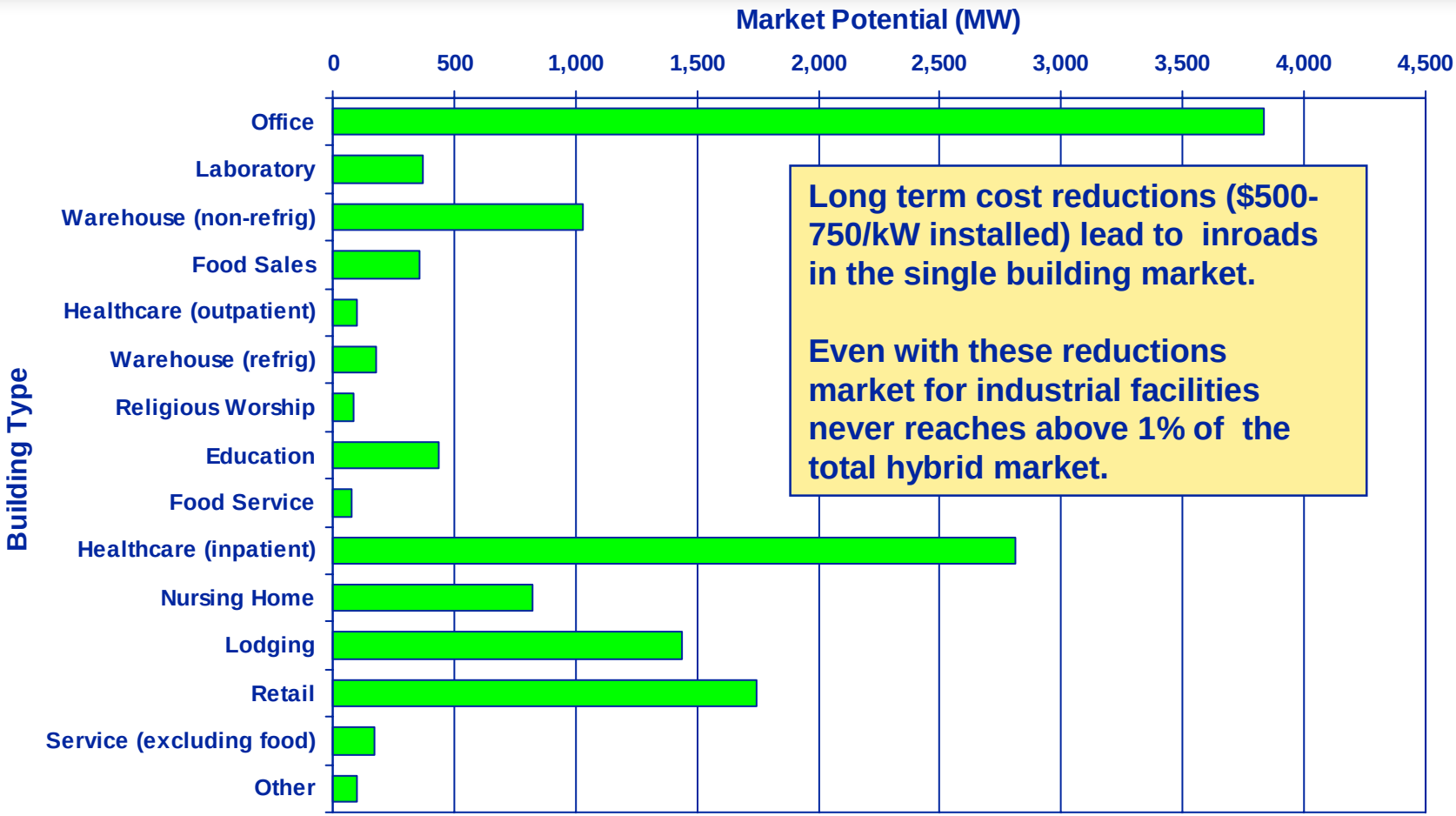
Results: Improving Cost & Performance of Hybrids Increases Market

Engines Lose Current Market, and Future Hybrids Also Beat Turbines



Results

Long-Term Cost Reductions Required to Meet Needs of Single Building Market

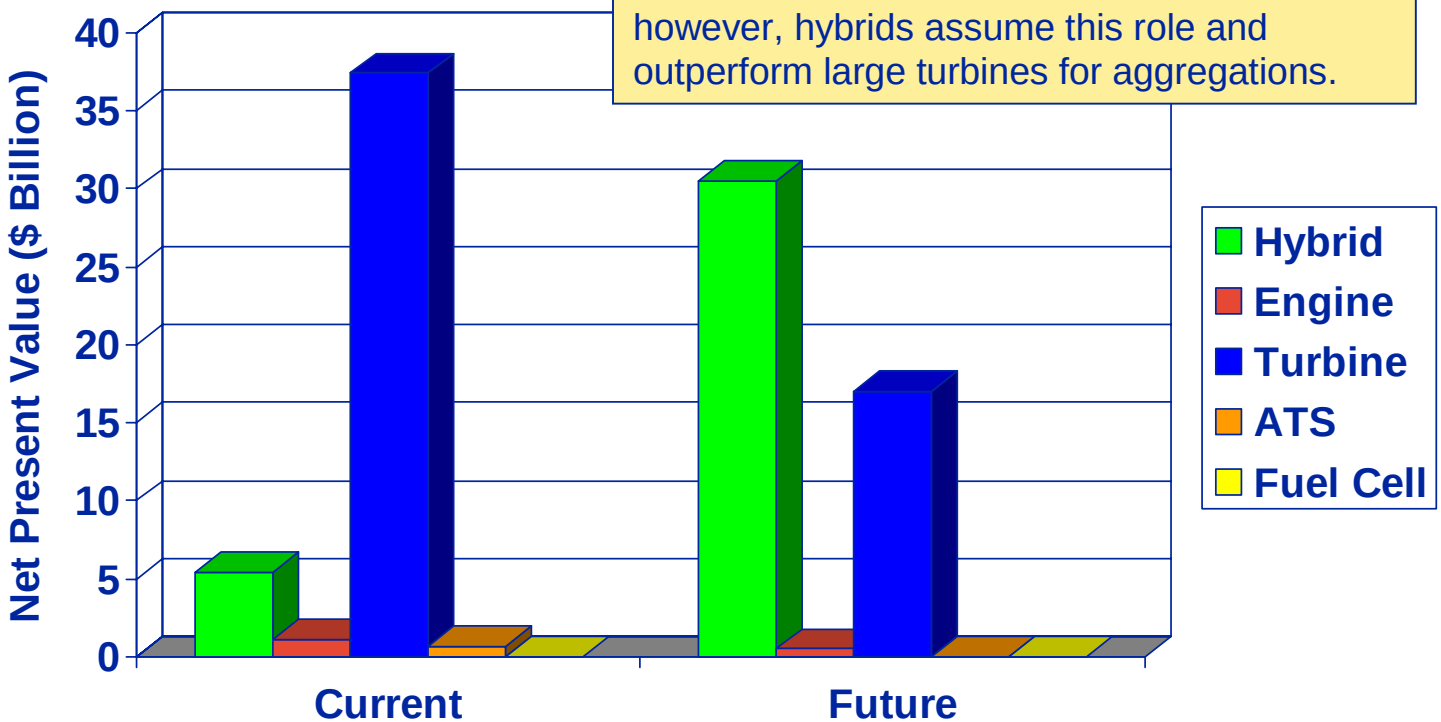


Results

Pay off for Future R&D in Hybrids

Hybrids Offer Over $30 Billion Potential Benefit From R&D

Turbines dominate the base case, particularly large 25-40+ MW units to serve aggregations of commercial customers. In the future, however, hybrids assume this role and outperform large turbines for aggregations.



Early Adopter Interviews Designed to Explore Needs and Barriers to Hybrids

- Questionnaire designed to explore needs and barriers to hybrid adoption. Also includes questions addressing:
  - Generation - Confirm how they currently procure generation.
  - Capacity and Environmental Issues - Capacity and distribution system constraints, line losses and emissions constraints
  - Customer Issues - Reliability or power quality concerns
  - Ideal fuel cell hybrid " product attributes"
  - Interviewees encouraged to speculate as to ideal applications for hybrids
- Contacts made include Munis (3), Coops (3), and Aggregators/Independent Power Producers (AES and Calpine)

Results
Municipalities Appear to be Leading Early Adopter Candidates

- Survey results reveal:
  - Munis cover urban areas where noise and emissions are constrained and thus would favor hybrids
  - Economics of hybrids can work due to relatively high cost of purchased and generated power
  - Hybrids 10-40 MW are large units for munis but may replace entire generation base
  - Munis would like to install hybrids on customers site and maintain them for the customer, but must be smaller (up to 5 MW) sizes
- Potential trends towards municipalization could be emerging niche for hybrids

Results
Early Adopter Findings

- Coops less likely to be early adopters
  - They tend to have favorable power purchase agreements and shy away from large (10-20 MW) generating units
  - Their location in rural areas makes low emissions less of a consideration
- Aggregator/Independent Power Producers want larger generating units
  - They tend to build 100-1,000 MW units, so 10-20 MW is too small
  - Potential niche applications include joint ventures with a large customer, or a baseload unit for winter minimum load conditions when 10-20 MW blocks of capacity are desirable
  - T&D constrained regions

Conclusions

- Near-term cost goals for fuel cell hybrids result in limited C&I market potential.
- Aggregation improves the prospects for near-term hybrids;
- Larger fuel cell hybrid systems are more competitive
- Future markets emerge in commercial sector only when long-term hybrid cost reductions are attained

Implications

- Given the limited competitiveness of near-term hybrids the early adopter implications are very important;
- Net present value shows high return on investment for hybrid development;
- To realize largest market, future R&D should focus on long-term cost improvement
- To achieve the aggressive cost goals - A broad industry / public partnership may be needed

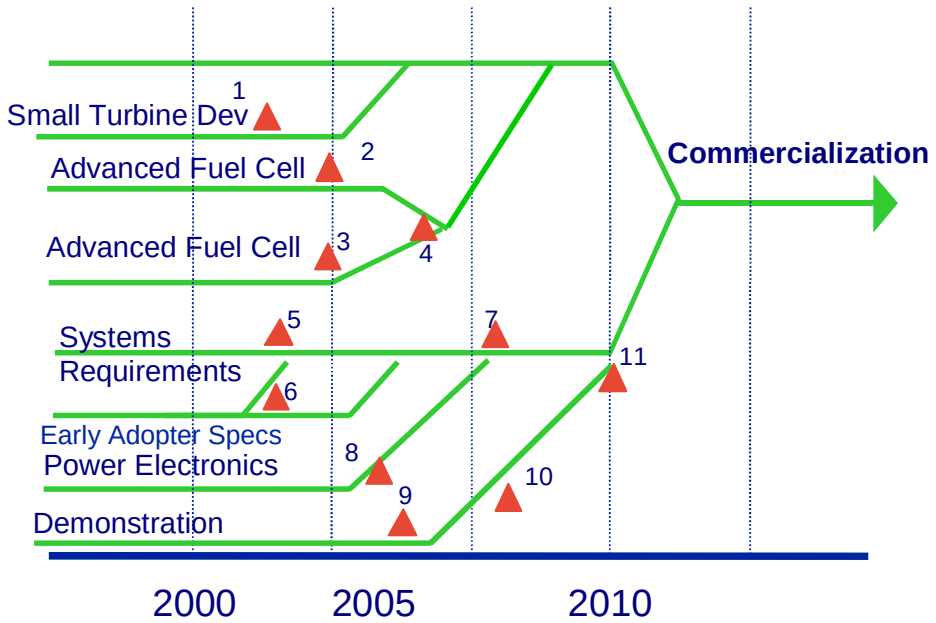
Recommendations

- Develop product requirements based on study findings

- Develop hybrid systems that offer biggest breakthrough potential based on:
  - Lowest installed cost
  - Lowest O&M
  - Attractive - siteable package for on-site or community power markets
  - Maintain efficiency advantage

Example Roadmap for Breakthrough Fuel Cell Hybrids

Develop, Demonstrate and Commercialize Advanced Hybrid Systems



Milestones

1. Adv. new CT's & microturbines for hybrids
2. Adv. MCFC development
3. Adv. SOFC development
4. Down-select best fuel cell for hybrid
5. System Requirements and Integration best hybrid system
6. Early Adopters set specifications and targets
7. Advanced Fuel Cell Hybrids achieve 65%
8. Low cost power electronics
9. 1st generation hybrid tested
10. Demonstration and market introduction 2-5 MW hybrid system on natural 2nd generation system
11. 25-50 MW Hybrid-Power Block for use Coal Gasifiers