Markets and Challenges for Residential CHP

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arpa-e GENSET Meeting
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Agenda

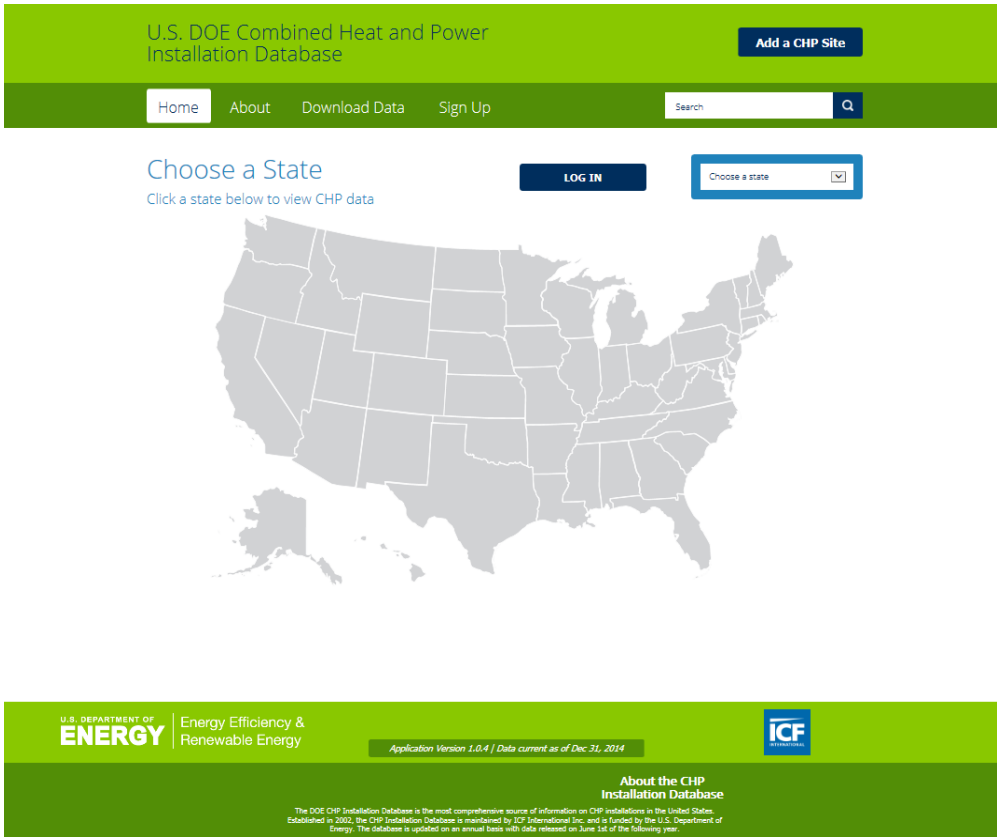
- **Overview of U.S. CHP market**
- **History and challenges of residential CHP**
- **Economics of CHP and technology implications**

Key Points

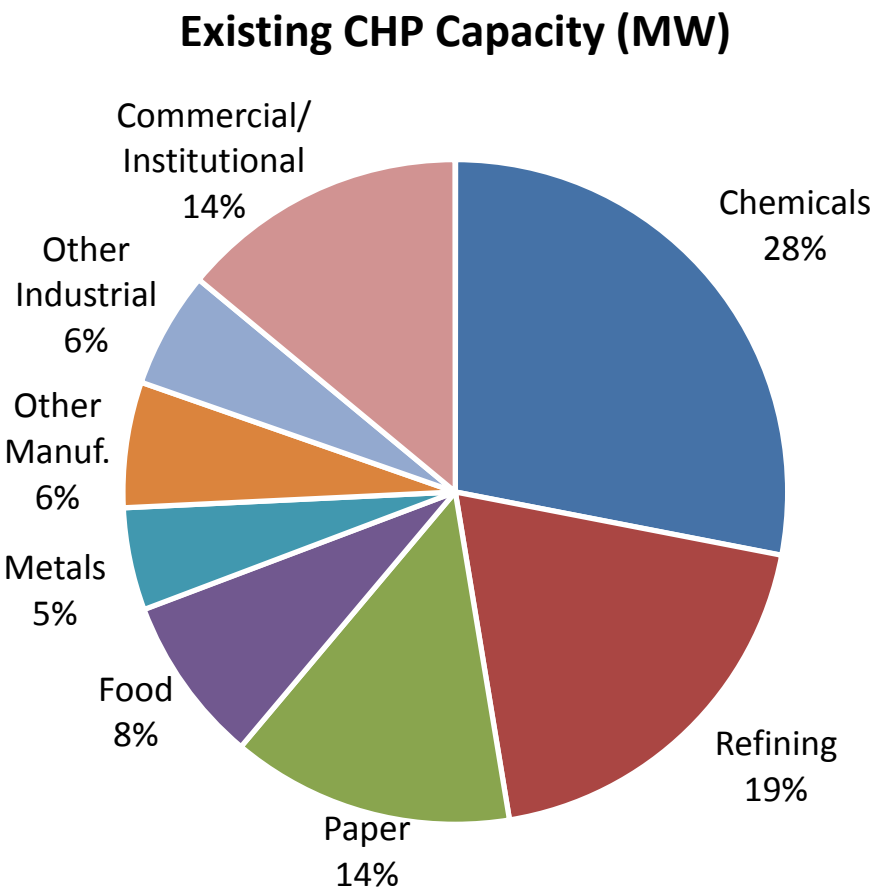
- **Residential CHP is a challenging market**
- **CHP is about integration – integration and application need to be addressed in the initial design**
- **The goal is overall efficiency – electrical efficiency is a trade-off**

DOE CHP Installation Database

- **Updated on June 1st, 2015.**
  - Reflects all US CHP installations through December 31, 2014.
- **Includes 4,400 sites and 82.7 GW of capacity.**
- **Website features a section to download the database with summary tables.**
- **Can be accessed at: https://doe.icfwebservices.com/chpdb/**



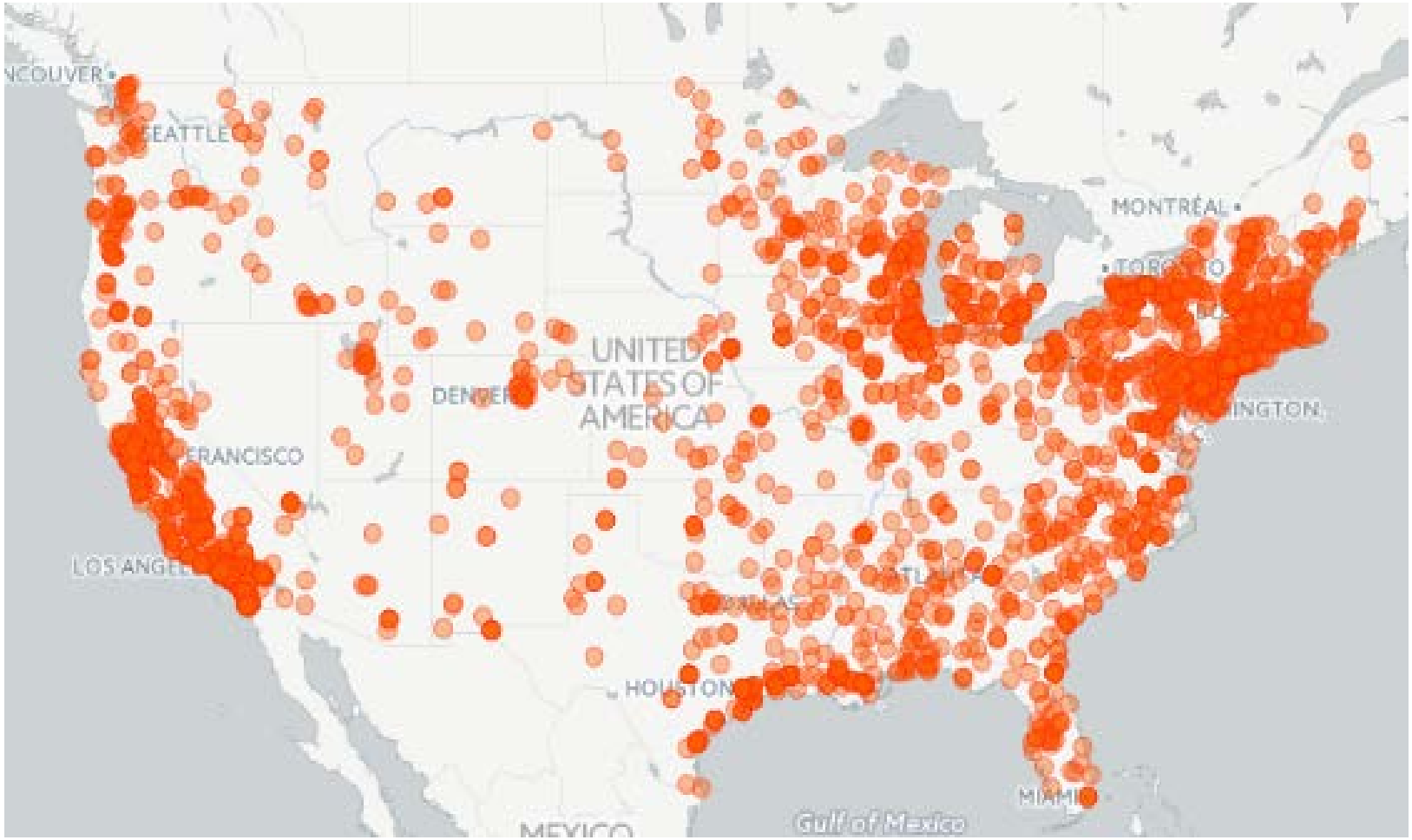
CHP Today in the United States



- **82.7 GW** of installed CHP at over 4,400 industrial and commercial facilities
- 8% of U.S. Electric Generating Capacity
- Avoids more than **1.8 quadrillion Btus** of fuel consumption annually
- Avoids **241 million metric tons of CO_2** compared to separate production

Sources: DOE/ICF CHP Installation Database (U.S. installations as of December 31, 2014);
EIA http://www.eia.gov/todayinenergy/detail.cfm?id=8250
Energetics, "US Manufacturing Energy Use and Greenhouse Gas Emissions Analysis, November 2012"

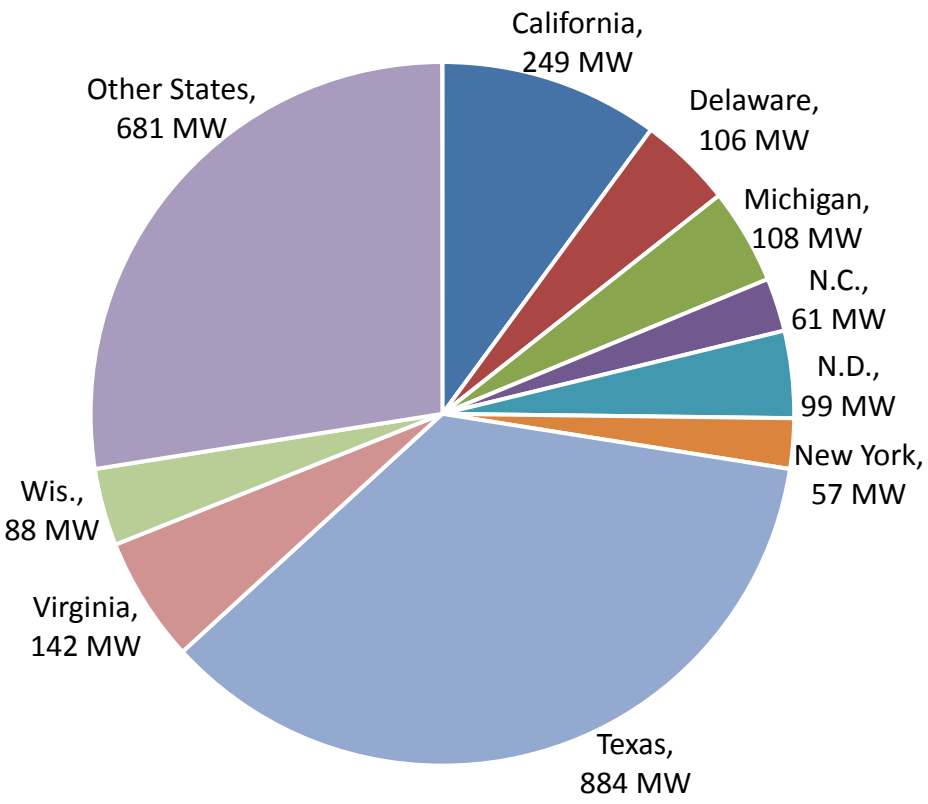
CHP is Located in Every State



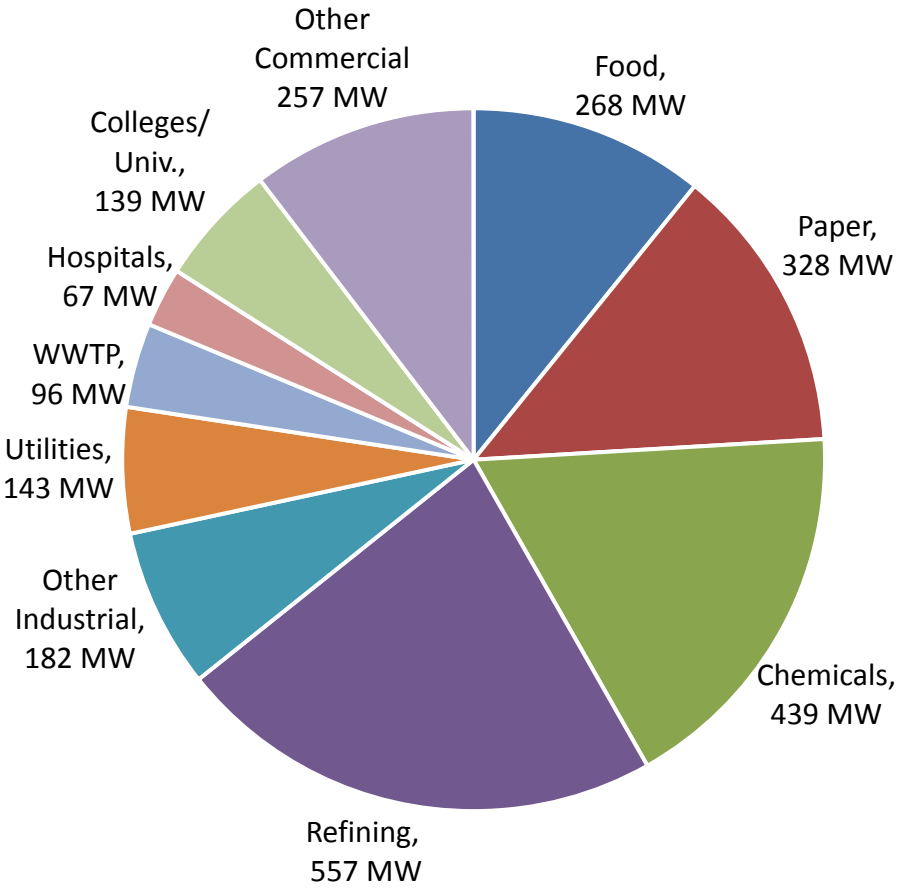
Source: CHP Association

CHP Additions 2012-2014 (2.5 GW)

By State (MW)



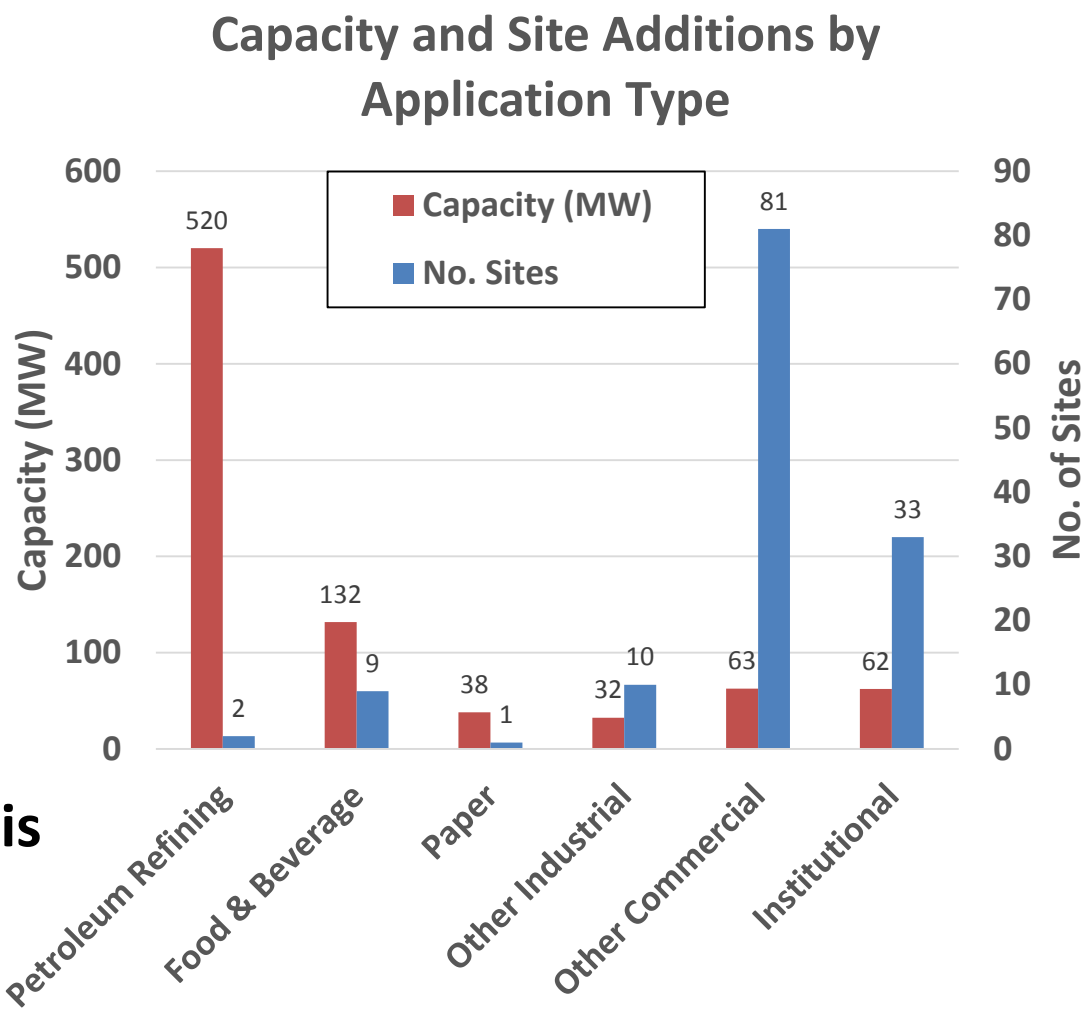
By Application (MW)



Source: DOE CHP Installation Database (U.S. installations as of Dec. 31, 2014)

CHP Additions 2014

- 136 sites and 847 MW installed in 2014
- 65% of sites are reciprocating engines
- 61% of capacity is combined cycle
- 75% of sites and capacity is fueled by natural gas

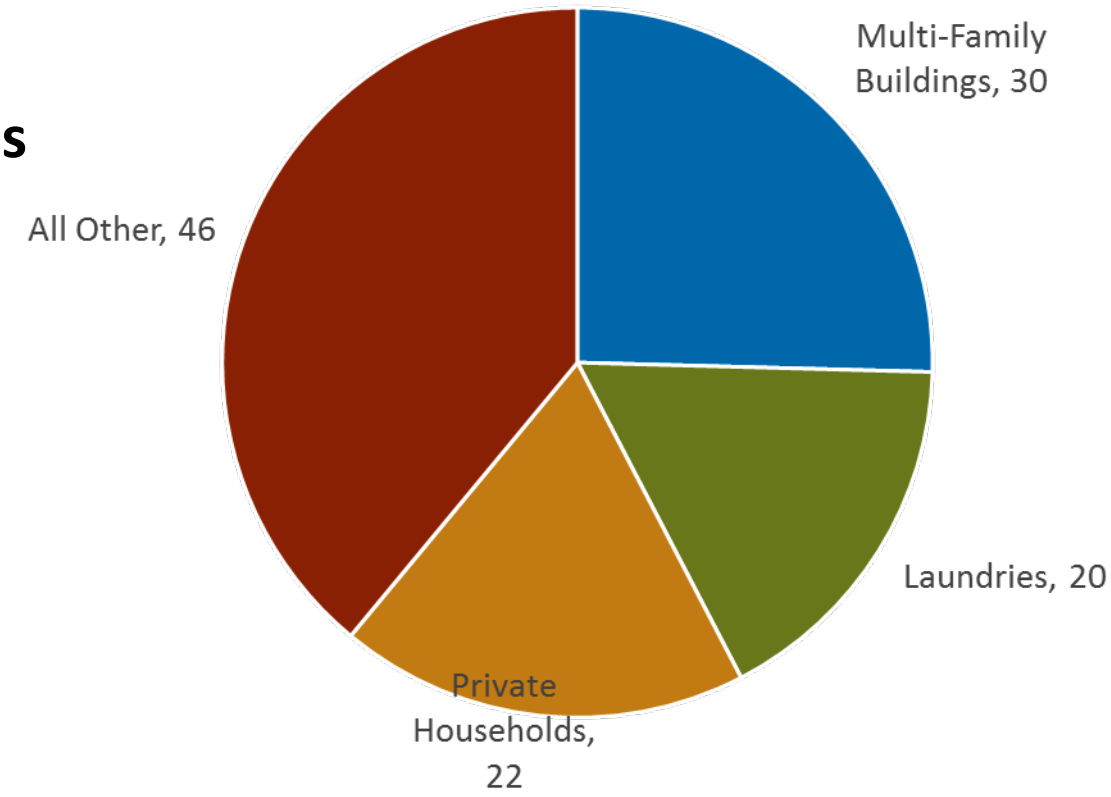


Source: DOE CHP Installation Database (U.S. installations as of Dec. 31, 2014)

CHP <10 kW

- **Database identifies 118 CHP sites < 10 kW**
- **Multifamily, private households, and laundries are the largest categories**
- **Households could be under-reported**
- **Mostly gas, mostly recip engine**

CHP Facilities < 10 kW



Source: DOE CHP Installation Database (U.S. installations as of Dec. 31, 2014)

History of Residential CHP

- **Attempts at micro-CHP residential systems go back to at least the 1930s.**
- **More recent systems based on engines (Honda, etc) have had some limited application in Europe and Japan.**
  - High electricity prices, attractive load profiles
- **The barriers in the U.S. are as much economic and institutional as technical.**

Historical Challenges for Residential CHP

- **Diseconomies of scale**
- **Sensitivity to noise, vibration, and emissions**
- **Aversion to complexity and operational concerns**
- **Need for electrical interconnects and other supporting equipment**
- **Sensitivity to first cost – lack of equipment displacement**
- **Lack of sophisticated economic analysis**

CHP Value Proposition

- **Integrated system provides combined electric and thermal service**
  - Typically adding on-site generation to a thermal system
- **Higher capital and fuel cost is offset by avoided electricity purchase at fuel/electric price differential (spark spread) and higher efficiency**
- **Avoiding thermal energy equipment can offset part of the increased capital cost**
- **The winner - CHP system that avoids the need for a boiler where electricity is much more expensive than fuel**
  - Typically matched to thermal load
  - Electrical efficiency is a design trade-off

Drivers of Good CHP Economics

- Consistent thermal load
- Good thermal/electric load match – size and timing
- High utilization
- Equipment displacement
- Low-cost fuel
- Low capital cost/green field installation

Implications for GENSET

- **Integration with the thermal side is critical for the economics**
- **Load factor and load match are very important**
- **High electrical efficiency is a trade-off with thermal requirements and the cost of the thermal equipment**
- **GENSET design basis – small output/high utilization – this makes hot water a much better market than space heating**
  - Used everywhere
  - Year-round requirement
  - Built-in energy storage/load match

GENSET Pro Forma – Key Inputs/Assumptions

- **Capital cost – 2 x engine cost**
- **Avoided electricity and gas price - $0.12/kWh, $10/MMBtu**
  - Is net metering required for high electric utilization? What is the value of electricity?
- **O&M cost - $100/yr**
- **Capacity factor – 85%?**
- **Thermal utilization – 60 – 80%?**
- **Thermal load match – assume 100% for hot water storage**

GENSET Pro Forma

- **For baseline assumptions, levelized cost of electricity (LCOE) for electricity-only might be in the 15 to 20 cent/kWh range.**
- **1 kW output and 40% electric efficiency implies about 1 – 1.2 kW thermal output – maybe 3.8 MBtu/hr.**
  - About half the output of a typical stove burner, 1/10 to 1/20 output of a gas water heater.
- **Applying the thermal displaced energy from a 75% efficient water heater brings the incremental electricity cost down to 12 to 15 cents/kWh.**
- **Simple payback 10 to 12 years.**

Conclusions

- **CHP is a wide-spread, well-established efficiency technology.**
- **Most of the existing capacity is in larger systems but there are successful smaller systems.**
- **Load match, high utilization, and system integration are critical to economic performance.**
- **Residential CHP has been a difficult market to reach, mostly for non-technical reasons.**
- **System design needs to consider the end use and total system integration up front.**

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