

the Energy to Lead

Expanded Use of Combined Heat and Power (CHP) for Homes and Small Businesses

**ARPA-E Workshop on Efficient Small Engines
for Combined Heat and Power (CHP)**

William E. Liss
Managing Director, End Use Solutions

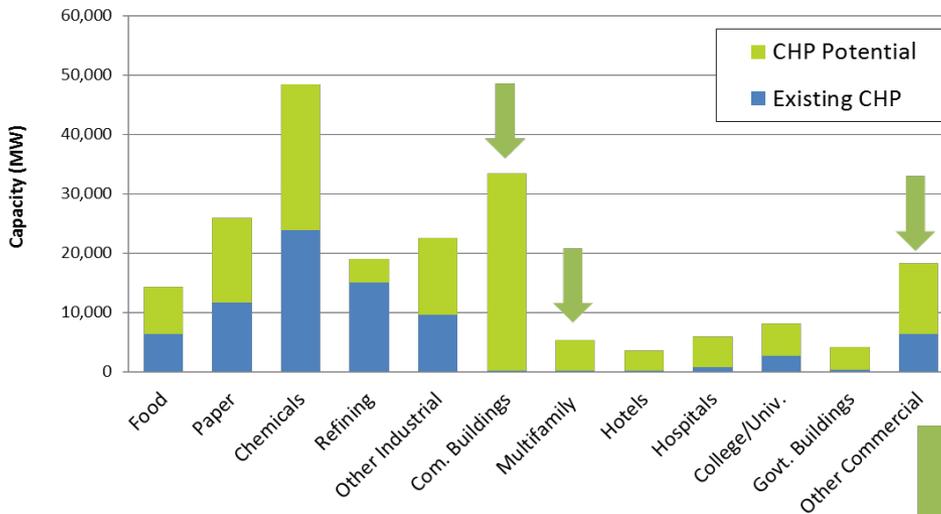
CHP in the U.S.

- > Over the past twenty-five years, U.S. has made good progress on CHP system deployment
- > Mainly industrial, with recent growth in commercial and institutional sector
- > Residential (single & multifamily) and light commercial sector, however, a large and untapped opportunity
- > Multi-faceted challenges addressing this sector
 - Right technology and product attributes
 - Right price and service requirements & infrastructure
 - Right regulatory environment

U.S. CHP Market

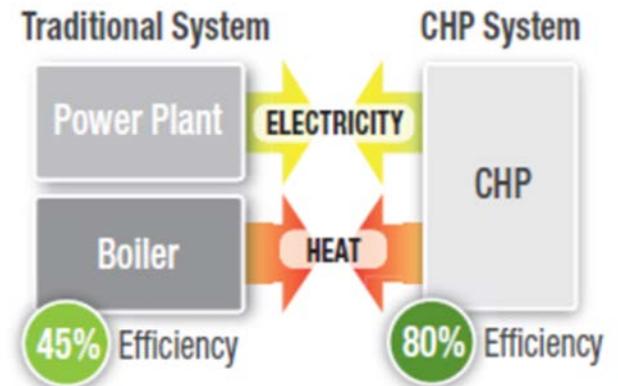
- 82 GW of installed CHP at almost 4,000 industrial and commercial facilities (2011)
- Avoids more than 1.8 quadrillion Btus of fuel consumption annually and 241 million metric tons of CO₂
- Majority of CHP Capacity in Industrial Sector and most (over 70%) use natural gas

Existing CHP (82 GW) vs. CHP Potential (130 GW) by Application



Plus single-family homes

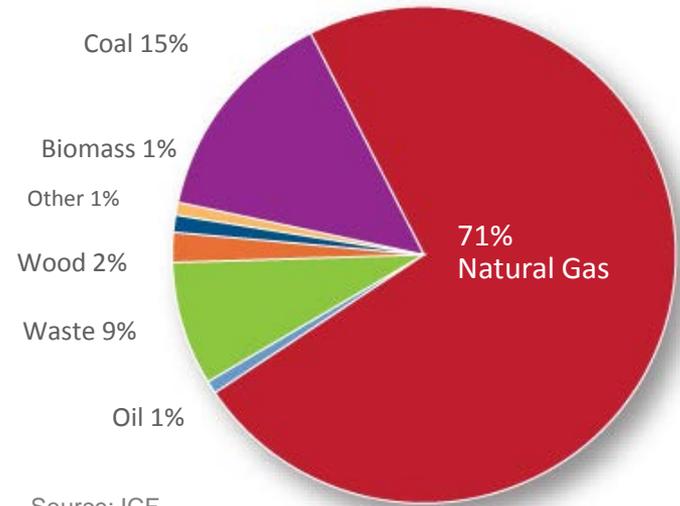
CHP Process Flow Diagram



Source: Estimates by ICF International and CHP Installation Database developed by ICF International for Oak Ridge National Laboratory and DOE. 2012.

Natural Gas Use in U.S. CHP Systems

Over 70% of CHP energy provided by natural gas. Over 2 Quads of natural gas used in CHP systems – about 9% of total natural gas use.



Source: ICF

Trillion BTUs	Energy for CHP Power	Energy for CHP Thermal	Total Gas Use for CHP by Sector	Total Natural Gas Use by Sector	% of Sector Total Use
Utility/IPP	403	330	733	9,144	8.0%
Industrial	649	530	1,179	6,899	17.1%
Commercial	65	49	114	2,905	3.9%
Residential	0	0	0	4,177	0.0%
Totals	1,117	909	2,026	23,125	8.8%

GTI estimates based on 2012 DOE EIA data

Gas Engines



Gas Turbines

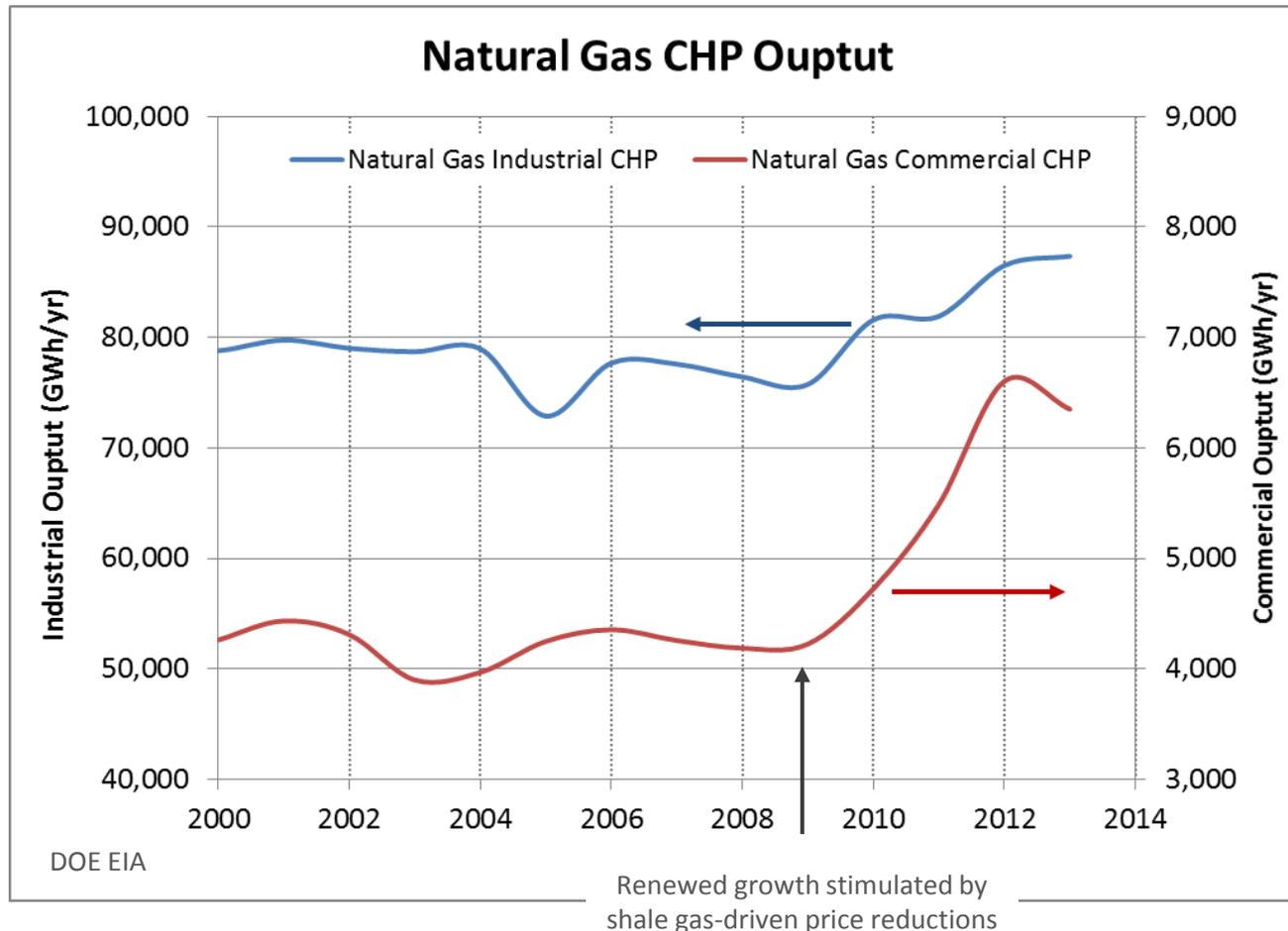


Fuel Cells



Microturbines

Commercial/Industrial Natural Gas CHP Market Trends: Recent Uptick, Stimulated By Lower Natural Gas Prices



Current Natural Gas Distributed Generation and CHP Products

Gas Engines



Gas Turbines



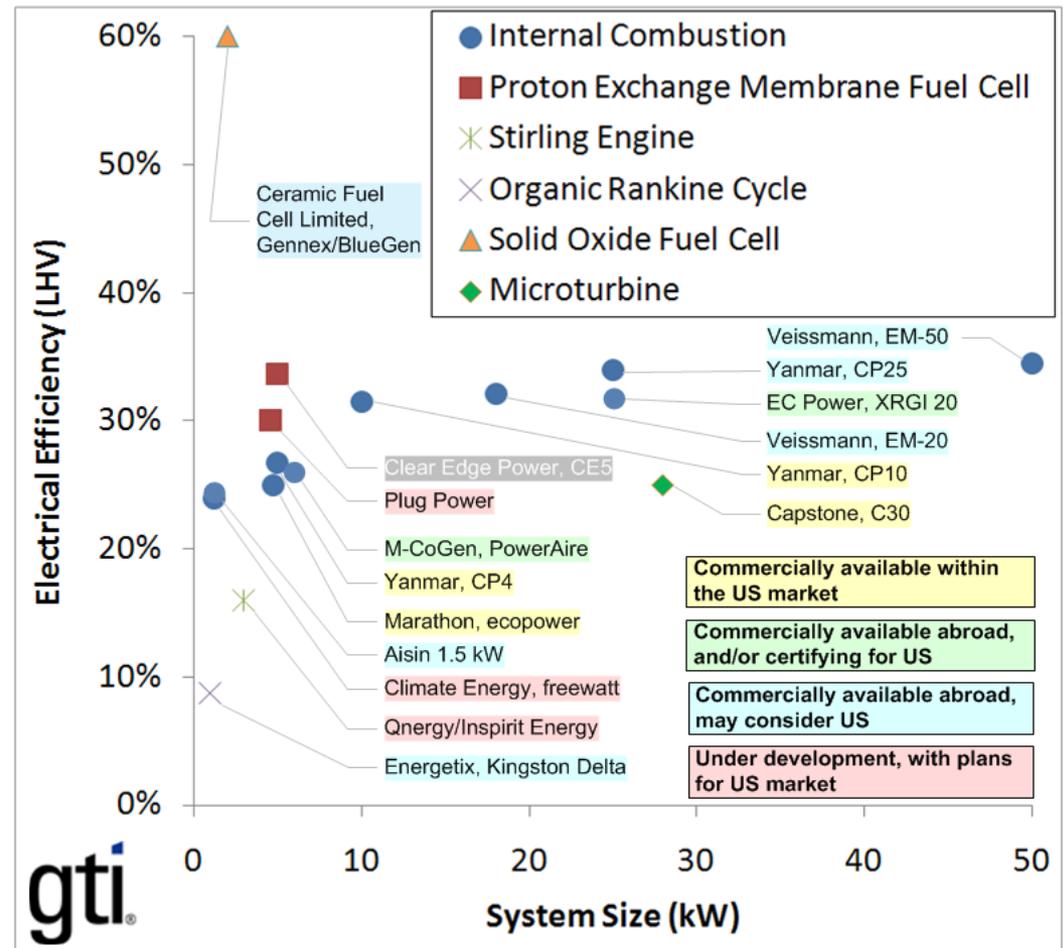
Fuel Cells



Microturbines

GTI Micro CHP Technology Landscape Assessment

- Less than 50kW
- Literature, interviews
- ~35 mCHP products
- 25 manufacturers
- 4 available in US
- +2 being certified
- Others considering US
- Comprehensive techno-economic modeling program completed



GTI/UTD MicroCHP Techno-Economic Study

> Locations

- Atlanta, Helena, Tulsa, Los Angeles, Phoenix

> Applications

- Residential
- Multifamily
- Big-box retail
- Small hotel
- Small office
- Full service restaurant

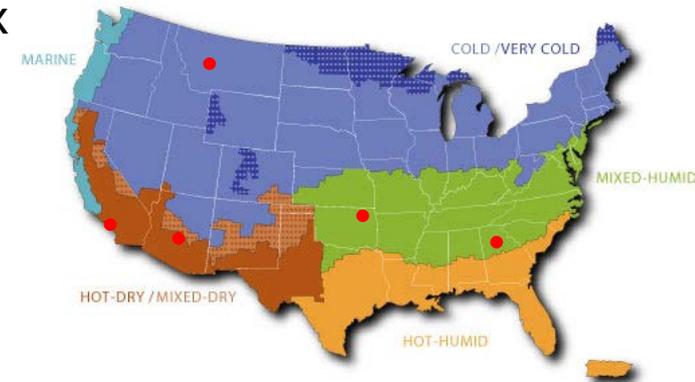
> Technologies evaluated

- Internal combustion, Micro-turbine, PEM Fuel Cell, SOFC Fuel Cell, Organic Rankine Cycle, Stirling

> 8,760 hour electricity & thermal modeling, year-round efficiency assessment

> Various operating strategies assessed

- Track Electric (TE)
- Track Thermal (TT)
- Track Greatest Demand (TG)
- Max Capacity (MC)



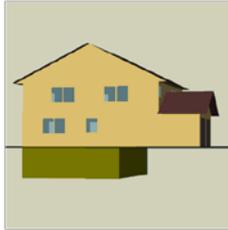
Building Models

> Single family

- 2,250 sq ft
- 3 beds, 2 baths

> Power, space heating, and DHW loads

- 1-min resolution w/ Energy Plus 6.0
- Power and space heating calculated using Energy Plus 6.0.
- DHW consumption was derived from NREL's standardized DHW schedules



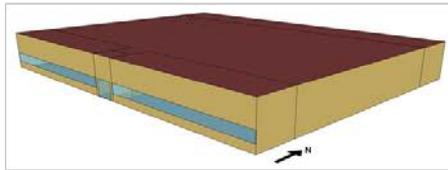
> Three progressive categories

- *Vintage*: represents 1940 – 2000
- *BA2010*: Building America prototype
- *Max EE*: Better than BA2010



Small Office Model

- 5,500 sq-ft single-story
- Satellite bank



Retail Model

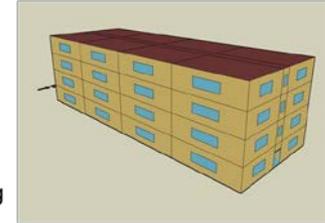
- 25,000 sq-ft single-story
- Big-box retail

> Mid-rise Multifamily

- 33,700 SqFt
- 4 Floors,
- 31 Apts, 1 Lobby

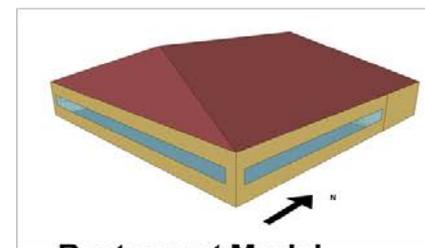
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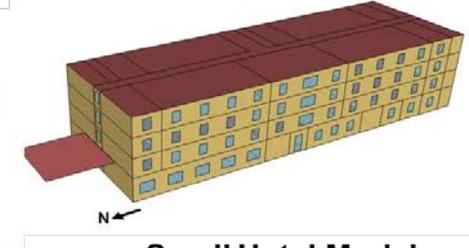
> Two building applications

- Central system serving multiple units,
- Distributed systems serving units individually.



Restaurant Model

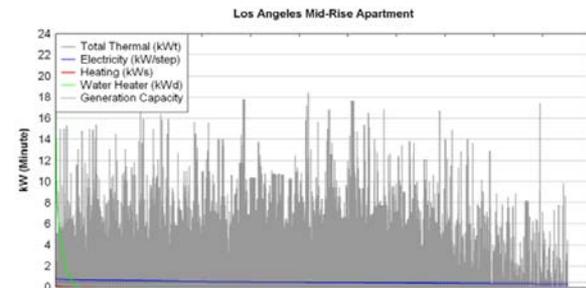
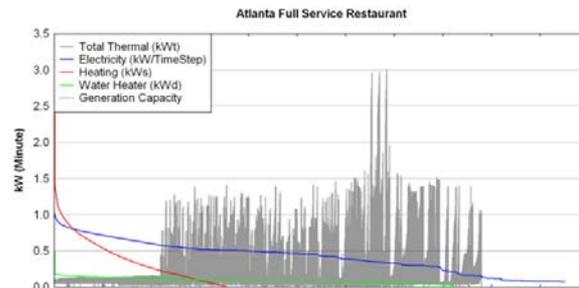
- 25,000 sq-ft single story
- Full service chain



Small Hotel Model

- 21,000 sq-ft
- Budget hotel

Model data provides insights on year-round electricity and thermal demand in buildings



MicroCHP Study Results and Key Findings

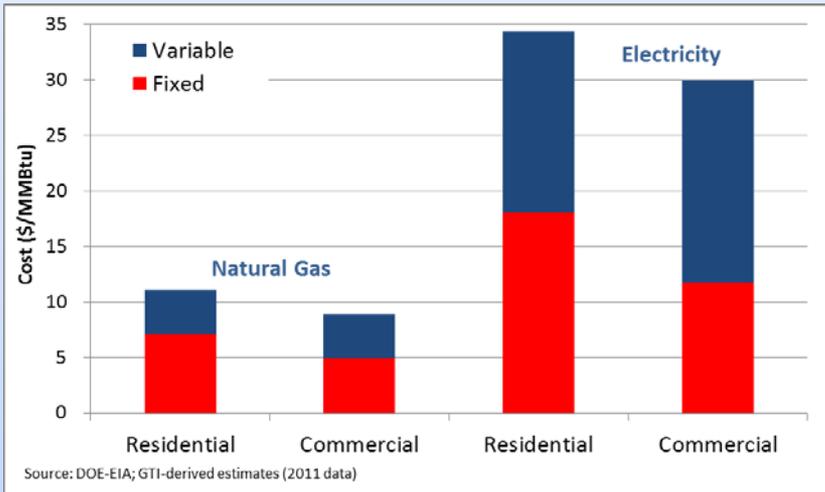
- > Results provide **directional** guidance on economic criteria – for example, first cost to achieve 6 year payback (see table below)
- > High electrical efficiency maximizes system value
- > Current microCHP products often challenged to meet payback criteria
- > **However**, other factors come into consideration
 - Market interest (and value proposition) of standby power
 - Role of utility pricing and marginal costs

Table identifies installed cost \$/kW that allows 6-year payback

Gas at \$6 to \$10	Atlanta, GA	Helena, MT	Los Angeles, CA	Phoenix, AZ	Tulsa, OK
Single-family BA2010	\$1,740 to \$2,570	\$1,130 to \$1,780	\$2,790 to \$3,560	\$2,410 to \$3,590	\$1,600 to \$2,650
Single-family MaxEE	\$1,470 to \$2,240	\$930 to \$1,620	\$2,510 to \$3,310	\$2,020 to \$3,120	\$1,470 to \$2,340
Single-family Vintage	\$1,880 to \$3,040	\$2,250 to \$2,270	\$3,050 to \$3,980	\$2,800 to \$3,980	\$1,620 to \$2,730
Multi-family by unit	\$2,060 to \$2,800	\$1,750 to \$2,680	\$3,710 to \$4,430	\$2,560 to \$3,150	\$2,150 to \$3,130
Budget Hotel	\$1,580 to \$3,080	\$890 to \$2,190	\$2,960 to \$4,540	\$1,370 to \$3,010	\$970 to \$2,440
Chain Restaurant	\$710 to \$2,330	NA to \$1,760	\$840 to \$3,430	\$850 to \$2,620	NA to \$1,850
Big-box Retail	\$690 to \$2,550	NA - \$1,510	\$2,180 to \$4,080	\$720 to \$2,620	NA - \$1,880
Small Office	\$890 to \$1,800	\$1,120 to \$1,920	\$2,690 to \$3,180	\$720 to \$2,430	\$700 to \$1,510
Multi-family Central	\$880 to \$2,610	NA to \$1,780	\$2,220 to \$4,030	\$900 to \$2,730	NA to \$2,050

Items To Consider

Marginal Energy Costs



Value of Emergency Power, Avoided Costs

2011 U.S. Gaseous Gen Set Production



Residential and light-commercial consumers buy nearly 100,000 gaseous gen sets per year and pay \$350 to \$700/kW (over \$500 million market) – plus investment in UPS systems.

This could be a value micro CHP systems provide – helping reduce net first costs.

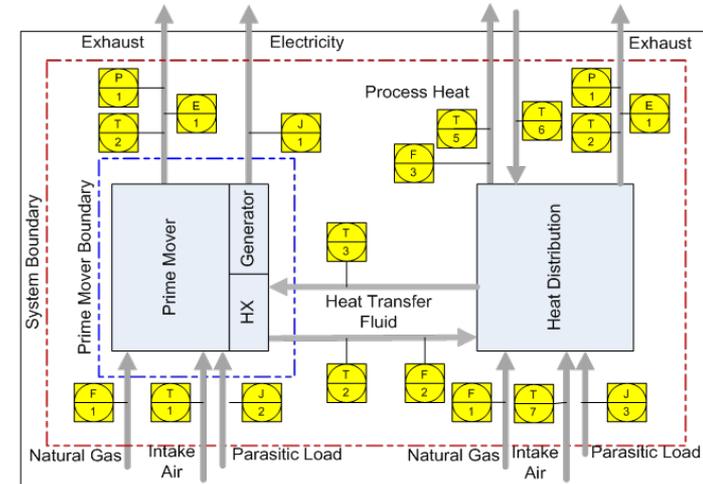
Also, capital cost may offset investment in other equipment (e.g., boiler, water heater) or avoided electric utility costs (a possible societal benefit).



	Retail Prices		Approximate Marginal/Variable Energy Costs	
	Natural Gas	Electricity	Natural Gas	Electricity
Residential	11.03	34.35	3.95	16.30
Spark Spread	3.11		4.13	
Commercial	8.92	29.98	3.95	18.23
Spark Spread	3.36		4.62	

Additional Factors

- > Industry, Utility, State, Federal codes, standards, regulations, policies
 - MicroCHP definition
 - Standby rates
 - Net metering and Feed-In tariffs
 - Interconnection requirements (IEEE 1547)
 - Need for US/North American test standard
 - > ASHRAE Standard Project Committee SPC204 – microCHP under 50 kW – GTI working with including NIST, others
- > Value and importance of power reliability and grid resiliency
 - And potential role for microgrids
- > Connectedness with Smart Energy Systems at home/business and utility level



Summary

- > CHP systems are playing an important role in reducing energy use, lowering CO₂ emissions, and providing energy cost savings for consumers
 - Natural gas is the leading choice for providing these consumer and societal benefits
- > The light commercial and residential markets represent a vast, untapped opportunity for capturing CHP benefits
 - ARPA-E can play an important role in developing DG and CHP options for the home and light-commercial market segments
 - Need to target product attributes, price, and service metrics along with overcoming other hurdles
 - Power reliability and grid resiliency are increasingly important factors

Thank You!

William E. Liss

Managing Director, End Use Solutions

Gas Technology Institute

1700 South Mount Prospect Road

Des Plaines, IL 60018

Phone: 847.768.0753

E-Mail: bill.liss@gastechnology.org

Web Page: <http://www.gastechnology.org>