Combined Heat and Power (CHP)

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Cliff Haefke
Energy Resources Center / University of Illinois at Chicago

recycling energy™ CHP It's time

MIDWEST CHP APPLICATION CENTER

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Presentation Outline

- Identifying CHP Technologies
- Opportunities for Technical Integration
- Recognizing Technical Barriers
- Recommended Paths Forward
- Additional Resources

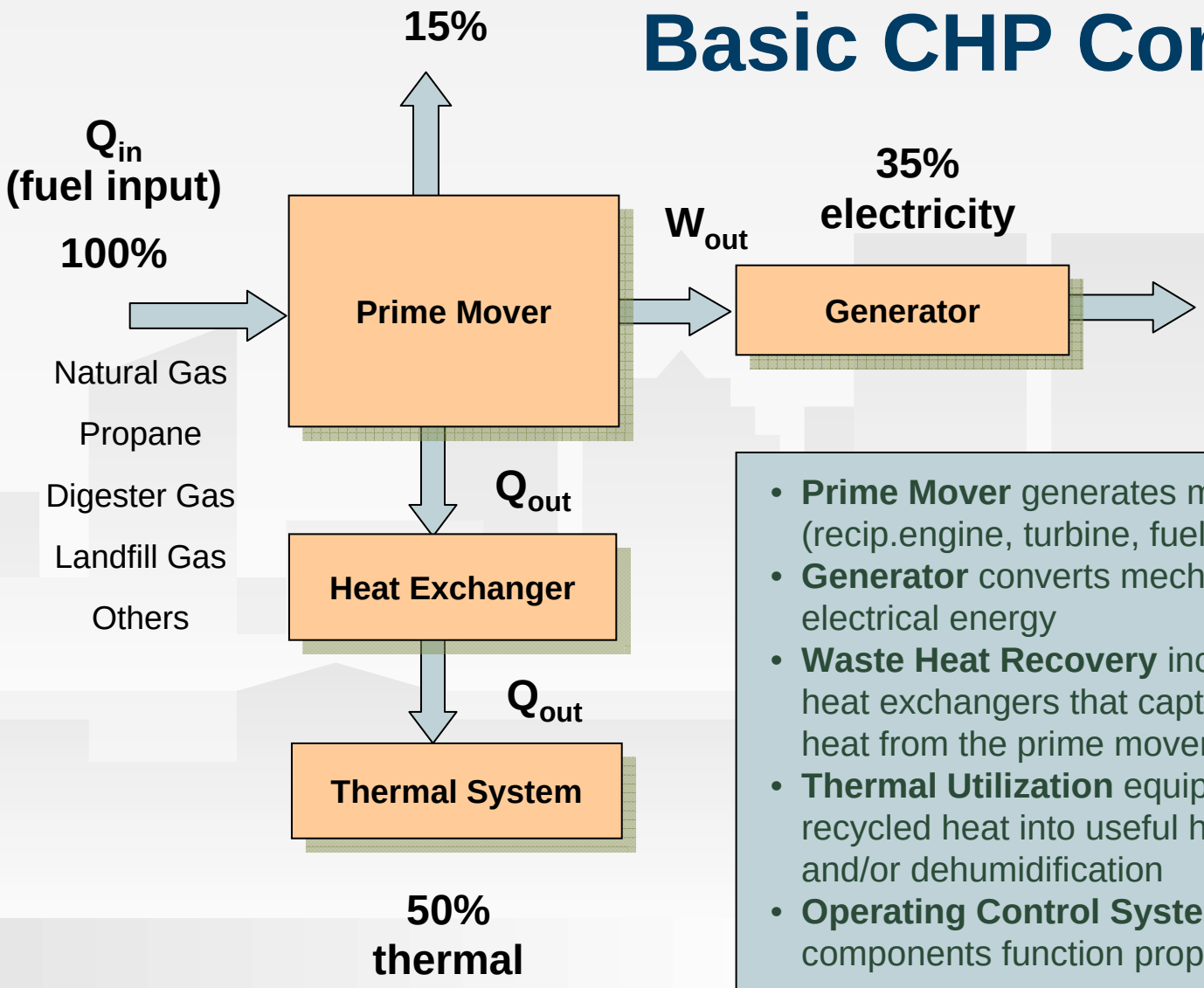
What is Combined Heat & Power (CHP)?

CHP is …

- An integrated system
- A suite of technologies
- Can use a variety of fuels
- Located at or near a building / facility
- Provides at least a portion of the electrical load and
- Recycles the thermal energy for
  - Space heating / cooling
  - Process heating / cooling
  - Dehumidification
  - Domestic hot water

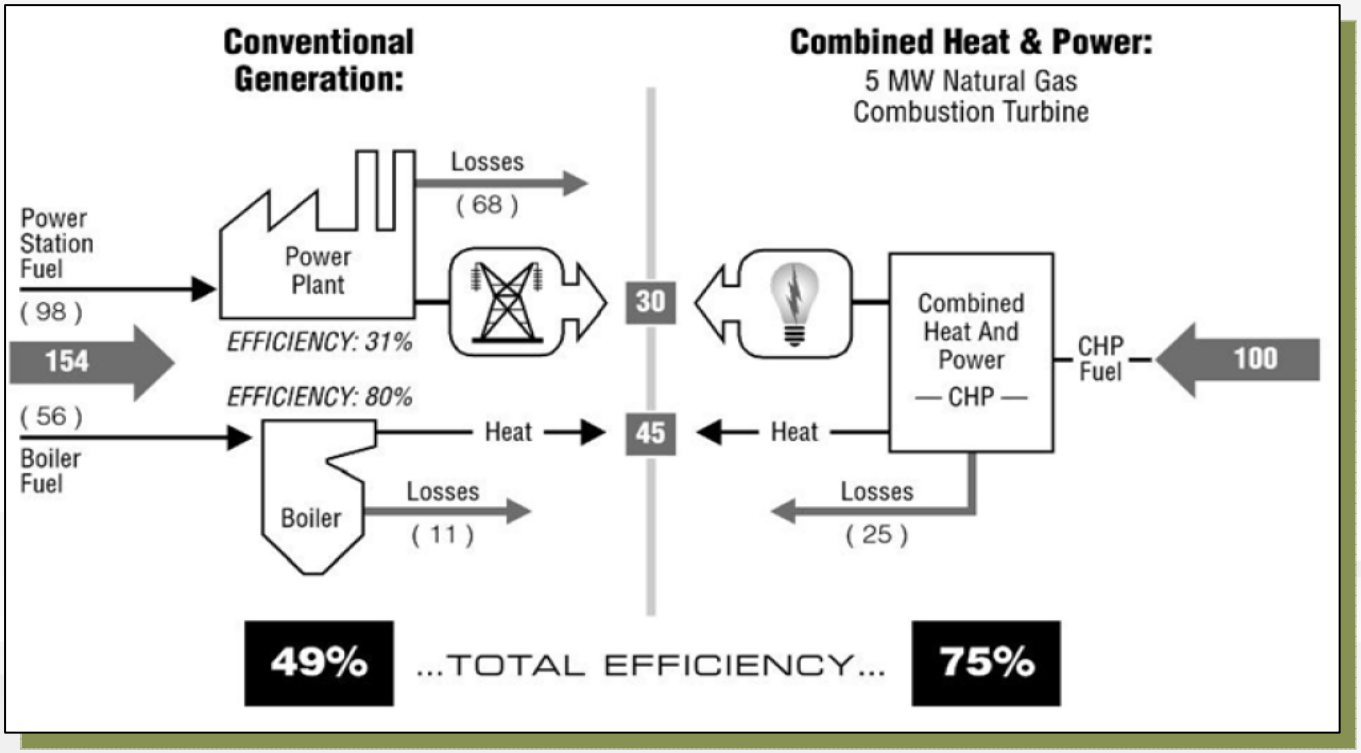
Picture Courtesy of UIC

Basic CHP Components



- **Prime Mover** generates mechanical energy (recip.engine, turbine, fuel cell)
- **Generator** converts mechanical energy into electrical energy
- **Waste Heat Recovery** includes one or more heat exchangers that capture and recycle the heat from the prime mover
- **Thermal Utilization** equipment converts the recycled heat into useful heating, cooling, and/or dehumidification
- **Operating Control Systems** insure the CHP components function properly together

Conventional Energy System vs. CHP



- Note, if we consider emissions output for the above diagram, the equivalent emissions losses would be 49 ktons/yr versus 23 kton/yr.

"In the U.S., the average power generating station was built in the 1960s using technology that is even older. The average age of a substation transformer is 42 years, but the transformers today were designed to have a maximum life of 40 years."

- The Galvin Electricity Initiative

CHP is not a New Concept

- *Historically…* CHP was owned and operated by the customer / end user (i.e. industrial firms, colleges, hospitals, etc.)
- *Historically…* electric utility was not enamored with (and in many cases) opposed to CHP installations on their utility lines
- *Historically…* CHP was looked at as single system connected safely in parallel to the existing grid that provided the customer many on-site benefits

CHP is a Proven Technology

National CHP Status (2009)

- ~85,000 MW installed at 3,500 sites (nationally)
- Average capacity is 25.2 MW
- Median capacity is 1.3 MW
- Represents almost 9% of total U.S. generating capacity, and over 12% of U.S. generation
- *Saves over 3 quads of fuel each year!*
- *Eliminates over 400 million tons of CO_2 emissions each year!*

CHP Positive Impacts and Benefits

- **Enhance our energy security** by reducing our national energy requirements and help businesses weather energy price volatility and supply disruptions
- **Advance our climate change and environmental goals** by reducing emissions of CO2 and other pollutants
- **Improve business competitiveness** by increasing energy efficiency and managing costs
- **Increase resiliency of our energy infrastructure** by limiting congestion and offsetting transmission losses
- **Diversify energy supply** by enabling further integration of domestically produced and renewable fuels
- **Improve energy efficiency** by capturing heat that is normally wasted

Source: Combined Heat & Power: Effective Energy Solutions for a Sustainable Future
http://www1.eere.energy.gov/industry/distributedenergy/pdfs/chp_report_12-08.pdf

Summary of CHP Technologies

CHP system	Advantages	Disadvantages	Available sizes
Gas turbine 	- High reliability. - Low emissions. - High grade heat available. - No cooling required	- Require high pressure gas or in-house gas compressor - Poor efficiency at low loading - Output falls as ambient temperature rises	500 kW to 250 MW
Microturbine 	- Small number of moving parts - Compact size and light weight - Low emissions - No cooling required	- High costs - Relatively low mechanical efficiency - Limited to lower temperature cogeneration applications	30 kW to 250 kW
Spark ignition (SI) reciprocating engine	- High power efficiency with part-load operational flexibility - Fast start-up - Relatively low investment cost - Can be used in island mode and have good load following capability - Can be overhauled on site with normal operators - Operate on low-pressure gas	- High maintenance costs - Limited to lower temperature cogeneration applications - Relatively high air emissions - Must be cooled even if recovered heat is not used - High levels of low frequency noise	< 5 MW in DG applications
Compression ignition (CI) reciprocating engine (dual fuel pilot ignition) 			High speed (1,200 RPM) ≤4MW Low speed (102-514 RPM) 4-75 MW
Steam turbine 	- High overall efficiency - Any type of fuel may be used - Ability to meet more than one site heat grade requirement - Long working life and high reliability - Power to heat ratio can be varied	- Slow start up - Low power to heat ratio	50 kW to 250 MW
Fuel Cells 	- Low emissions and low noise - High efficiency over load range - Modular design	- High costs - Low durability and power density - Fuels require processing unless pure H used	5 kW to 2 MW

Typical Cost and Performance Characteris-tics

Technology	Steam Turbine[1]	Recip. Engine	Gas Turbine	Microturbine	Fuel Cell
Power efficiency (HHV)	15-38%	22-40%	22-36%	18-27%	30-63%
Overall efficiency (HHV)	80%	70-80%	70-75%	65-75%	55-80%
Effective electrical efficiency	75%	70-80%	50-70%	50-70%	55-80%
Typical capacity (MW_e)	0.5-250	0..01-5	0.5-250	0.03-0.25	0.005-2
Typical power to heat ratio	0.1-0.3	0.5-1	0.5-2	0.4-0.7	1-2
Part-load	ok	ok	poor	ok	good
CHP Installed costs ($/$kW_e$)	430-1,100	1,100-2,200	970-1,300 (5-40 MW)	2,400-3,000	5,000-6,500
O&M costs ($/$kWh_e$)	<0.005	0.009-0.022	0.004-0.011	0.012-0.025	0.032-0.038
Availability	near 100%	92-97%	90-98%	90-98%	>95%
Hours to overhauls	>50,000	25,000-50,000	25,000-50,000	20,000-40,000	32,000-64,000
Start-up time	1 hr - 1 day	10 sec	10 min - 1 hr	60 sec	3 hrs - 2 days
Fuel pressure (psig)	n/a	1-45	100-500 (compressor)	50-80 (compressor)	0.5-45
Fuels	all	natural gas, biogas, propane, landfill gas	natural gas, biogas, propane, oil	natural gas, biogas, propane, oil	hydrogen, natural gas, propane, methanol
Noise	high	high	moderate	moderate	low
Uses for thermal output	LP-HP steam	hot water, LP steam	heat, hot water, LP-HP steam	heat, hot water, LP steam	hot water, LP-HP steam
Power Density (kW/m^2)	>100	35-50	20-500	5-70	5-20
NO_x (lb/MMBtu) (not including SCR)	Gas 0.1-.2 Wood 0.2-.5 Coal 0.3-1.2	0.013 rich burn 3-way cat. 0.17 lean burn	0.036-0.05	0.015-0.036	0.0025-.0040
$lb/MWh_{TotalOutput}$ (not including SCR)	Gas 0.4-0.8 Wood 0.9-1.4 Coal 1.2-5.0.	0.06 rich burn 3-way cat. 0.8 lean burn	0.17-0.25	0.08-0.20	0.011-0.016

* Data are illustrative values for typically available systems; All costs are in 2007$

[1]For steam turbine, not entire boiler package

Source: Catalog of CHP Technologies (Dec. 2008), http://www.epa.gov/chp/documents/catalog_chptech_full.pdf

Keys to CHP Integration

- Good coincidence between electric and thermal loads
- Central heating/cooling system
- Large cost differential between electricity (grid) and CHP fuel --- “Spark Spread”
- Long operating hours
- Economic value of power reliability is high
- Installed cost differential between a Conventional and a CHP System (replacing aging HVAC equipment?)
- Increase facility efficiency before implementing CHP / DG projects

Integrating Diverse Fuel Opportunities

- Diverse fuel type options
  - Fossil-based fuels (natural gas, oil, coal, propane, etc.)
  - Renewable-based fuels (digester gas, landfill gas, biogas, biomass)
    - Gas conditioning / treatment is critical
  - Process waste streams
  - Steam pressure drops (replacing PRVs)
- Duel fuel operating opportunities
  - Option 1: duel fuel mixing
  - Option 2: operating on either fuel

Integrating CHP Thermal Opportunities

- Heat recovery opportunities
  - Hot water
  - Low pressure steam
  - High pressure steam
  - Direct exhaust gases
- Thermal applications
  - Building / process heating
  - Building / process cooling (absorption cooling)
  - Desiccant dehumidification
  - Thermal storage

Recent Interest in CHP

- Advantage over many other electricity and thermal generating technologies with regard to **performance, availability, and cost**
- Micro-grids, smart grids, and net zero energy
- New approaches to upgrading old and inefficient grids
- More holistic approach to reducing energy consumption
  - Integration of many approaches and technologies
  - Community-based and partnership-based projects
- CHP can play a significant role in new modes of operation (i.e. smart grids) as the same advantages that have existed in the past are valid in modern applications

CHP Barriers in Modern Applications

- How do we integrate CHP into a smart grid?
- How do we integrate several CHP and renewable DG prime movers into a grid system to ensure there are no negative interactions?
- New technologies to interact with include:
  - Smart meters
  - Intelligent controls, sensors, and facility energy management systems
  - Electric and thermal storage
  - Interacting with other technologies in a net zero environment

"Interoperability"

"The biggest impediment to the smart electric grid transition is neither technical nor economic. Instead, the transition is limited today by obsolete regulatory barriers and disincentives that echo from an earlier era."

Kurt Yaeger
Executive Director
The Galvin Electricity Initiative

Needs for Future CHP Implementation

- Improved or different controls hardware and algorithms
- Improved system communications
- Improved or different system monitoring (intelligent monitoring)
- Operating scenarios for CHP (demand response, real time pricing, rapid restoration of existing grid)
- More plug and play capabilities ("enterprising systems")
- Integrate with other DG technologies to meet net zero standards (solar, wind, geothermal, etc.)
- Increased fuel flexibility of combustion systems
- Technical demonstrations and reporting (education)

Summary

- CHP technologies are a proven concept
- Modern CHP integration is a different mind set
- Looking forward to participating and learning more about other net zero technologies and how CHP can effectively play a positive role

Additional Resources

- Regional CHP Application Centers (DOE sponsored)
  - Midwest CHP Application Center… www.chpcentermw.org
  - Intermountain CHP Application Center… www.intermountainchp.org
- CHP Resource Guide (CHP rules-of-thumb hand book)
  - http://www.chpcentermw.org/pdfs/Resource_Guide_10312005_Final_Rev5.pdf
- CHP Effective Energy Solutions for a Sustainable Future (Dec. 2008)
  - http://www1.eere.energy.gov/industry/distributedenergy/pdfs/chp_report_12-08.pdf
- Catalog of CHP Technologies (Dec. 2008)
  - http://www.epa.gov/chp/documents/catalog_chptech_full.pdf
- Smart Grid: Enabler of the New Energy Economy (Dec. 2008)
  - http://www.oe.energy.gov/DocumentsandMedia/final-smart-grid-report.pdf
- Database of State Incentives for Renewables & Efficiency
  - http://www.dsireusa.org/

Thank You

Contact Information

Cliff Haefke
Energy Resources Center
University of Illinois @ Chicago
312/355-3465
chaefk1@uic.edu
www.erc.uic.edu

Midwest CHP Application Center
www.chpcentermw.org