Thermal Energy Recovery Overview

Gearoid Foley

President

Integrated CHP Systems Corp.

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CHP Overview

What Is CHP

Recovery of waste Thermal Energy from power generation -

Why Consider It

- to offset fuel that would otherwise be used for cooling, heating and dehumidification.

What is CHP

- Combined Heat and Power (sometimes referred to as Cogeneration) describes any system that simultaneously generates electricity and useful, recovered thermal energy. It is the oldest commercially demonstrated form of power generation, as Thomas Edison's Pearl Street Station in Manhattan (the world's first electric power plant, commissioned in 1882) was a CHP facility.
- Fundamentally, CHP is a form of recycling, as it converts waste materials into valuable commodities, thus providing both enhanced revenue and reduced environmental impact.
- While thermal energy is recovered directly from CHP systems as heat, it may be used either for cooling, heating or dehumidification applications, via thermally-activated technologies.

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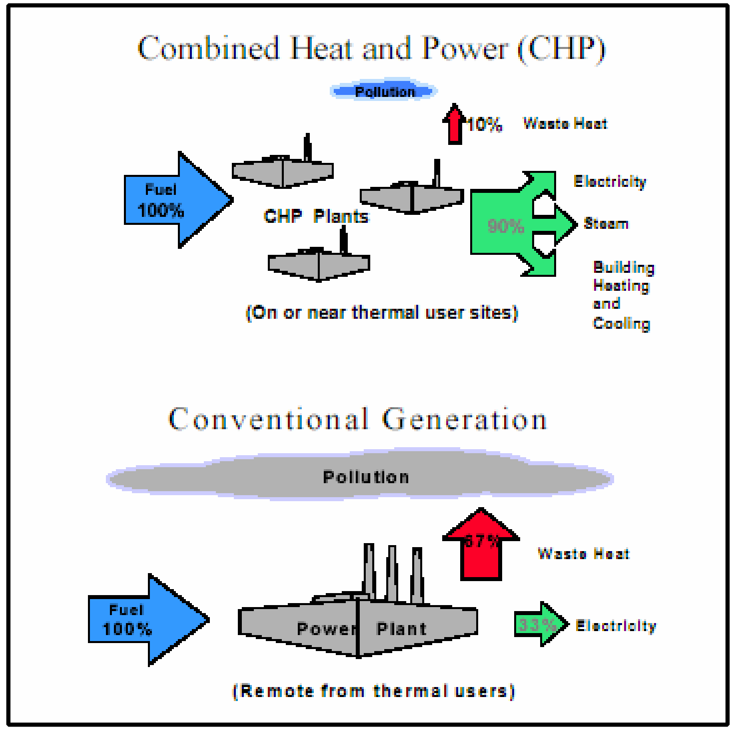
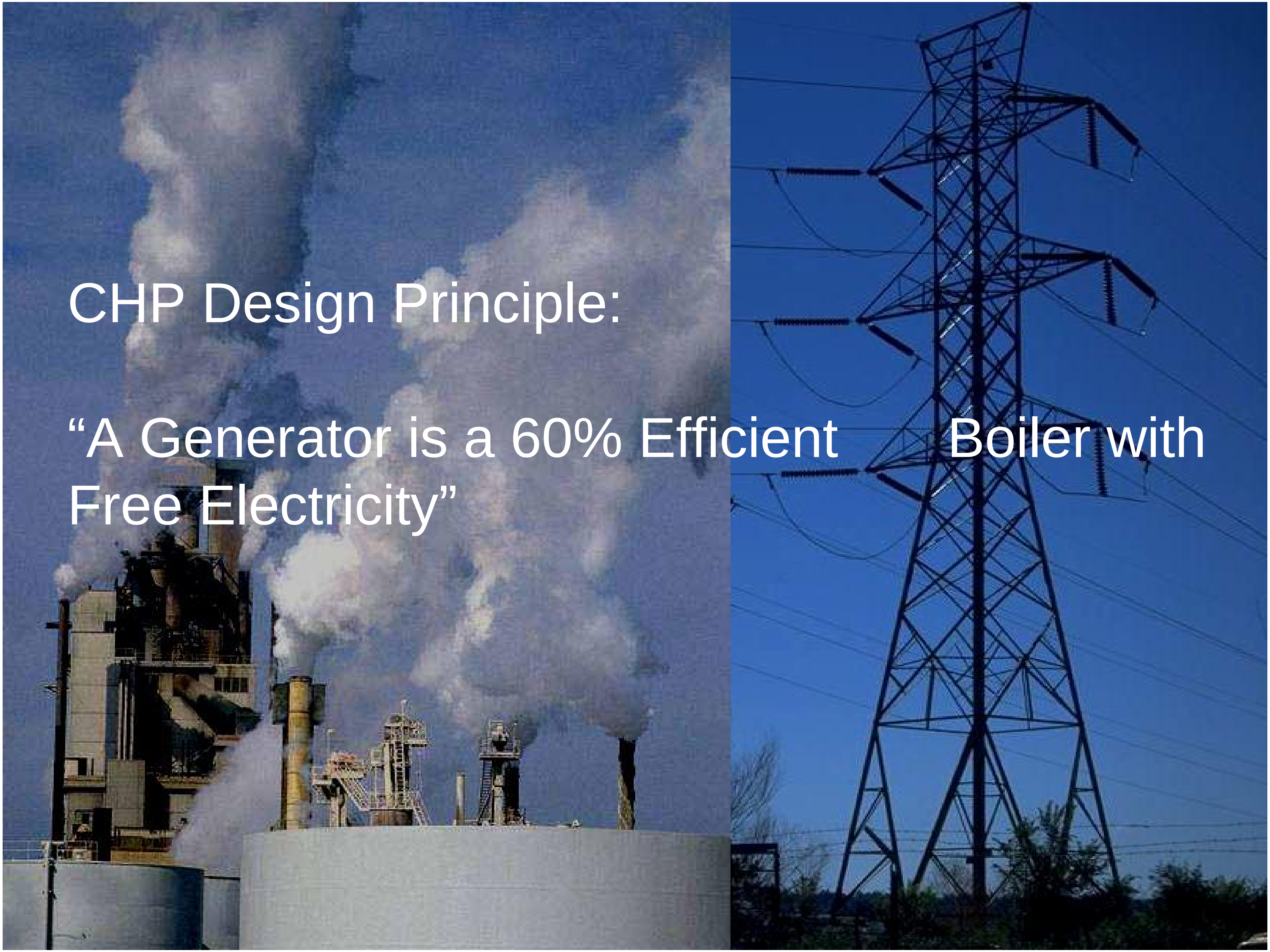
What is CHP

- Conventional grid based generators are located remote from thermal applications while CHP plants are located close to thermal applications allowing the heat produced from the generation process to be used.



Source: USCHPA


CHP Design Principle:
“A Generator is a 60% Efficient Boiler with Free Electricity”

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What is CHP

- Currently CHP
  - Produce almost 8% of U.S. electric power – 67,000 MW.
  - Saves building and industry owners over $5 billion/year in energy costs.
  - Decrease energy use by almost 1.3 trillion BTUs/year.
  - Reduce NOx emissions by 0.4 million tons/year.
  - Reduce SO2 emissions by over 0.9 million tons/year.
  - Prevent release of over 35 million metric tons of carbon equivalent into the atmosphere.

Source: USCHPA

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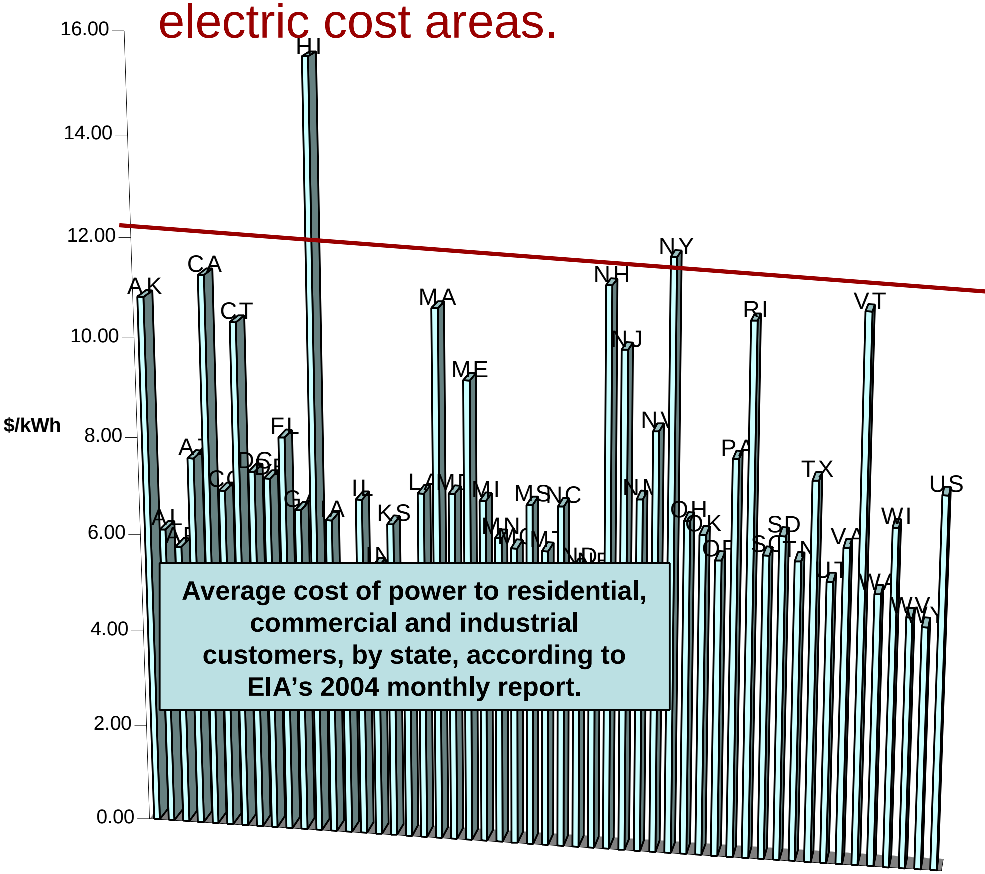
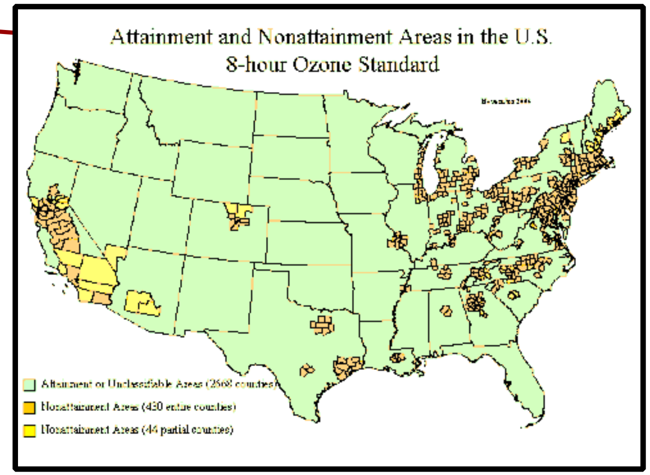
Why Consider It

- The Four E's:
  - Economics
  - Efficiency
  - Electricity
  - Emissions

California and Northeast are high electric cost areas.





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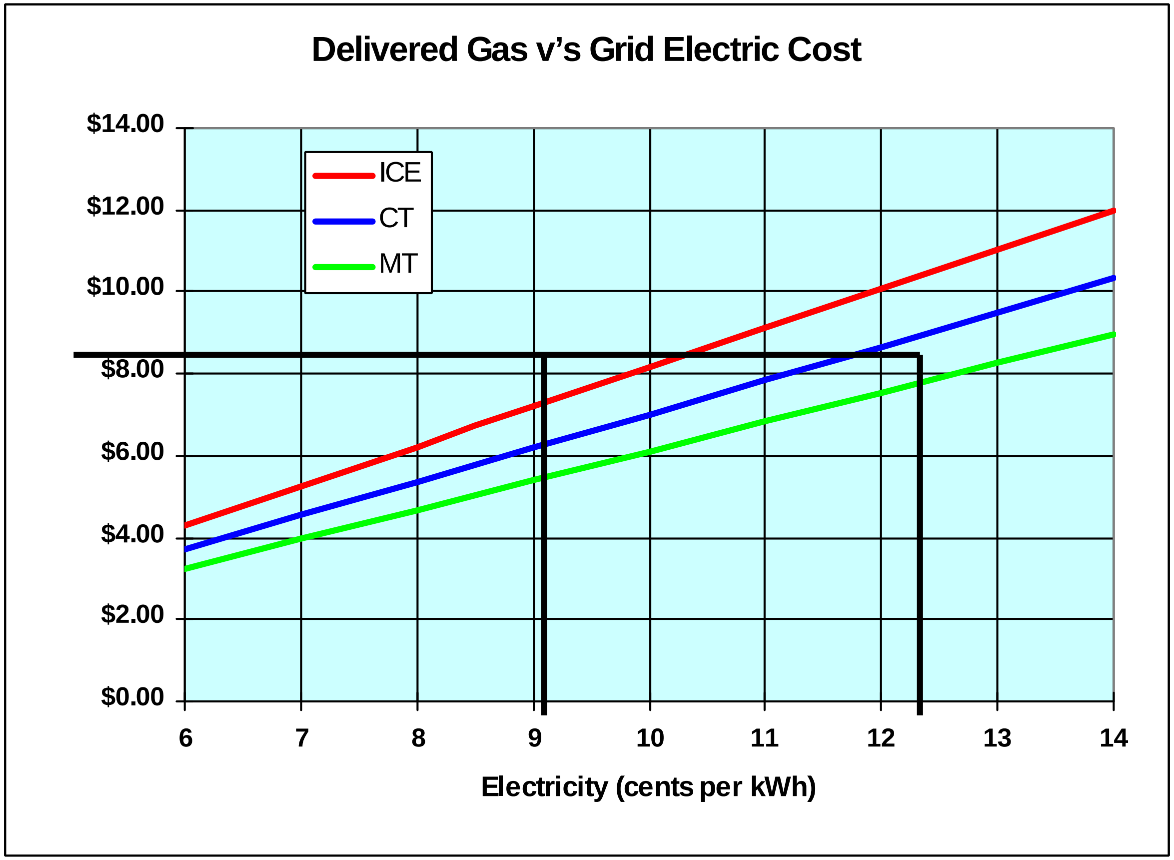
Economics

At a natural gas cost of $8/MMBH delivered, on-site generators will produce electricity at between 9½ and 13 cents/kWh including maintenance



Source: ICHPS

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Economics

1 MW IC Engine

Site Parameters

Annual Run Hours	8,322	
Cooling Season, mths	7	
Avg Natural Gas Price, $/mmBTU	$8.00	
Avg Power Price, $/kWh	$0.1100	

Co-Gen Performance

Engine Heat Rate, BTU/kWh	11,000	HHV
Availability, %	95%	
Gross Power Output, kW	1,000	
Engine Aux Power, kW	50	
ICHM Plant Aux Power, kW	55	
Hot Water, MBH	0	
Chilling Capacity, Tons	0	
Electric Load Factor, %	95%	
Thermal Load Factor, %	0%	

Annual Cash Flow Analysis

Avoided Cooling, Heating & Power Credit		**$778,336**
Existing Avg Chiller Eff, kW/ton	0.65	
Existing Avg Boiler Eff, %	75%	
Capital Cost		**$700,000**
Estimated Capital Cost, $	$700,000	
Co-Funding, $	$0	
O&M Cost		**$124,830**
Generator Maintenance, $/kWh	$0.0150	
ICHM Maintenance, $/ton/yr	$40.00	
Co-Gen Fuel Cost		**$695,719**
Total Project Capital Cost		**$700,000**
Net Project Capital Cost		**$700,000**
Net Annaul Savings		**-$42,213**
Payback Years		**-16.6**

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Economics

1 MW IC Engine w/ ICHM

Site Parameters

Annual Run Hours	8,322	
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Thermal Load Factor, %	0%	

Annual Cash Flow Analysis

Avoided Cooling, Heating & Power Credit		**$1,025,484**
Existing Avg Chiller Eff, kW/ton	0.65	
Existing Avg Boiler Eff, %	75%	
Capital Cost		**$835,000**
Estimated Capital Cost, $	$1,135,000	
Co-Funding, $	$300,000	
O&M Cost		**$135,630**
Generator Maintenance, $/kWh	$0.0150	
ICHM Maintenance, $/ton/yr	$40.00	
Co-Gen Fuel Cost		**$695,719**
Total Project Capital Cost		**$1,135,000**
Net Project Capital Cost		**$835,000**
Net Annaul Savings		**$194,135**
Payback Years		**4.3**

Thermal Contribution: $247,000

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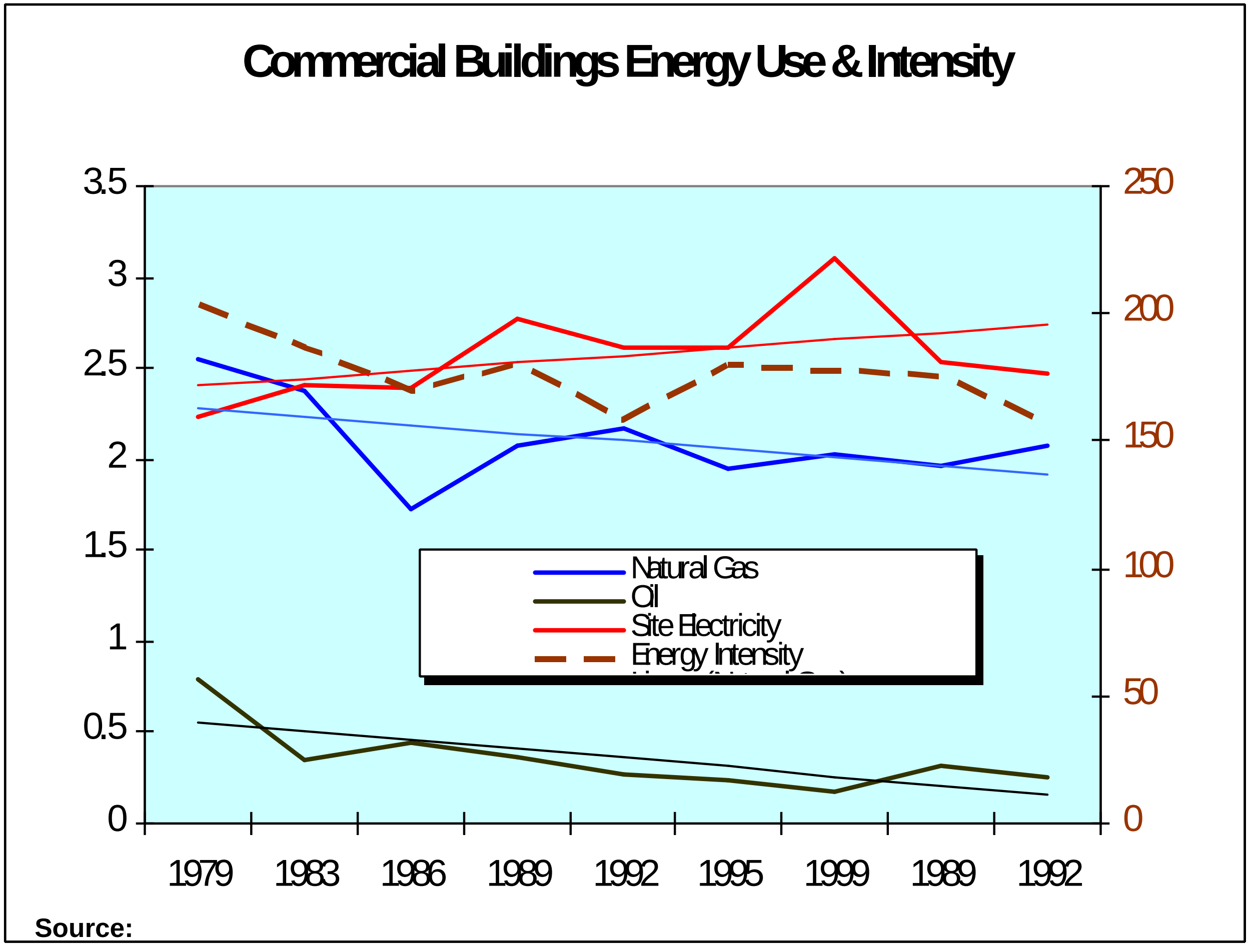
Economics

While commercial energy use remains static there has been a switch from fossil fuel to electricity as a source of energy.



Source: ICHPS

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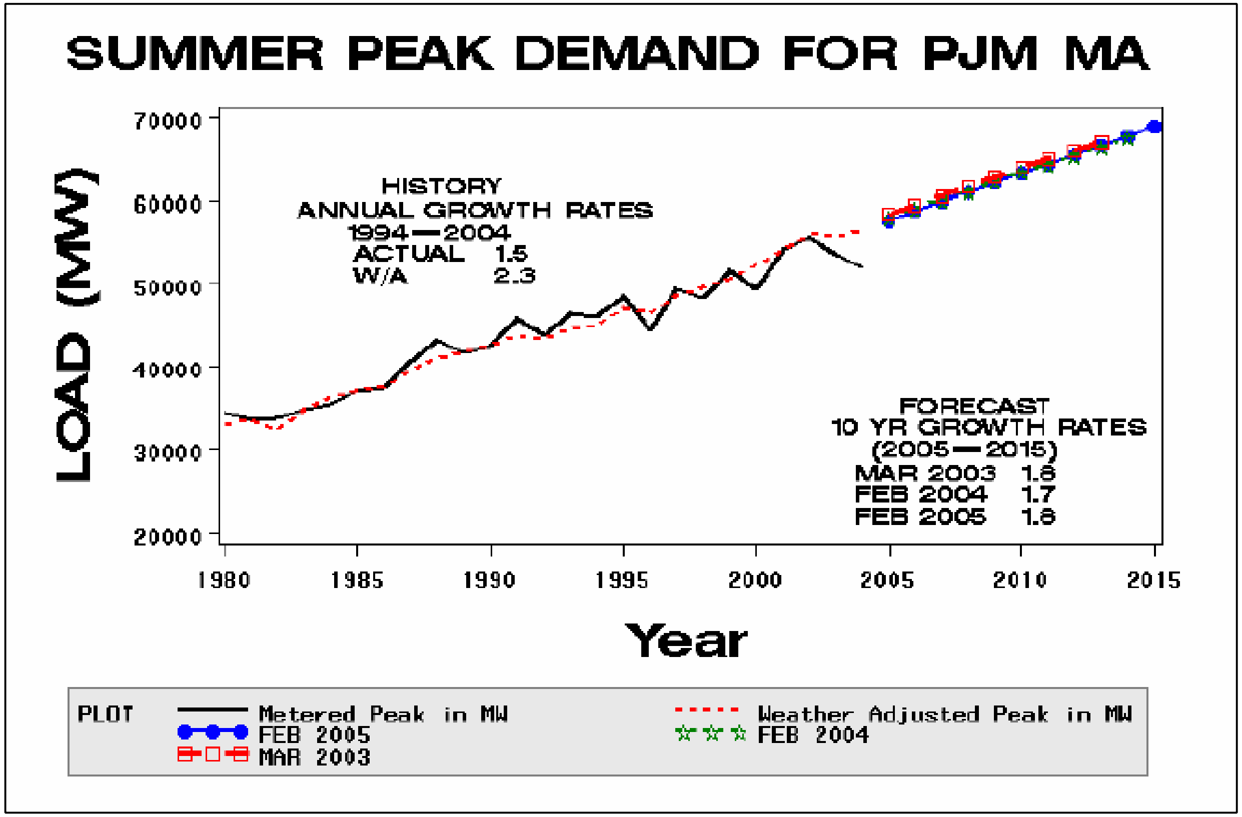
Economics

Future electric power demand growth will continue in line with economic growth.



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Economics

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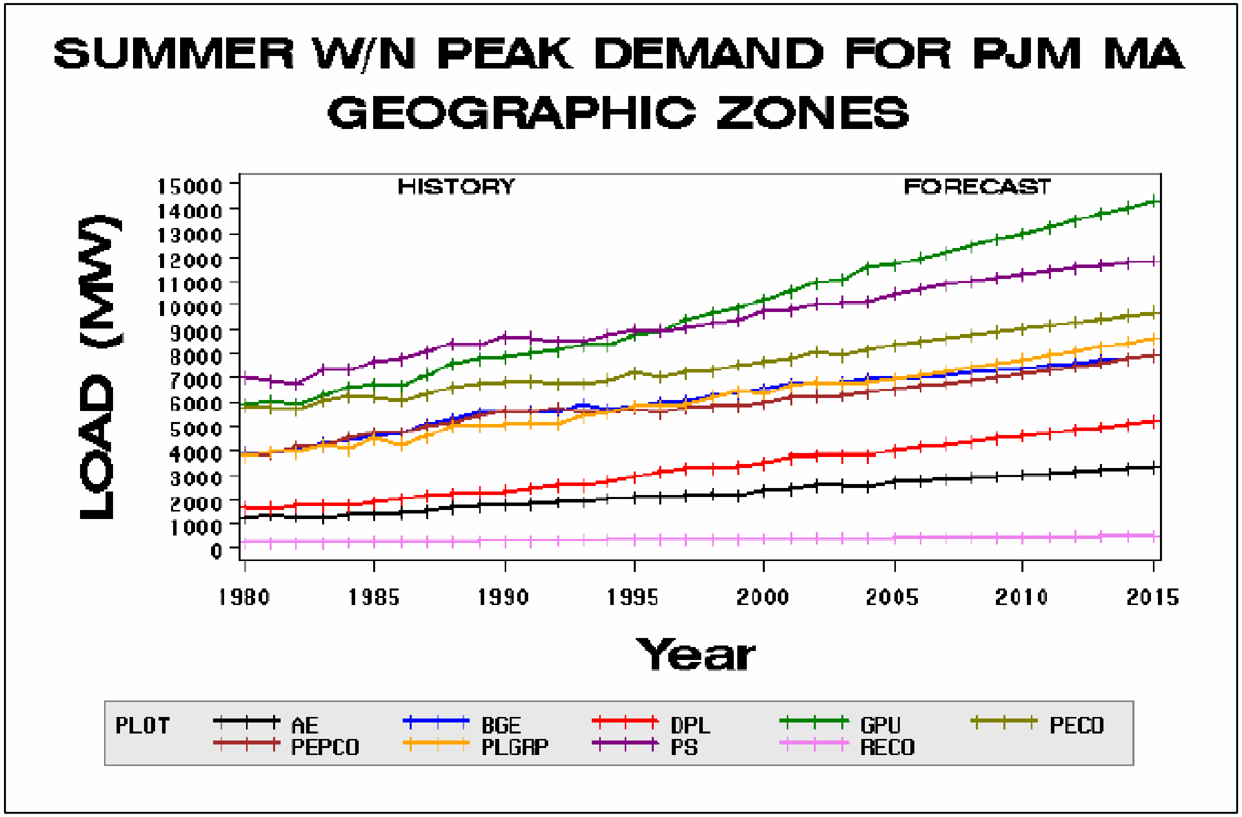
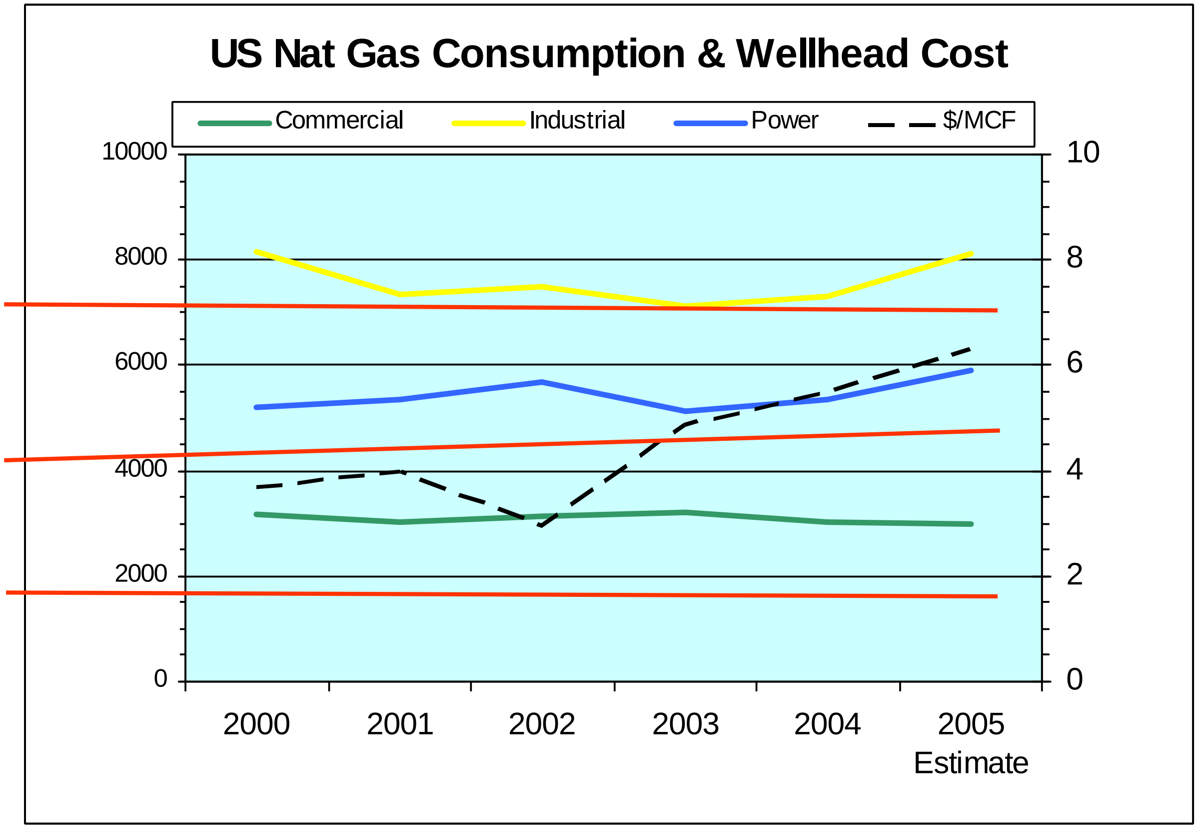


Economics

Consumption of natural gas for power production will continue to pressure electric prices.



Source: ICHPS

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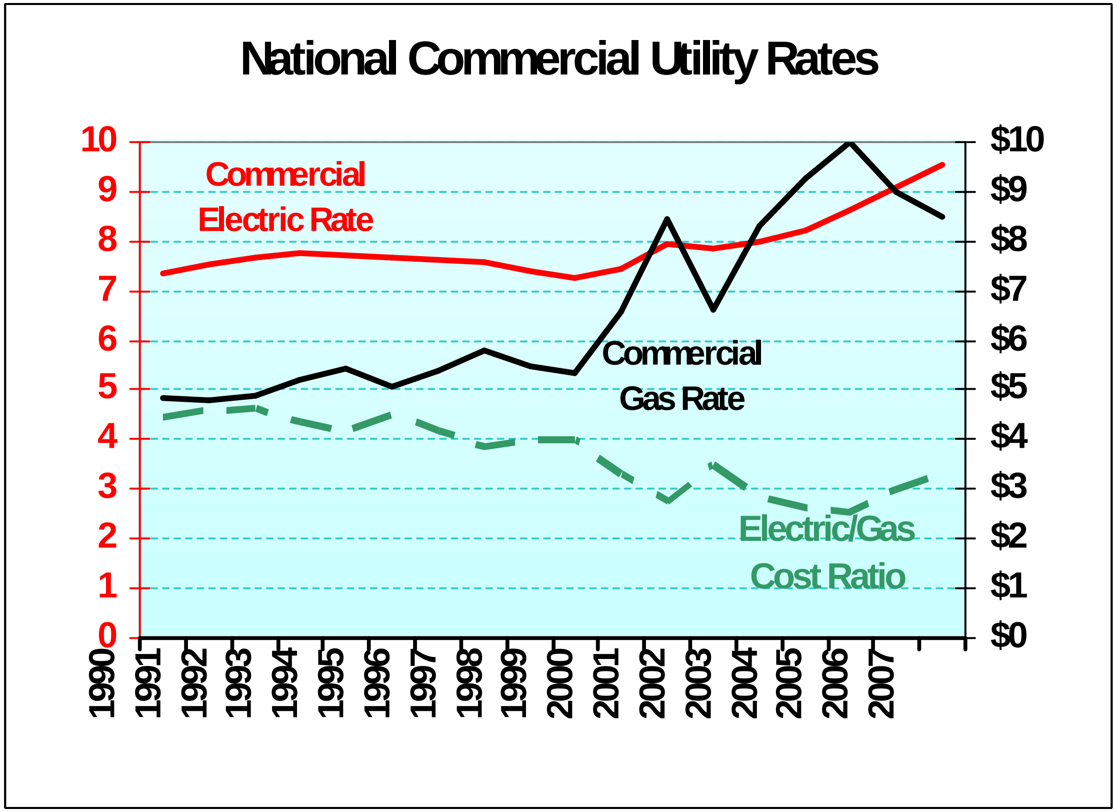
Economics

Gas cost increases are now showing up in electric pricing as utilities renew long term supply contracts.



Source: ICHPS

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Economics

EIA Table 5.6.B. Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, Year-to-Date through November 2005 and 2004

(Cents per Kilowatthour)

State	Commercial		Percentage Increase	Industrial		Percentage Increase
	Nov-05	Nov-04		Nov-05	Nov-04	
New York	13.19	13.03	1%	7.62	7.05	8%
Massachusetts	12.79	11.03	**16%**	8.68	8.5	2%
California	11.98	11.57	4%	8.64	9.53	-9%
Connecticut	11.4	9.94	**15%**	9.5	7.9	**20%**
New Jersey	11.11	10	11%	9.55	9.04	6%
Maryland	10.73	7.58	**42%**	4.88	6	-19%
Pennsylvania	8.91	8.54	4%	5.9	5.88	0%
Texas	8.79	7.93	**11%**	7.06	5.88	**20%**
Florida	8.15	7.64	7%	6.53	5.85	12%
Illinois	8.14	7.57	8%	4.55	4.66	-2%
Michigan	8.07	7.6	6%	5.58	4.93	13%
Ohio	7.94	7.78	2%	5.02	4.9	2%
Georgia	7.69	6.91	11%	5.25	4.43	**19%**
U.S. Total	**8.67**	**8.19**	6%	**5.56**	**5.28**	5%

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Economics

Incentives/Rebates for CHP installations

NEW YORK:

NYSERDA Distributed Generation and Combined Heat and Power Program:

Purpose of Program

The Distributed Generation and Combined Heat & Power (DG-CHP) Program is funded at a level of $15 million per year. This Program supports the development and demonstration of distributed generation (DG) systems, components and related power systems technologies, and combined heat and power (CHP) application in industrial, municipal, commercial and residential sectors.

Connecticut:

ECONOMIC INCENTIVES:

The state of Connecticut allows municipalities the option of offering property tax exemptions for certain renewable energy systems including cogeneration. A CHP system must be installed by on or after July 1, 1981, and before October 1, 2006. This exemption is good for 15 years and may be used on residential, commercial or industrial property. Contact your local tax office for more information.

NEW JERSEY:

NJ Clean Energy Board Announces Incentives for CHP (07/2004) The Office of Clean Energy will be providing financial incentives for Combined Heat and Power (CHP) installations to enhance energy efficiency through on-site power generation with recovery and productive use of waste heat, and reducing existing and new demands to the electric power grid. This program will meet the objective of the New Jersey Clean Energy program to use energy efficiency, and clean distributed generation to provide reliability solutions for New Jersey. The program's goals are to increase energy efficiency, reduce overall system peak demand and to encourage the use of emerging technologies.

Michigan:

Financial Incentives for CHP Syst

On September 28, 2001, Governor John Engle[...] bill which [...] Industry Services fiscal year appropriations bill which [...] distributions [...] Public Service Commission (MPSC) to begin making distributions [...] Efficiency Fund (LI/EE) of up to $60 million annually, for a period of 6 years. [...] on December 21, 2001 the MPSC issued a request for proposal for LI/EE grant funds. [...] CHP projects may be able to qualify for portions of this grant based on their high energy

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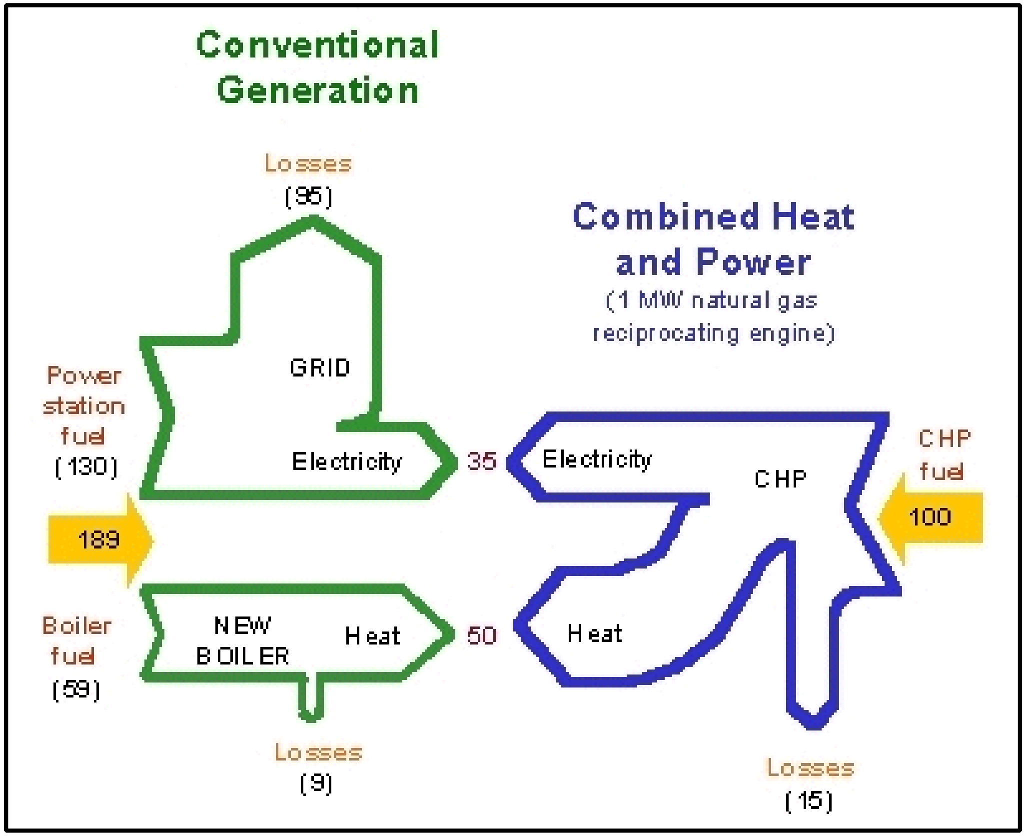
Efficiency

- CHP provides two outputs – electricity and heat.
- No waste heat is rejected to the atmosphere.
- CHP efficiency is typically twice to three times that of grid power.



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Electricity

- CHP facilities are relatively small and distributed widely helping to alleviate electric grid congestion. Their locations at the point of need eliminate their vulnerability to a disruption of the transmission system, and indeed create the ability to provide emergency power downstream of such a disruption.
- Their locations in facilities of many sorts mean they are not physically isolated and vulnerable to terrorist attack, but instead share the security implicit in their host facilities.
- Electric reliability is greatly enhanced by avoiding outages from transmission and distribution system problems.
- The efficiency of CHP also has an inherent security benefit, since vulnerability to fuel interruptions is proportionate to fuel consumption.

Emissions

- Currently, power plants are responsible for two-thirds of the nation's annual sulfur dioxide (SO_2) emissions, one-quarter of the nitrogen oxide (NO_x) emissions, one-third of the mercury (Hg) emissions, and one-third of the carbon dioxide (CO_2) emissions, a leading greenhouse gas.
- In the same way that it saves fuel cost, CHP reduces pollution by using the fuel's energy twice or three times, yielding half to a third of the emissions from separate applications.
- According to the U.S. Department of Energy, CHP systems could reduce annual greenhouse gas emissions by at least 25 million tons of carbon if the Agency's goal to double US installed capacity by 2010 were met.
- New power plants have major environmental impacts. CHP plants are small and usually sited unobtrusively inside existing buildings and plants, without offending neighbors.

Emissions

- The U.S. Environmental Protection Agency supports combined heat and power because there are significant cost-effective emissions reductions that can be achieved by increasing efficient energy supply. The average efficiency of fossil-fueled power plants in the US is 33% and has remained virtually unchanged for 40 years. This means that two-thirds of the energy in the fuel is lost (vented as heat) at most power plants in the United States. CHP systems achieve effective electrical efficiencies of 50% to 70%. This improvement in efficiency is an excellent pollution prevention strategy that reduces emissions of air pollutants and carbon dioxide, the leading greenhouse gas associated with climate change. Furthermore, CHP may reduce electric transmission and distribution losses resulting in further efficiency gains.

  …………US EPA Web Site

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CHP Prime Movers

- Combustion Turbines 0.5 – 10 MW
- Microturbines 30 – 250 kW
- IC Engines 30 kW – 5 MW
- Fuel Cells 200 kW – 1 MW

- 65% - 50% WASTE HEAT
- 25% - 40% Electricity

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Generator Thermal Output

- Simple Cycle Combustion Turbine:
  - High Volume, High Temp Exhaust (900 – 1000 F)
- Recuperated Microturbine:
  - High Volume, Medium Temp Exhaust (500 – 600 F)
- IC Engine:
  - Low Volume, High Temp Exhaust (900 – 1000 F)
  - + Hot Water (200 – 220 F)
- Fuel Cell (SOFC):
  - Low Volume, Medium Temp Exhaust (600 – 700 F)

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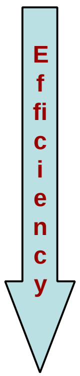
Cooling Technologies

- Thermal Technologies for CHP are HVAC devices that produce cooling from waste heat and include:



Steam Turbine Chillers

Double Effect Absorbers

Single Effect Absorbers

Desiccants

- Cooling and Dehumidification Systems are available across a wide range of CHP configurations and sizes, from 50 kW to multi-MW applications.

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DG/TAT Match

Distributed Generation Technologies

Gas-turbine

Solid Oxide Fuel Cell

Microturbine

I.C. Engine Exhaust

I.C. Engine Jacket + Exhaust

800ºF

600ºF

360ºF

180ºF

Thermally-Activated Cooling Technologies

Steam Turbine Centrifugal Chiller

Double-Effect Absorption Chiller

Single-Effect Absorption Chiller

Desiccant Technology

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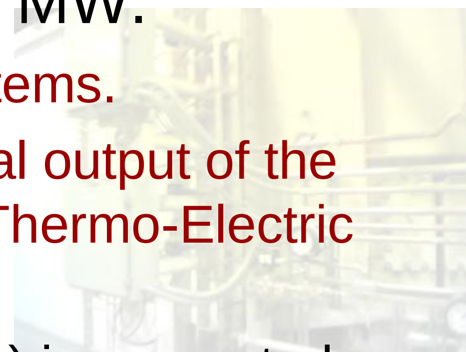
ST/GT

- Steam turbine chillers are suitable for application with large non-recuperated and recuperated gas turbines with an output of over 1.5 MW.
  - These make highly efficient CHP systems.
  - Duct Burners can increase the thermal output of the CHP system, therefore increase the Thermo-Electric ratio.
  - High Pressure Steam (125 – 300 psig) is generated using a Heat Recovery Steam Generator (HRSG).
  - Project sizes are typically 1 million sq ft or larger.
  - Cooling Tower performance can affect CHP efficiency.
  - Thermal-Electric Ratio is high.



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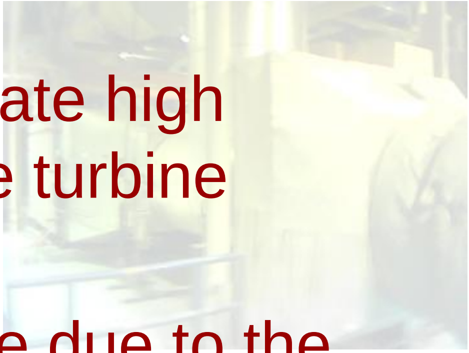
2E/GT

- GT's under 2 MW are typically less electrically efficient than larger sizes.
- The low electric efficiency is compensated for by additional waste heat making the overall CHP Output Efficiency comparable to larger GT based systems.
- Typically a HRSG is used to generate high pressure steam (125 psig) from the turbine exhaust.



- Double Effect Absorption is suitable due to the thermal size range being 300 to 1,500 tons.
- Tough competition from Reciprocating Engines.
- Thermal-Electric Ratio is High

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2E/ICE 2E/MT

- High pressure steam (125 psig) can be generated from IC Engine and Microturbine Exhaust.
- Exhaust Fired 2E Absorbers for Microturbines
- IC Engines over 1 MW have sufficient exhaust energy to supply high pressure steam to a 2E Absorber while engines under 1 MW will generally provide too little steam for economic viability.
- Output efficiency is good but heat recovery efficiency is low when jacket water is not used.
- Large IC Engines with low jacket water return temperatures (< 170 F), are suited to this type of configuration.

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1E/ICE 1E/MT

- Single Effect Absorbers are well suited to the lower quality heat of IC Engines when jacket water heat is recovery and Microturbines
- IC Engines under 2 MW are very compatible with the 1E absorbers showing high heat recovery efficiencies
- IC Engines are the mainstay of the distributed generation market between 250 kW and 2 MW
- Overall CHP Output Efficiency is high
- 1E/ICE is Lowest Cost in Class and has a suitable Thermal-Electric Ratio at 0.3 Ton/kW
- 1E Absorbers are simple and reliable

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Desiccants

- Low activation temperature makes both technologies compatible with all prime movers.
- Desiccants provide unique latent heat removal and improved IAQ
- Desiccants require small amounts of waste heat and can be combined with other cooling technologies for high efficiency
- Thermal-Electric Ratio is Low

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CHP Choices

Generator	Range	Cooling TAT	T/E Ratio (Ton/kW)
Gas Turbine	> 1 MW	Steam Turbine 2E Absorber	0.6 - 0.7
Microturbine	< .4 MW	2E Absorber Desiccant	0.4 - 0.5
IC Engine	.1 to 3 MW	1E Absorber Desiccant	0.2 - 0.4
Fuel Cell	> .25 MW	2E Absorber	0.1 - 0.2