Combined Heat and Power: The U.S. Experience

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What is IIP?

OUR MISSION: Reduce GHG emissions by giving business leaders and policymakers access to effective practices, technologies and tools to advance industrial productivity.

WHO WE ARE:
• A non-profit established by the ClimateWorks Foundation in 2010
• Strategically linked to a global network of groups addressing climate change
• Work in partnership with industries, governments, financial institutions etc.

WHAT WE DO:
• Sharing best practices
• Technical support
• Policy assistance
• Financing expertise

OFFICES:
• Beijing, New Delhi, Washington DC, Paris
IIP’s Best Practice Databases

Industrial Efficiency Technology Database
www.ietyd.iipnetwork.org

Industrial Efficiency Policy Database
www.iepd.iipnetwork.org

Industrial Efficiency Finance Database
www.iipnetwork.org/databases/finance

Supply Chain Initiatives Database
www.iipnetwork.org/databases/supply-chain
IIP’s China Program

Key Activities:

• Develop best practice, case studies, database and tools in support of EnMS implementation in Top-10,000 Enterprises Program

• Assist Dezhou Energy Conservation and Supervision Center in pilot program to advance Energy Management Systems in key enterprises

• Develop case studies for energy systems optimization in Iron and Steel industry
What Are the Benefits of CHP?

• **User** - Reduced energy costs and improved power reliability

• **Environment** – Reduced energy use and lower emissions (greenhouse gases, NOx, SOx, CO and PM)

• **Public Safety** – Keep critical infrastructure operating and support the grid in times of emergency
The CHP Value Equation

- Reduced purchased electricity costs
+ Increased fuel costs
+ Increased O&M costs
+ Increased capital expenditure
- Displaced capital?
- Reliability, other operational savings?

Overall Cost Savings
CHP Cost Savings

Monthly Costs of 10 MW CHP system: 85% capacity factor, 65 lbs/hr steam, $0.07 /kWh purchased power costs, $5.50 /MMBtu gas costs
## CHP Energy Savings

<table>
<thead>
<tr>
<th>Technology (10 MW Fractional Basis)</th>
<th>CHP</th>
<th>Combined Cycle</th>
<th>Wind</th>
<th>Solar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Capacity Factor</td>
<td>85%</td>
<td>60%</td>
<td>30%</td>
<td>16%</td>
</tr>
<tr>
<td>Average Power Production (per hr)</td>
<td>8.5 MWh</td>
<td>6.0 MWh</td>
<td>3.0 MWh</td>
<td>1.6 MWh</td>
</tr>
<tr>
<td>Total Fuel Consumption (Baseload of 10 MW and 65 mlb/hr steam)</td>
<td>140 MMBtu/hr</td>
<td>174 MMBtu/hr</td>
<td>168 MMBtu/hr</td>
<td>184 MMBtu/hr</td>
</tr>
<tr>
<td>Fuel Savings</td>
<td>-</td>
<td>34 MMBtu/hr</td>
<td>28 MMBtu/hr</td>
<td>44 MMBtu/hr</td>
</tr>
</tbody>
</table>

- The Total Fuel Consumption for each case is defined as that required to meet baseload energy requirements of 10 MW and 65 mlb/hr steam.
- The high efficiency and baseload operation of a CHP provides energy savings over other clean energy systems.

Source: Pace Global, a Siemens Business
CHP Emissions Savings

- The energy and emissions savings compared to meeting the 10 MW and 65mlb/h baseload requirements via purchased power (based on national average generation efficiency and emissions factors) and an 84% efficient natural gas fired boiler system.
CHP in Critical Infrastructure – Super Storm Sandy

- Nearly $20 billion in losses from suspended business activity
- Total losses estimated between $30 to $50 billion
- Two-day shutdown of the NY Stock Exchange, costing an estimated $7 billion from halted trading
- Estimated economic losses of $11.7 billion for New Jersey GDP
New York Presbyterian Hospital
Weill Cornell Medical Center, Manhattan, NY

- 7.5 MW natural gas-fired CHP system (gas turbine with HRSG)
- Maintained full service while the surrounding grid was shut down for several days
- The hospital not only cared for its own patients during the blackout, but was able to admit patients from nearby hospitals that had lost power during the storm
CHP Annual MW Additions

Annual CHP Capacity Additions by Size

Source: ICF CHP Installation Database (2012 data)
History of CHP Growth in the U.S. – Part 1

• 1960s – Power market dominated by large, regulated utilities using central station generation – little incentive to promote CHP
  - Minimum amount of CHP in large steam using industrials (mostly solid fuel boiler/steam turbine systems)

• 1978 – Congress passes Public Utility Regulatory Policy Act (PURPA) to promote energy efficiency and CHP
  - Required utilities to interconnect with “qualified facilities”
  - Required utilities to provide reasonable back-up charges
  - Required utilities to purchase excess power and avoided costs of new generation
  - Included minimum efficiency standards for cogeneration (CHP

• 1980s – CHP capacity grew quickly
  - PURPA
  - Tax incentives
  - Availability of natural gas
  - New gas turbine technology
CHP Annual MW Additions

Annual CHP Capacity Additions by Size

Source: ICF CHP Installation Database (2012 data)
History of CHP Growth in the U.S. – Part 2

• Mid-1990s – Deregulation of the wholesale power market
  - Independent power producers could sell power without being a
    PURPA Qualified Facility
  - More restricted access to markets for CHP

• Late-1990s – Threat of constrained electricity
  - Merchant plants enhanced economics by collocating with
    industrials and supplying steam

• 2000s – Market uncertainty has dampened market for CHP
  - Volatile natural gas prices
  - Financial crisis
  - Regulatory uncertainty

• Today
  - Policy makers recognizing energy efficiency and CO₂ reduction
    benefits of CHP
  - Natural gas supply and price outlook positive
CHP Is an Important U.S. Energy Resource

- **82.4 GW** of installed CHP at 4,200 industrial and commercial facilities (2012)
- 87% of capacity in industrial applications
- 70% of capacity is natural gas fired
- Avoids more than **1.8 quadrillion Btus** of fuel consumption annually
- Avoids **241 million metric tons of CO₂** compared to separate production

Source: ICF CHP Installation Database (2012 data)
Where Can CHP Be Used?

• High thermal (steam, hot water, direct heat, or cooling) demands
• High electric demands
• Coincident thermal and electric demands
• Extended operating hours
• Access to fuels (byproducts, natural gas)
• Where the rates and regulatory climate are favorable
• Where power reliability is important
Typical CHP Applications

**Industrial Plants**
- Food Processing
- Textiles
- Paper production
- Chemicals
- Refineries
- Steel production
- Coke production
- Cement
- Manufacturing and assembly
- Data Centers

**Commercial Buildings**
- Hospitals
- Hotels
- Spas
- Prisons
- Universities
- Laundries
- Large office buildings
- Apartments
- Multi-family
Natural Gas is the Preferred Fuel for Existing CHP (Based on Capacity)

- Natural Gas: 70%
- Coal: 15%
- Wood: 2%
- Other: 1%
- Biomass: 2%
- Waste: 9%
- Oil: 1%

Source: ICF CHP Installation Database (2012 data)
Frito-Lay CHP System

Killingly, Connecticut Facility

• 400 employees
• Processes 250,000 lb/day of corn and potatoes

CHP System

• 4.6 MW Gas Turbine with SCR for NOx Control
• Provides 100% electricity needs and 80% of site steam needs

Start-up March 2009
Killingly Facility and CHP System
4 MW Natural Gas Combustion Turbine
Duct Burner and Heat Recovery Boiler
**Estimated Economic Performance**

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Annual Energy Savings</strong></td>
<td>$1,263,350</td>
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<tr>
<td>Annual O&amp;M Costs</td>
<td>$352,515</td>
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<tr>
<td>Net annual operating savings</td>
<td>$910,834</td>
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<tr>
<td>Incremental CHP Capital Cost</td>
<td>$8,012,000</td>
</tr>
<tr>
<td>Payback, years</td>
<td>8.8</td>
</tr>
</tbody>
</table>

- Average electric rate: $0.106/kWh (CL&P Rate 57)
- Average natural gas price:
  - $7.63/MMBtu (w/o CHP)
  - $6.88/MMBtu (w/ CHP)

Source: Energy Solutions Center: Industrial Gas Turbine Brief – Frito Lay Food Processing
CHP Uses a Variety of Technologies

- 34% Boiler/Steam Turbine
- 50% Combined Cycle
- 13% Combustion Turbine
- 3% Reciprocating Engine
- <1% Other

Source: ICF CHP Installation Database (2012 data)
CHP Technology Preference – Number of Sites

- **51% Reciprocating Engine**
- **18% Boiler/Steam Turbine**
- **11% Combustion Turbine**
- **5% Combined Cycle**
- **13% Other**

**Existing CHP Sites by Technology**

Source: ICF CHP Installation Database (2012 data)
Arrow Linen Supply CHP System

- Laundry service for restaurants in New York
- Two 150 kW reciprocating engine packages
- Peak demand of 370 kW
- Hot water thermal recovery for washers and processing
- Electric Load Following
- CHP system provides 70% of facility’s power
Arrow Linen Supply – Project Economics

- Annual energy costs of $900,000 before CHP
- CHP installed cost $700,000
- CHP savings of $115,000 per year
- 6.1 year payback based on typical costs
- 3.7 year payback for project with incentives

Source: Energy Solutions Center: Distributed Generation Brief – Arrow Linen
Natural Gas CHP Technologies

- Gas Turbines
- Lean Burn Engines
- Rich Burn Engines
- Fuel Cells
- MicroTurbines

CHP Electric Capacity, kW<sub>e</sub>

- Strong Market Position
- Market Position
- Emerging Position