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.

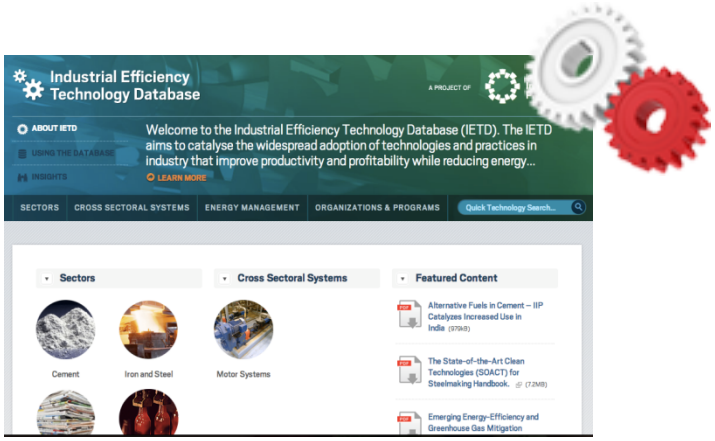
WHAT WE DO:

- Sharing best practices
- Technical support
- Policy assistance
- Financing expertise

OFFICES:

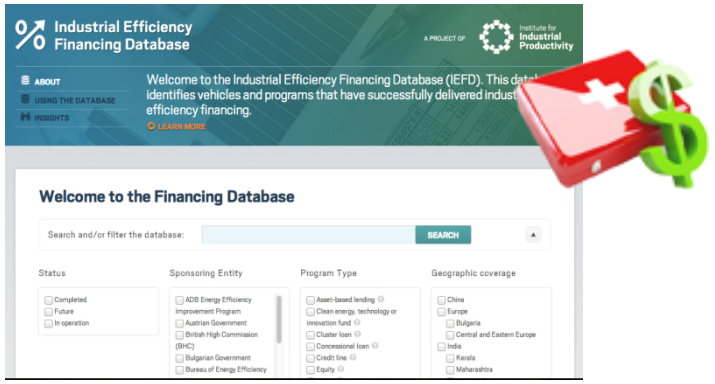
- Beijing, New Delhi, Washington DC, Paris

IIP's Best Practice Databases

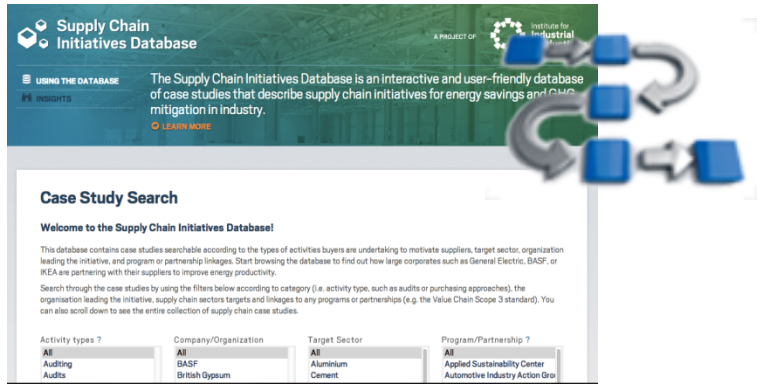


Industrial Efficiency Technology Database
www.ietd.iipnetwork.org

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

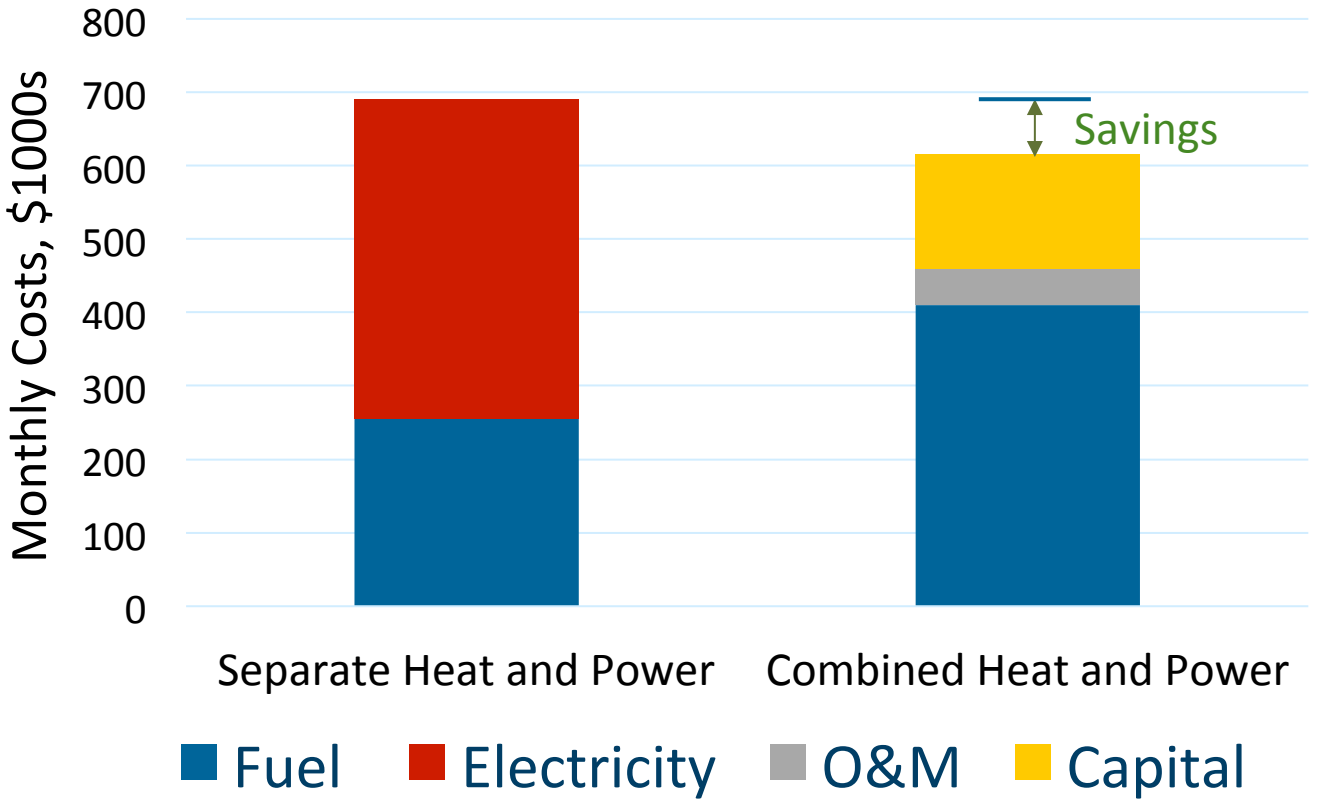
\+ Increased capital expenditure

— 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

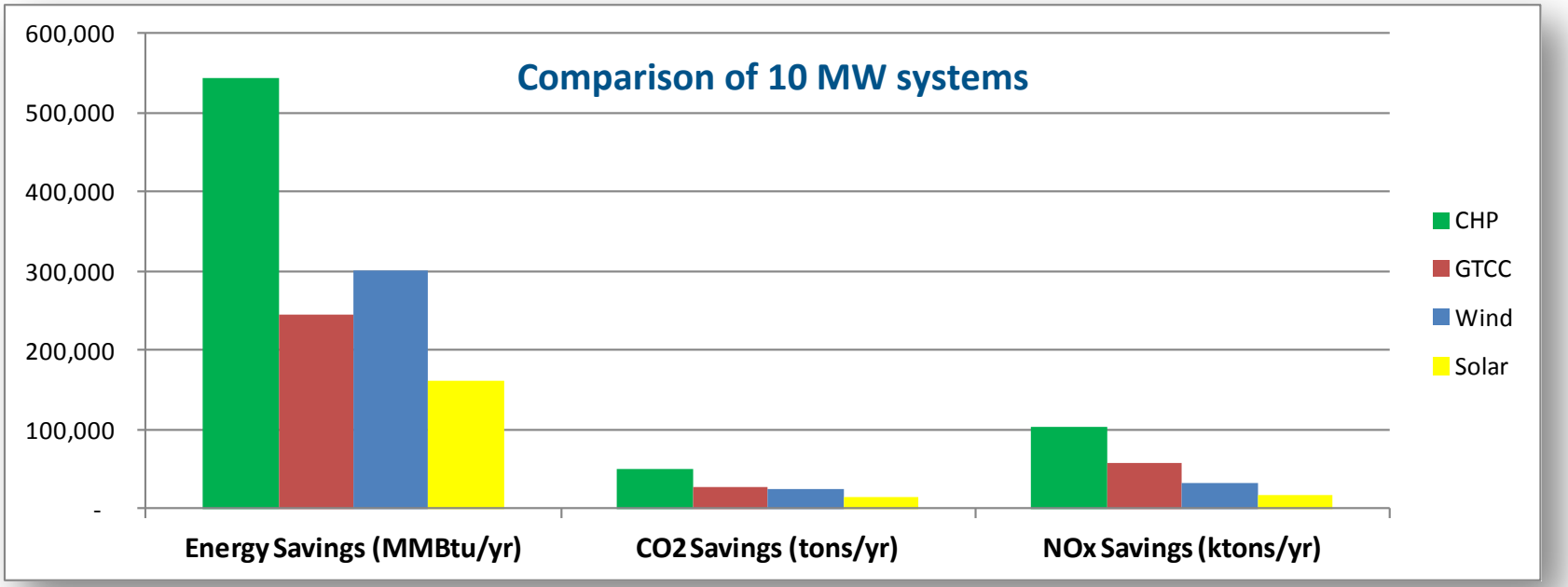
Technology (10 MW Fractional Basis)	CHP	Combined Cycle	Wind	Solar
Annual Capacity Factor	85%	60%	30%	16%
Average Power Production (per hr)	8.5 MWh	6.0 MWh	3.0 MWh	1.6 MWh
Total Fuel Consumption (Baseload of 10 MW and 65 mlb/hr steam)	140 MMBtu/ hr	174 MMBtu/ hr	168 MMBtu/ hr	184 MMBtu/ hr
Fuel Savings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

- 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.



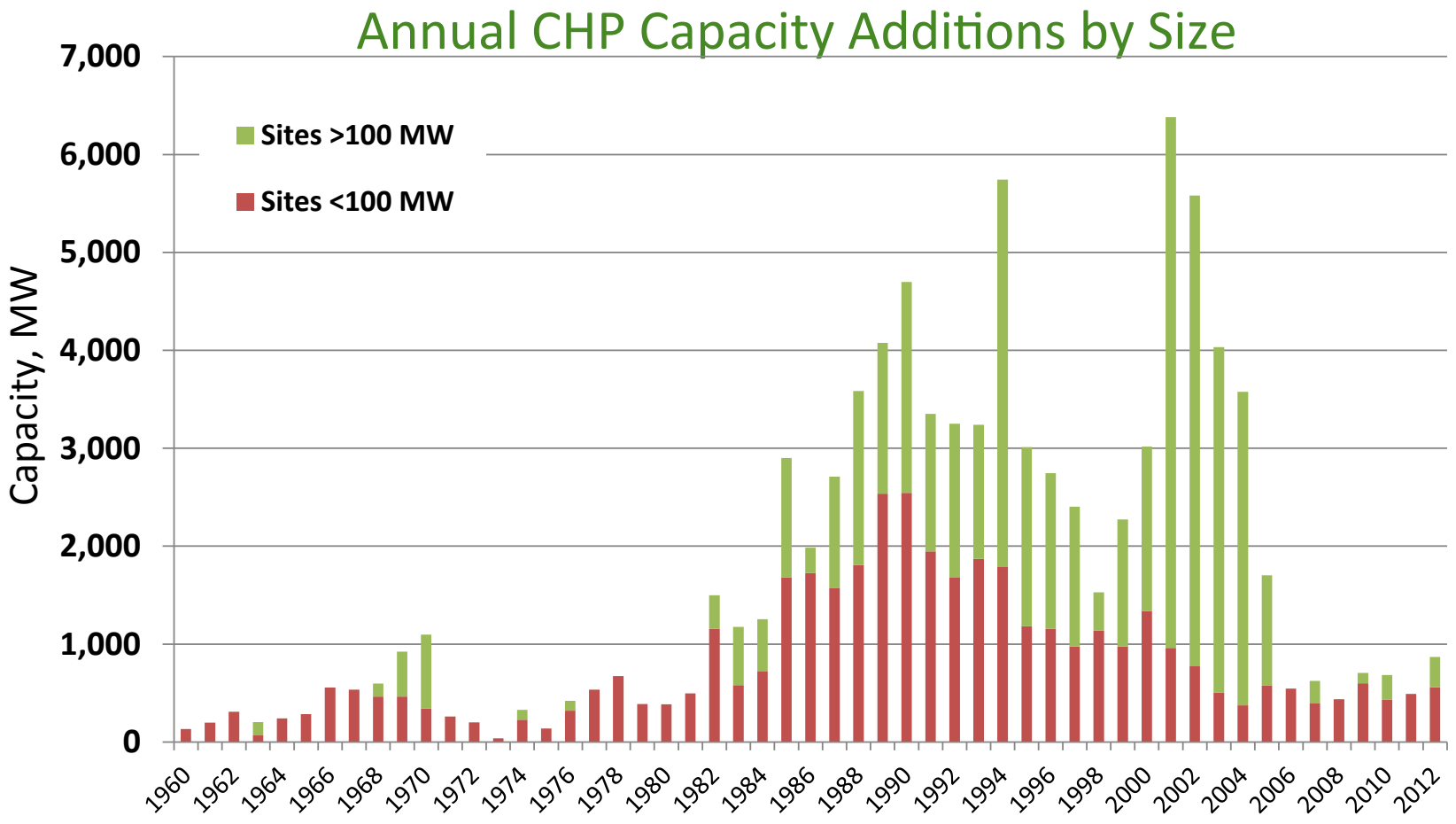
CHP in Critical Infrastructure – Super Storm Sandy

- 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



Source: ICF CHP Installation Database (2012 data)

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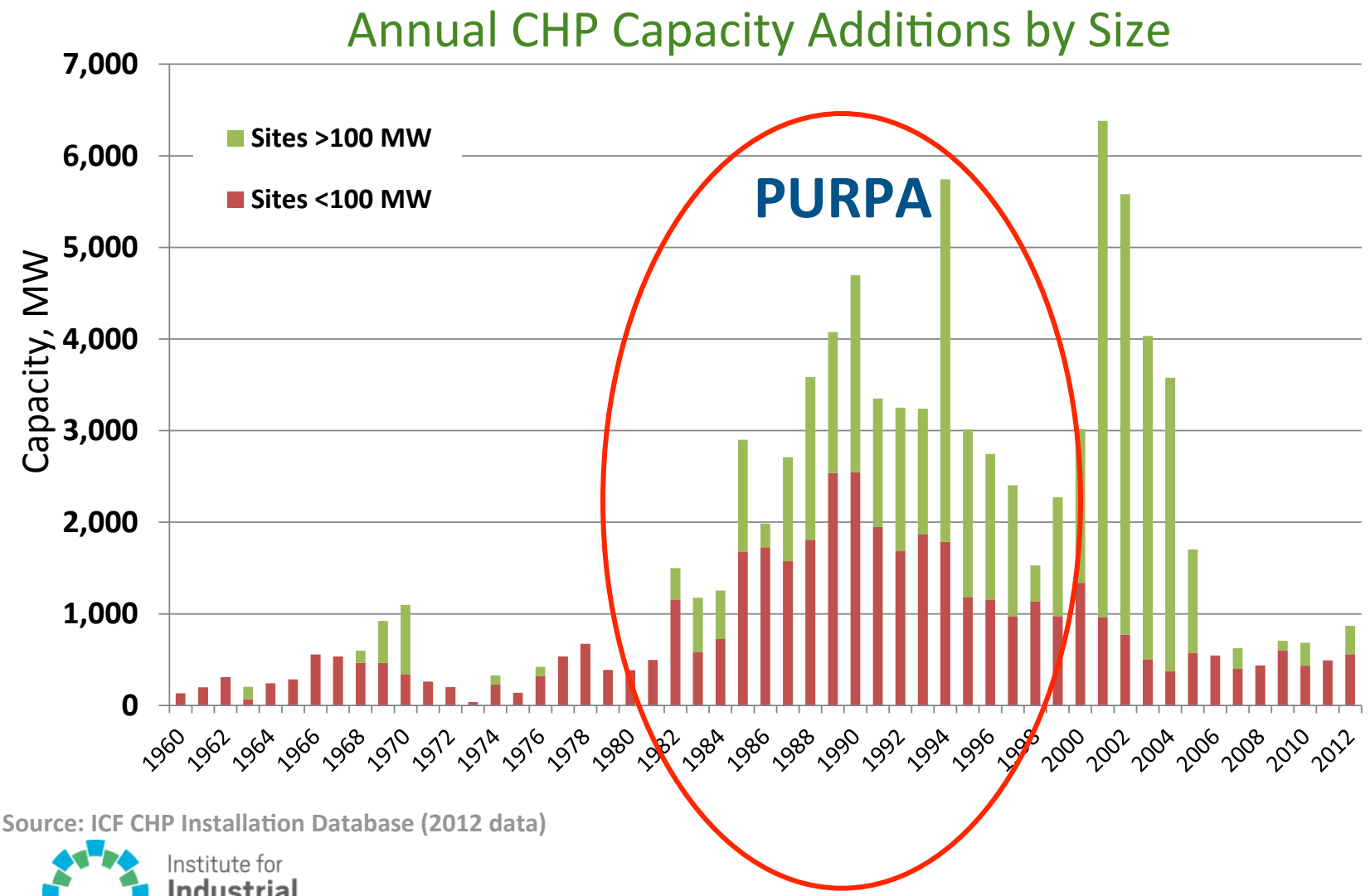
History of CHP Growth in the U.S. – Part 1

- 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 ga
  - New gas turbine technology

CHP Annual MW Additions



Source: ICF CHP Installation Database (2012 data)

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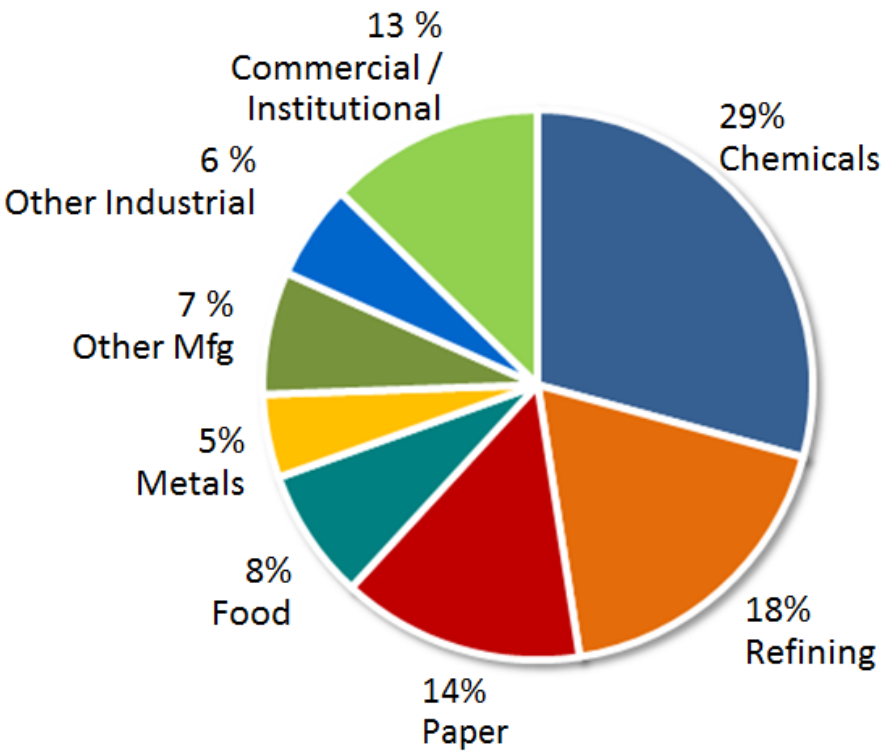
History of CHP Growth in the U.S. – Part 2

- 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 CO_2 reduction benefits of CHP
  - Natural gas supply and price outlook positive

CHP Is an Important U.S. Energy Resource



Source: ICF CHP Installation Database (2012 data)

- **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 CO_2** compared to separate production

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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

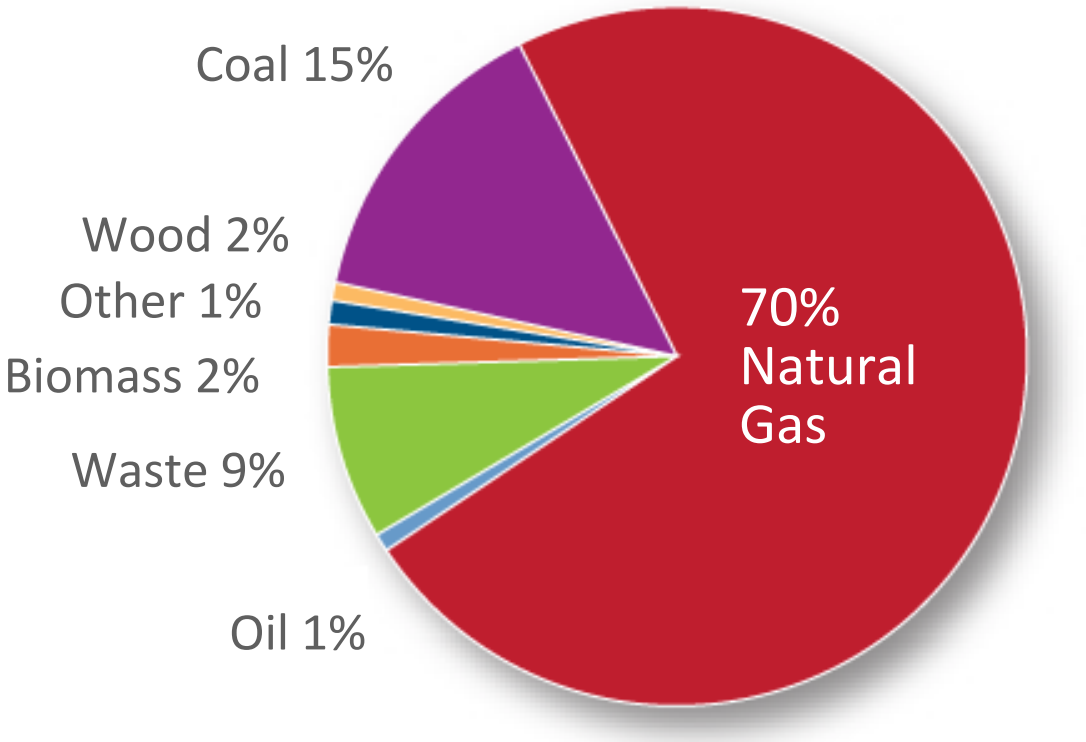
Industrial Plants

- 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)



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

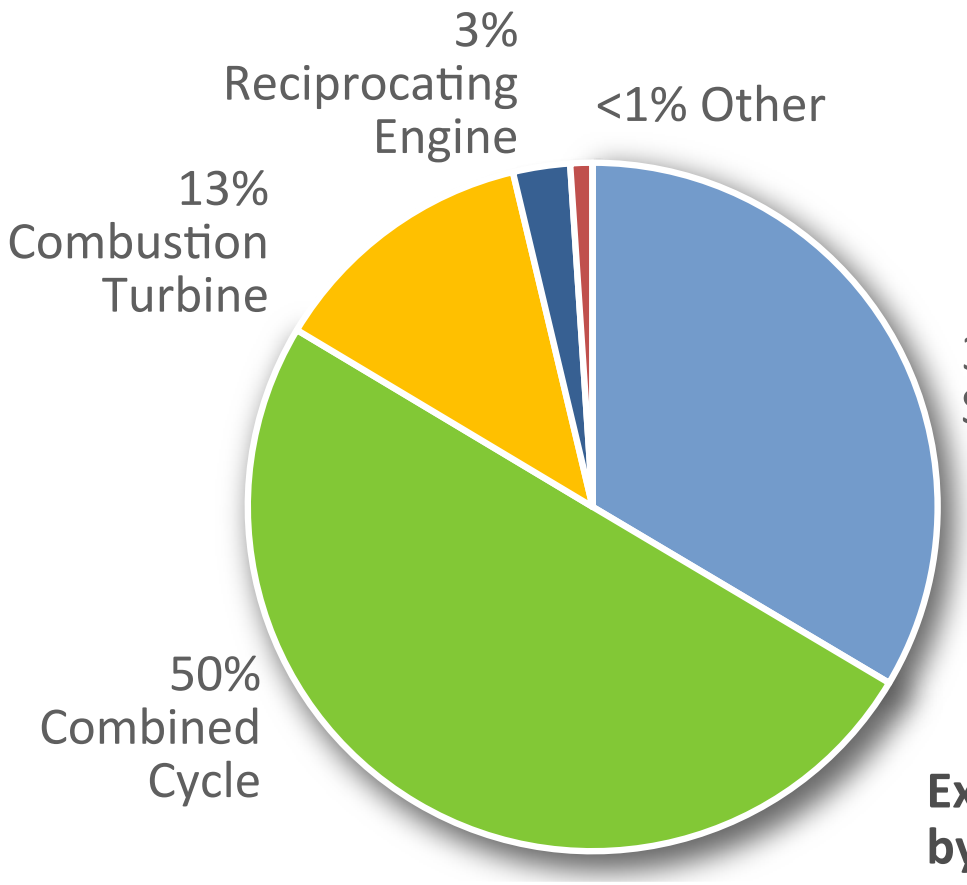
Estimated Economic Performance

Annual Energy Savings	$1,263,350
Annual O&M Costs	$352,515
Net annual operating savings	$910,834
Incremental CHP Capital Cost	$8,012,000
Payback, years	8.8

- 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



Existing CHP Capacity by Technology – 82.4 GW

Source: ICF CHP Installation Database (2012 data)

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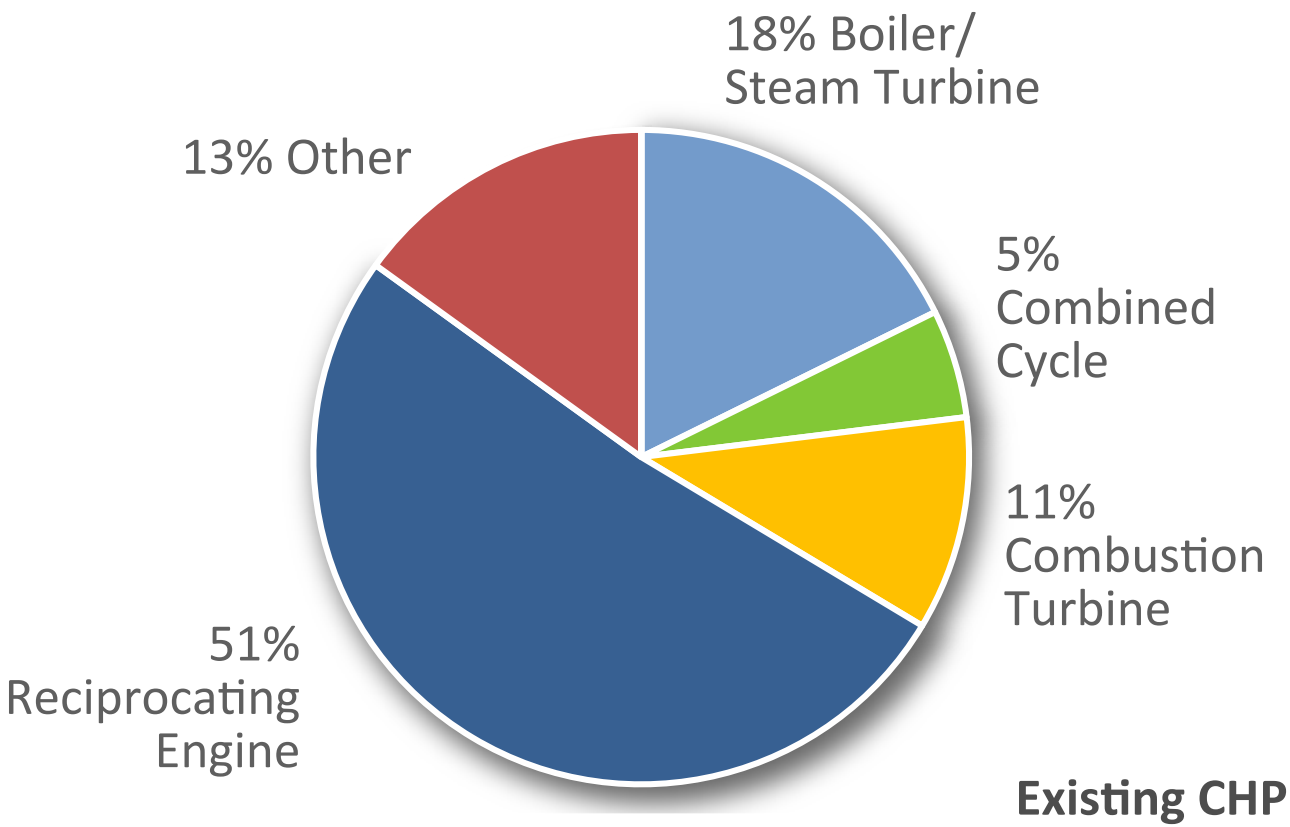
CHP Technology Preference – Number of Sites



Existing CHP Sites by Technology

Source: ICF CHP Installation Database (2012 data)

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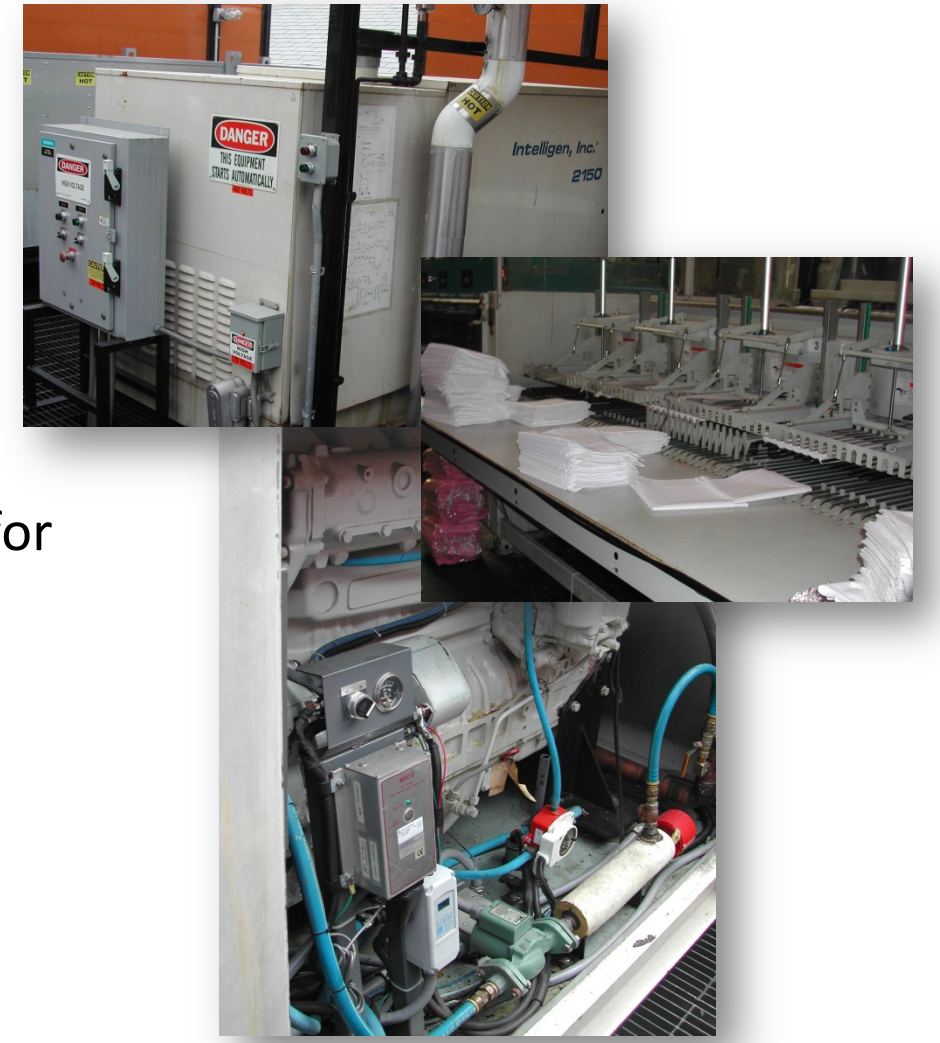
Arrow Linen Supply CHP System

- 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



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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