Combined Heat and Power
When and Where Does It Make $ense Today

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recycling energy™ CHP It's time

MIDWEST CHP APPLICATION CENTER In Partnership with the US DOE

Energy / Environmental Issues

- High Natural Gas Prices
- Natural Gas Price Volatility
- Rising Electric Prices
- Competitive Electric Market (Potential Price Volatility)
- Uncertain Environmental Constraints
  - Air & Water Permits
  - Global Warming (CO_2)
- Reliability – Natural / Man Made Disasters

Energy Efficiency

- "One" of Several Potential Solutions
- Reducing Energy Consumption Wisely Will:
  - Lower Energy Bills
  - Lower Emissions
  - Should Lower Overall Energy Prices

Energy Efficiency Measures

- Energy Efficient Lighting / Daylighting
- High Efficiency Boilers / Furnaces
- High Efficiency Chillers
- Insulation
- Eliminate Steam Leaks
- Energy Efficient Motors
- Compressed Air Systems

What About CHP?

Distributed Generation

DG is …

- An Electric Generator
- Located At a Substation or Near a Building / Facility
- Generates at least a portion of the Electric Load

DG Technologies …..

- Solar Photovoltaic
- Wind Turbines
- Engine Generator Sets
- Turbine Generator Sets
  - Combustion Turbines
  - Micro-Turbines
  - Steam Turbines
- Fuel Cells

Combined Heat and Power
A Form of Distributed Generation

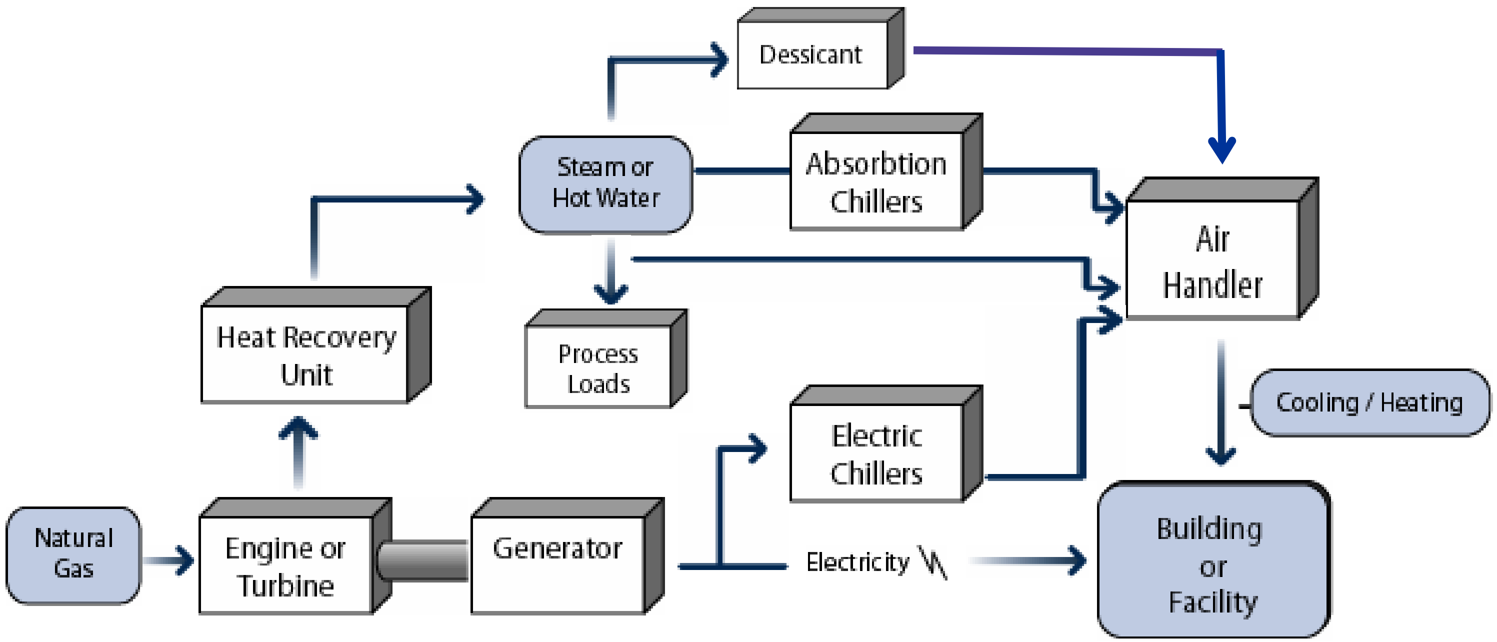
Combined Heat and Power (CHP) is …

- An Integrated System
- Located at or near a Building/Facility
- Providing a Portion of the Electrical Load

and

- Recycles the Thermal Energy for
  - Process Heating / Cooling
  - Space Heating / Cooling
  - Dehumidification

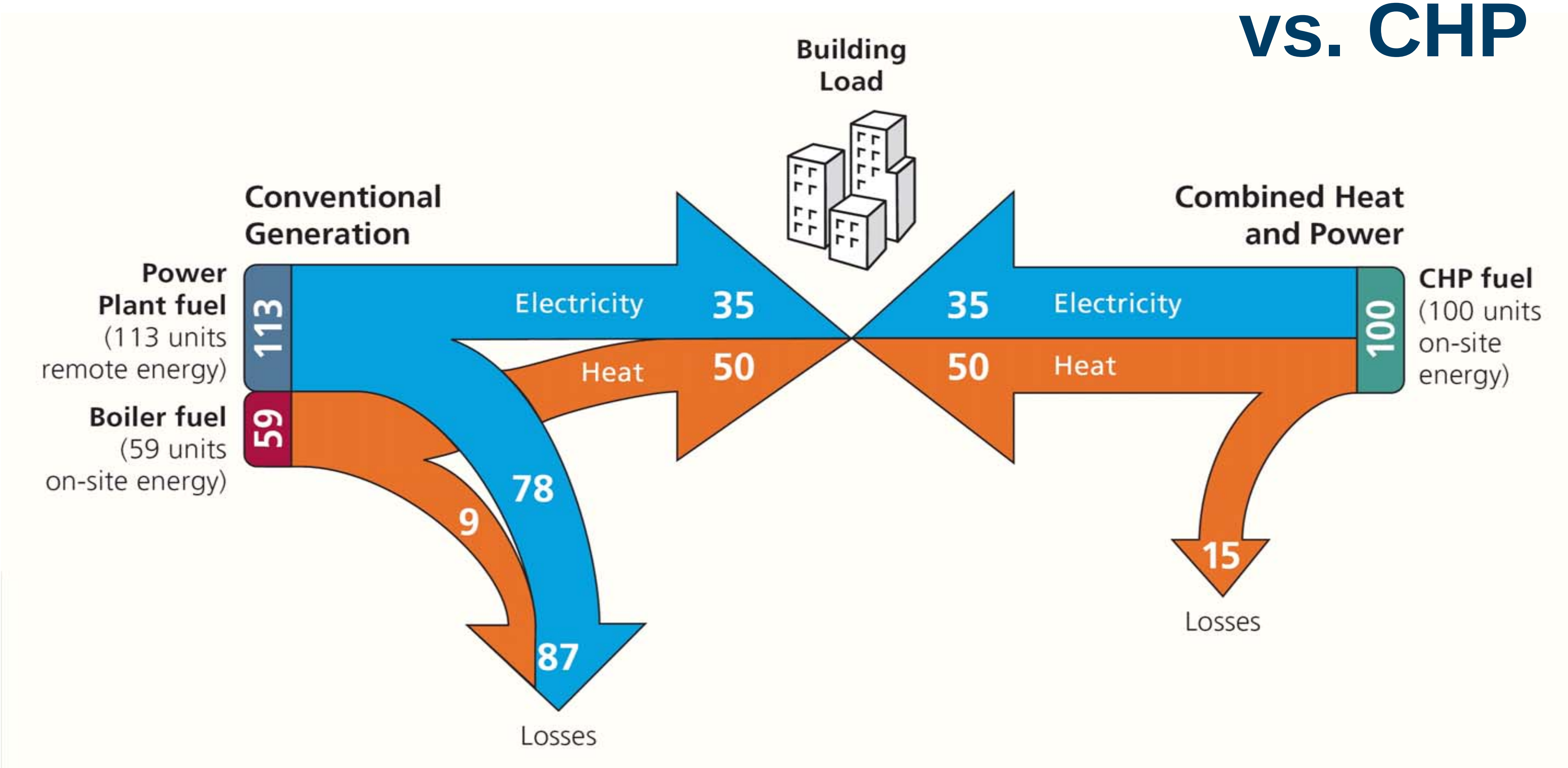
Typical Commercial CHP Configuration



Typical CHP Configuration

- CHP Systems are Normally Installed in Parallel with the Electric Grid (CHP does not replace the grid)
- Both the CHP and Grid Supply Electricity to the Customer
- Recycled Heat From the Prime Mover Used for:
  - Space Heating (Steam or Hot Water Loop)
  - Space Cooling (Absorption Chiller)
  - Process Heating and/or Cooling
  - Dehumidification (Desiccant Regeneration)

Conv. Generation vs. CHP



What Makes A Good CHP Application?

- Good Coincidence Between Electric and Thermal Loads
- 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 (*smaller is better*)

Application Rules of Thumb

- If > 50% of the available thermal energy from the prime mover can be used on an annual basis, CHP probably makes good $ense.
- Spark Spread > $12/MMBtu – application worth further evaluation
- CHP operating hours should be > 3,000 hrs/yr
- Doubling the capacity of the CHP system does not normally double the cost and reduces the installed “cost per kW”.
- Larger sized facilities usually translates to a lower CHP installed cost differential and larger annual savings

Why is There an Opportunity?

- DOE/EIA Project Over 360 GWe of New Capacity
  - To Meet Growing Demand
  - To Compensate for Plant Retirements
- Today's Central Station Plants Lose 23 Quads of Thermal Energy
- Aging Electric Transmission/Distribution System
  - Difficult to Site New Lines
  - Capacity Constrained
  - Costly to Maintain

Why is There an Opportunity?

- Rising Concerns Over
  - Blackouts/Brownouts
  - Power Supply Constraints
  - Electricity Prices
- Selected Power Outage Costs

Industry	Avg. Cost of Downtime
Cellular Communications	$41,000 per hour
Telephone Ticket Sales	$72,000 per hour
Airline Reservations	$90,000 per hour
Credit Card Operations	$2,580,000 per hour
Brokerage Operations	$6,480,000 per hour

CHP System Sizes (Terminology)

System Designation	Size Range	Comments
Mega	50 to 100+ MWe	Very Large Industrial Usually Multiple Smaller Units Custom Engineered Systems
Large	10's of MWe	Industrial & Large Commercial Usually Multiple Smaller Units Custom Engineered Systems
Mid	10's of kWe to Several MWe	Commercial & Light Industrial Single to Multiple Units Potential Packaged Units
Micro	<60 kWe	Small Commercial & Residential Appliance Like

What are the Customer Benefits of CHP?

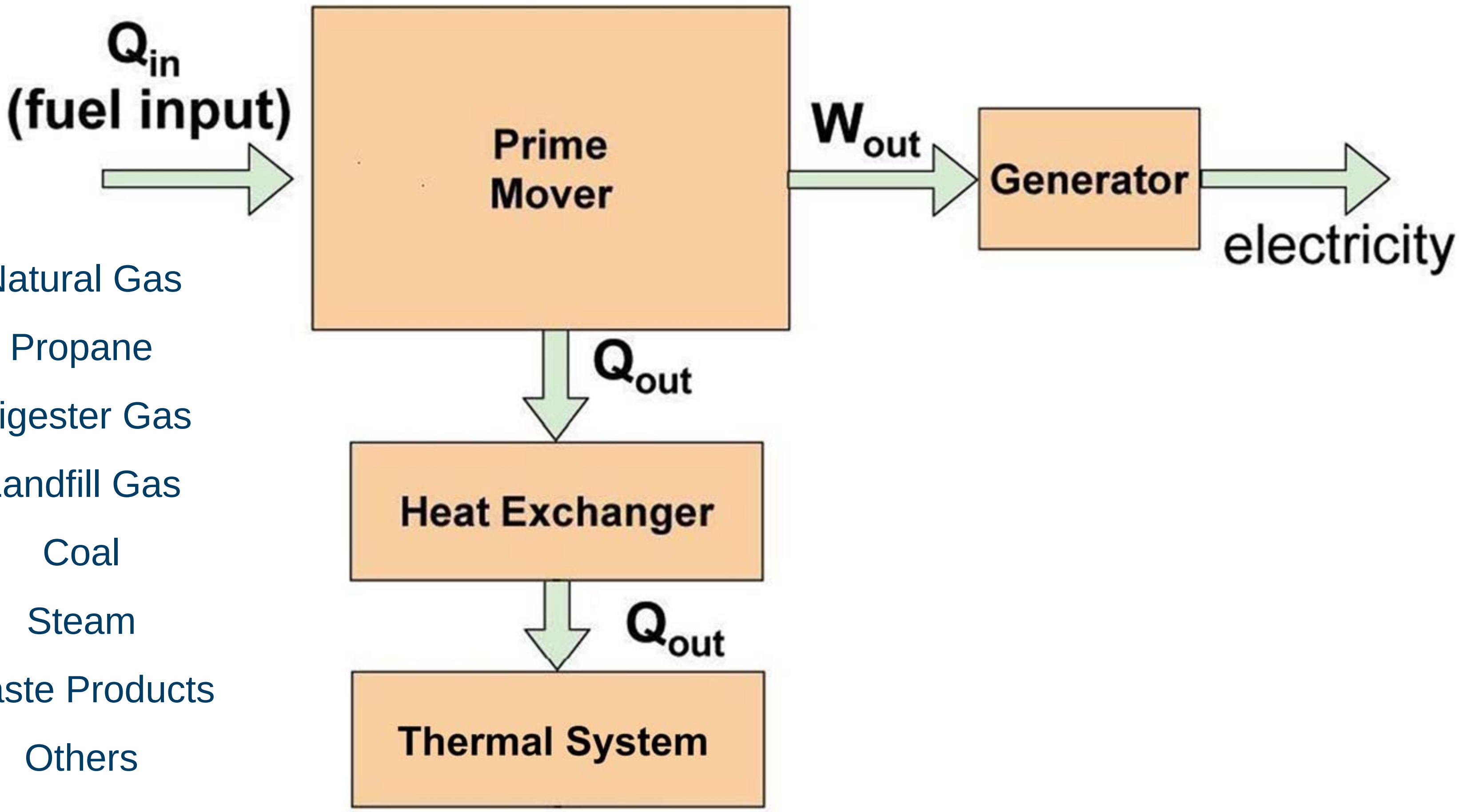
CHP does not make sense in all applications, but where it does make technical and economic sense, it will provide

- Lower Energy Costs
- Reduced Energy Consumption
- Increased Electric Reliability
- Standby Power
- Improved Environmental Quality

Market Challenges

- Lack of a Critical Need (high energy prices??)
- Unstable / Uncertain Energy Prices (Deregulation?)
- Electric Utility Resistance
- Lack of Awareness of the Technology Concept, Status, Benefits, and Issues
- Need for Internal Champions: Technical & Financial
- Competing for Capital Development $
- Not Enough “Sizzle”
- Quantifying Non Utility Cost Benefits

Combined Heat and Power



Natural Gas

Propane

Digester Gas

Landfill Gas

Coal

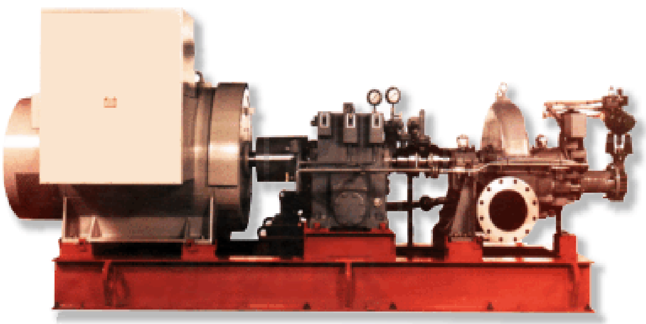
Steam

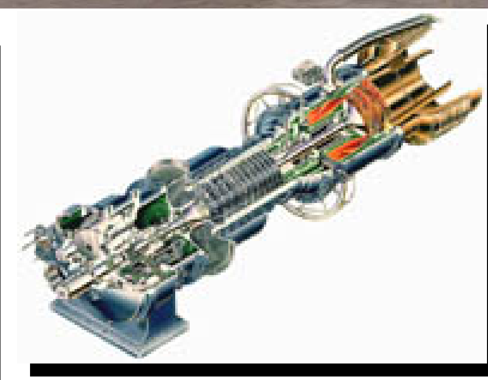
Waste Products

Others

CHP Prime Movers

- Reciprocating Engines
- Industrial Gas Turbines
- Steam Turbines
- Micro-turbines
- Fuel Cells





Which Prime Mover to Use

- Recip. Engine --- Hot Water / Low Pressure Steam
- Industrial Gas Turbines --- High Pressure Steam, Usually over 3 to 4 MW in Capacity
- Steam Turbines --- Large Industrials with Waste Streams, Large Pressure Drop Requirements
- Micro-Turbines --- Fuel Flexibility, Relatively Small Capacities Required
- Fuel Cells --- Extremely Clean, Very Expensive

Rule of Thumb
Which Prime Mover to Use – T/P Ratio

1. Determine Thermal Use			
a.	Sum # of therms used over last 12 months of bills		Therms
b.	Multiply a by 1,000 to get thermal Btus purchased		Btus
c.	Multiply Btus purchased by Boiler Eff. (typical 80%)		Btus
2. Determine Electric Power Use			
d.	Sum # of kWh used over last 12 months of bills		kWh
e.	Multiply d by 3413 Btu/kWh to get Btus purchased		Btus
3. Determine T/P Ratio			
f.	Divide total thermal (c) by total electric (e)		T/P

Rule of Thumb
T/P Ratio

If T/P =	
0.5 to 1.5	Consider Engines
1 to 10	Consider Gas Turbines
3 to 20	Consider Steam Turbines

Prime Mover Summary

	Diesel Engine	Natural Gas Engine	Gas Turbine	Microturbine	Fuel Cells
Electric Efficiency (LHV)	30-50 %	25-45 %	25-40 % (simple) 40-60 % (combined)	20-30 %	40-70 %
Power Output (MW)	0.05-5	0.05-5	3-200	0.025-0.25	0.2-2
Footprint (ft^2/kW)	0.22	0.22-0.31	0.02-0.61	0.15-1.5	0.6-4
CHP installed cost ($/kW)	800-1,500	800-1,500	700-900	500-1,300	>3,000
O&M cost ($/kW)	0.005-0.010	0.007-0.015	0.002-0.008	0.002-0.01	0.003-0.015
Availability (uptime)	90-95 %	92-97 %	90-98 %	90-98 %	>95 %
Hours between Overhauls	25,000-30,000	24,000-60,000	30,000-50,000	5,000-40,000	10,000-40,000
Start-up time	10 sec	10 sec	10 min-1 hr	60 sec	3 hrs-2 days

Prime Mover Summary

	Diesel Engine	Natural Gas Engine	Gas Turbine	Microturbine	Fuel Cells
Fuel pressure (psi)	<5	1-45	125-500 (may require compressor)	40-100 (may require compressor)	0.5-45
Fuels	Diesel and residual oil	Natural gas, biogas, propane	Natural gas, biogas, propane, distillate oil	Natural gas, biogas, propane, distillate oil	Hydrogen, natural gas, propane
Noise	Moderate to high (requires building enclosure)	Moderate to high (requires building enclosure)	Moderate (enclosure supplied with unit)	Moderate (enclosure supplied with unit)	Low (no enclosure required)
NO_X emissions (lb/MW-hr)	3-33	2.2-28	0.3-4	0.4-2.2	<0.02
Uses for Heat Recovery	Hot water, LP steam, district heating	Hot water, LP steam, district heating	Direct heat, hot water, LP-HP steam, district heating	Direct heat, hot water, LP steam	Hot water, LP-HP steam
CHP output (Btu/kWh)	3,400	1,000-5,000	3,400-12,000	4,000-15,000	500-3,700
Useable Temp for CHP (8F)	180-900	300-500	500-1,100	400-650	140-700

Generators and Inverters

Two Types of Generators

Induction

- Requires External Power Source to Operate (Grid)
- When Grid Goes Down, CHP System Goes Down
- Less Complicated & Less Costly to Interconnect
- Preferred by Utilities

Synchronous

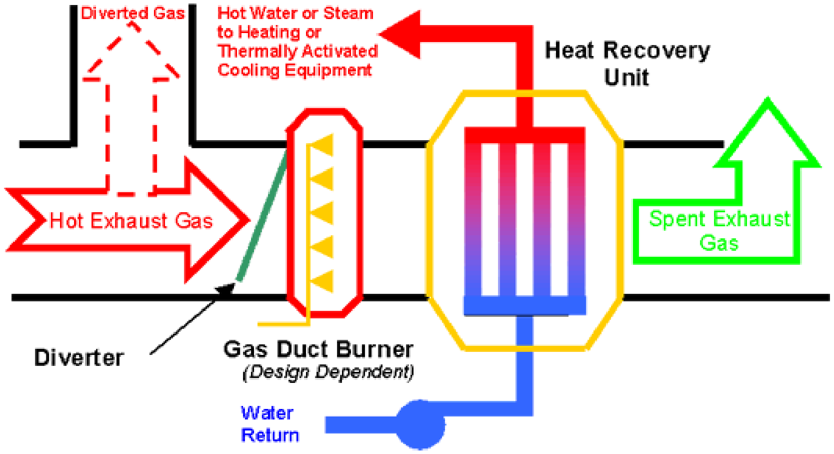
- Self Excited (Does Not Need Grid to Operate)
- CHP System can Continue to Operate thru Grid Outages
- More Complicated & Costly to Interconnect (Safety)
- Preferred by CHP Customers

Inverters

- Devices that Convert DC Power to AC Power
- Inverter Voltage & Frequency Automatically Synchronize with the Utility Grid
- Inverter Systems Include: Fuel Cells and Micro-turbines
- When the Grid Goes Down, the Inverter Based CHP System Goes Down

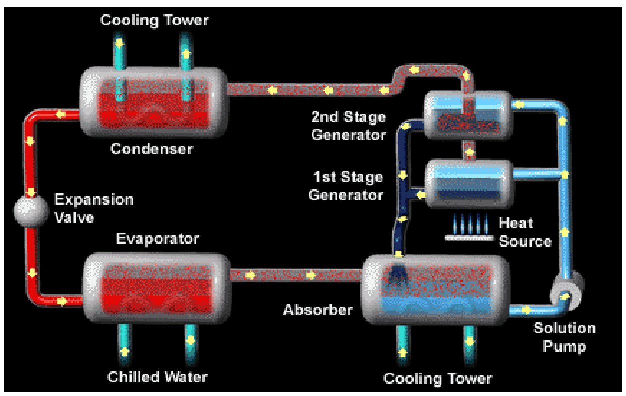
Heat Recovery (Recycled Energy)

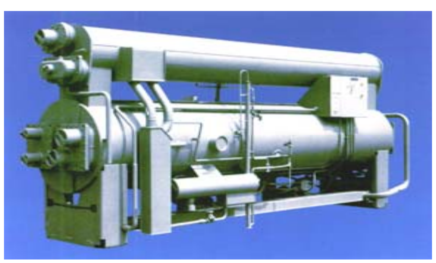
- Hot Exhaust Gases
  - Direct
  - Steam, Hot Water, Air

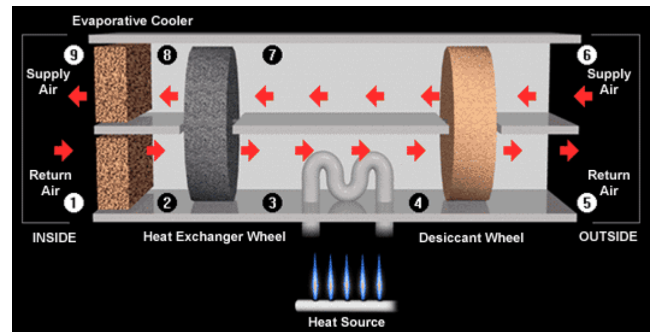


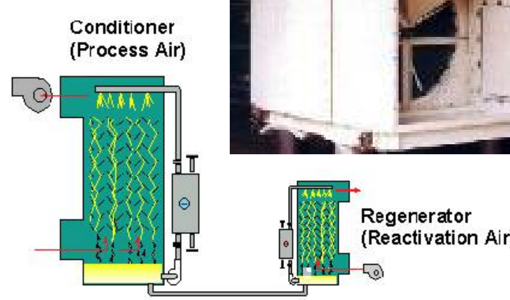
Thermally Activated Machines

- Space and Process Heat Systems
- Absorption Chillers / Refrigeration Systems
- Desiccant Dehumidifiers









Absorption Cooling Rules of Thumb

- LiBr – water absorption systems normally used for cooling down to 40^{o} F (space cooling)
- Water – ammonia absorption systems typically used for refrigeration < 32^{o} F
- CHP systems usually utilize single effect absorption chillers (less expensive, less efficient but operates on recycled heat)

System Configuration Rules of Thumb

- CHP systems normally interconnected "in parallel" to the grid (electricity supplied by the grid & CHP system simultaneously)
- CHP systems normally sized for the thermal load of the facility (excess power sold to the grid, shortage purchased from grid)
- Black Start Capability: Should the grid and the CHP go down, the CHP system can be restarted without grid support.

Candidate Applications for CHP

- Hospitals
- Colleges / Universities
- High Schools
- Residential Confinement
- High Rise Hotels
- Fitness Centers

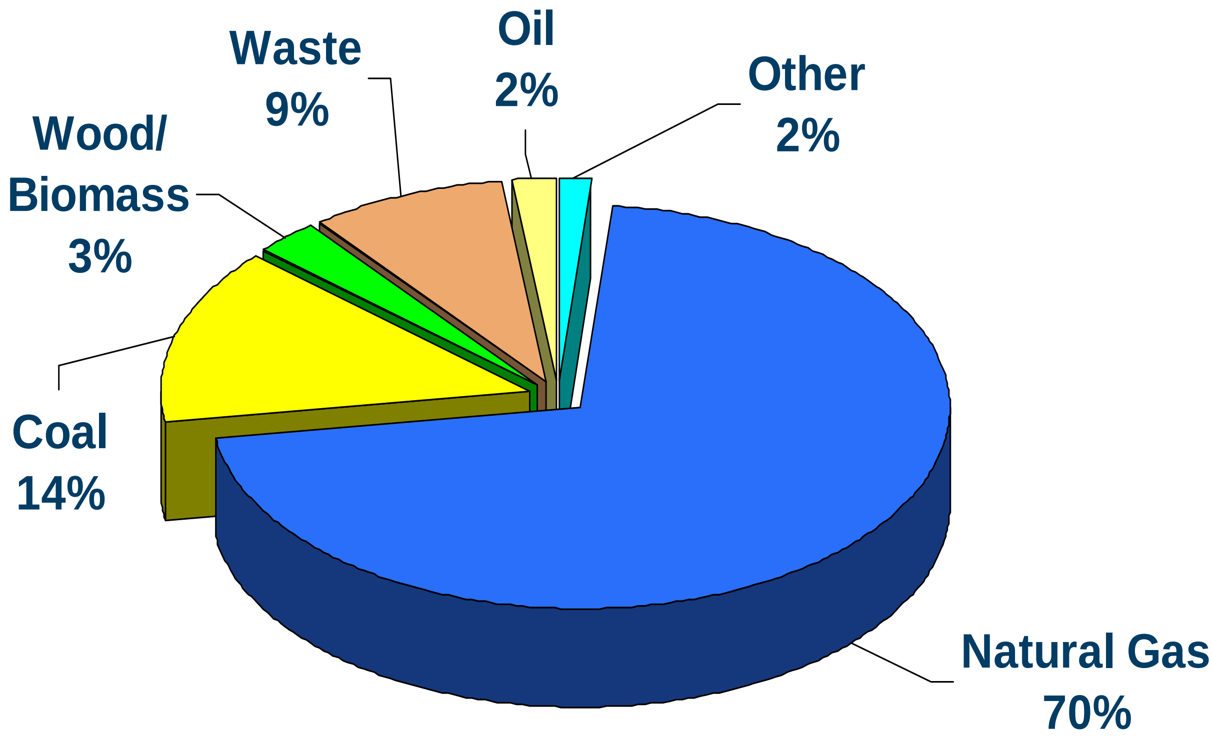
- Food Processing
- Pulp & Paper Mills
- Chemicals Manufacturing
- Metal Fabrication
- Ethanol / Biodiesel Plants
- Livestock Farms (Digesters)
- Landfill / Waste Water Treatment Plants

Installed CHP in 2005

- 82,400 MW at 2,960 sites
- Average capacity is 28 MW
- Median capacity is 2.2 MW
- Represents about 9% of total U.S. generating capacity
- Saves over 3 quads of fuel each year
- Eliminates over 400 million tons of CO2 emissions each year

Natural Gas Is the Preferred Fuel

- *Existing CHP Capacity (2005): 82,411 MW*



Source: EEA

Emergency / Energy Assurance Plans

- Historically dealt more with energy shortages & response planning to those shortages
- Today, more emphasis placed on Critical Infrastructure Protection – losing energy services for prolonged periods of time due to:
  - Deliberate Attacks (man made)
  - Natural Disasters (weather related)
  - Accidental Disasters (technology failures)
  - Systemic Threats (physical inability of the delivery system to meet demands)

Loss of Electricity

- Critical air handling & space conditioning equipment shuts down
- Gas stations can not pump fuel for vehicles (evacuation routes)
- Water supply, purification, & sewage systems fail
- Operation of hospitals, nursing homes, and other critical facilities are compromised once diesel stored on-site for emergency generator sets is consumed (normally hours)
- Businesses shut down (commercial & industrial)

CHP Systems Configuration
(Energy Emergencies)

- Configured with synchronous generator
- Be grid connected with stand-alone capability
- Be sized to handle all or a major portion of the electric load
- Recycle the heat from the prime movers for space heating, space cooling, and possibly dehumidification
- Have “Black Start” capability
- Have a continuous source of fuel (usually natural gas or dual fueled natural gas and/or fuel oil)

Recent Examples

- Mississippi Baptist Medical Center, Jackson Ms:
  – 624 bed full service hospital remained fully operational during the 54 hour blackout caused by Hurricane Katrina
- Montefiore Medical Center, New York City:
  – Continued to admit patients, perform surgeries, and asses patients using specialized diagnostic equipment during the August 2003 Northeast and parts of the Midwest blackout
- Norwalk Hospital, Norwalk Connecticut:
  – Operated as designed – sensed the August, 2003 blackout, disconnected the CHP system from the grid, switched to emergency gen sets for life critical loads, CHP system restarted “black start” reconnecting 100% of load to CHP system

Potential Critical Market Sectors

- Hospital & Nursing Homes
- Emergency Command Centers
- Schools and Convention Centers (emergency shelters)
- Evacuation Route Facilities (gas stations, road side oasis)
- Water and Waste Water Treatment Facilities
- Police & Fire Stations
- Data Centers

CHP Can Help Public Power Organizations:

- Source of Self Generation (generation flexibility)
- Potential for Economic Development
  - Partnership with Customers (business retention and/or expansion)
- Potential for Added Revenues
  - Sale of Thermal Energy (Heating and Cooling)
- Increased Security During Natural or Terrorist Disasters (emergency centers)

Example Muni Partnerships

Ethanol Plants

- City of Macon, Missouri & Northeast Missouri Grain
  - 10 MW Gas Turbine, Purchased / Operated / Maintained by the City of Macon
  - CHP System Located on the Ethanol Plant Facility
  - Ethanol Facility Utilizes the Steam, Municipal Receives Credits for Adding Capacity to the Local Power Pool
  - Utility and Ethanol Plant Split Fuel Costs

Summary Natural Gas Fueled CHP

- Difficult sell in parts of the Midwest today on the basis of reduced utility bills only (Spark spread not large enough)
- Quantifying other benefits can justify the investment:
  - Hedge against high energy prices
  - Need for increased electric reliability (voltage sags as well as extended outages)
  - Emergency planning (should the electric infrastructure be compromised)
  - Generation flexibility and/or economic development – Municipal Utilities
  - Solution to grid congestion – Investor or Public Utilities

Alternative Fueled CHP

- Landfill Gas (clean & pipe the gas)
- Anaerobic Digester Gas (food processors, farm manure, waster water treatment)
- Coal
- Industrial Waste
- Steam

Midwest CHP Application Center

- U.S. DOE Sponsored Center
  - With Support From 12 Midwest States
- Service Area Includes:
  - Illinois
  - Indiana
  - Iowa
  - Michigan
  - Nebraska
  - North Dakota
  - Minnesota
  - Missouri
  - Ohio
  - Wisconsin
  - Kansas
  - South Dakota
- Close Coordination with the Midwest CHP Initiative & Midwest Cogeneration Assoc.

Application Center – Mission & Focus

Mission:

Develop Technology Application Knowledge and the Educational Infrastructure Necessary to:

- Reduce Perceived Risks
- Foster CHP as a Viable:
  - Technical and Financial Option
  - Energy and Environmental Option

Focus:

Foster Project Identification and Implementation through:

- Education
- Information
- Technical Assistance

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Questions / Discussion