CHP As An Option In Illinois and Chicago

William W. Worek, PhD
Director & Professor
University of Illinois at Chicago
Energy Resources Center

July 9, 2002
Combined Heat and Power
A Workshop for Illinois Businesses

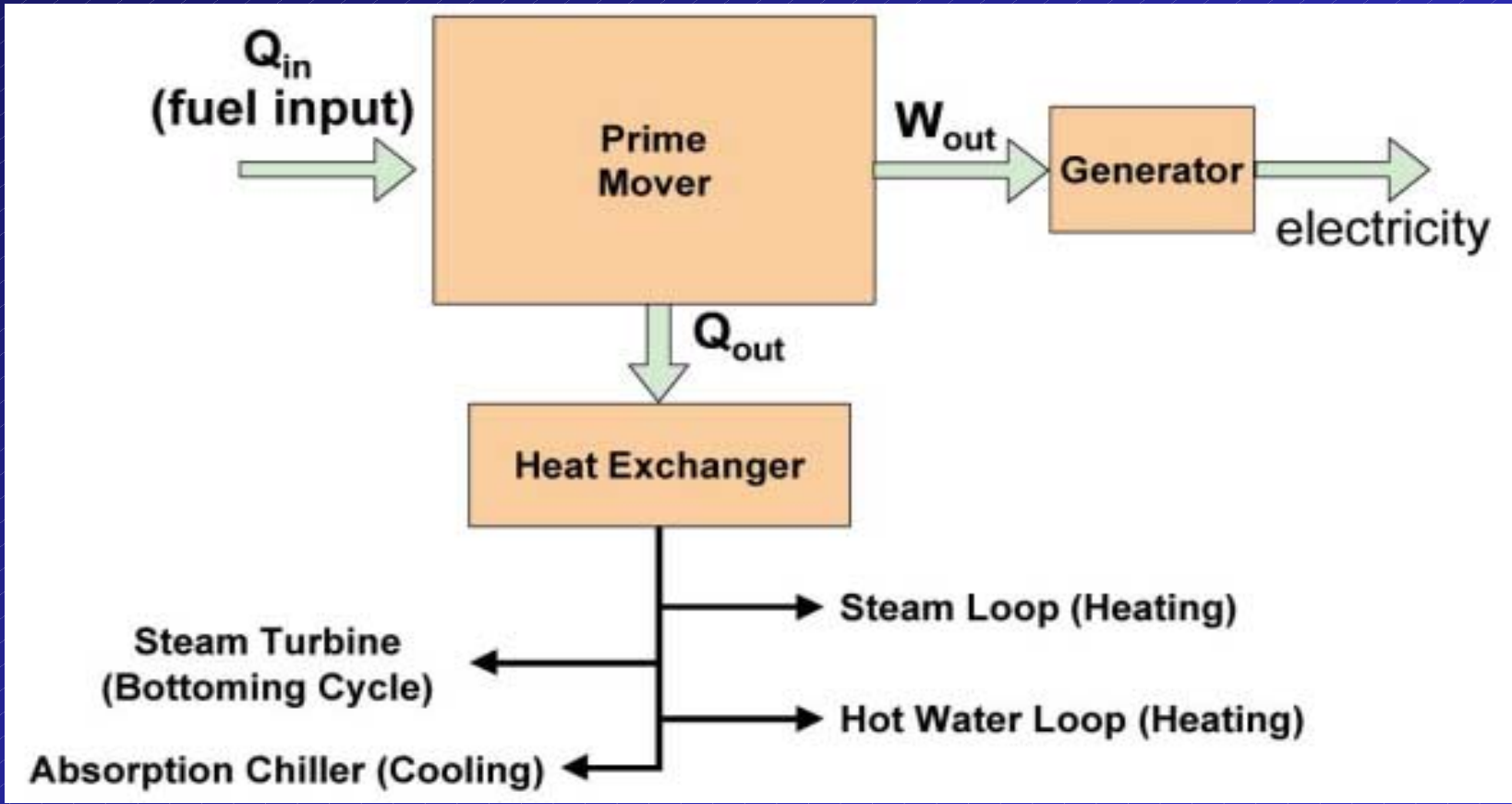
Overview

- CHP Equipment
- When to Consider CHP
- Utility Rates and Cost
- CHP in Illinois – Policy Issues
- Status and Potential of CHP

What is CHP?

- Integrated Energy System
- Located **At** or **Near** A Building/Facility
- Provides **All** or a **Portion** of Electrical Load
- **Utilizes** the **Thermal Energy**
  - Cooling
  - Heating
  - Dehumidification
  - Process Heat

Typical CHP System



Why Consider CHP?

- Peak Electric Power Reduction
- High Efficiency – Up to 80%
- Power Reliability and Quality
- Significant Emissions Reductions
  - 40% Less than Central Plants
  - Improved Indoor Air Quality
- Supports the Electric Grid Infrastructure
  - Grid Reliability
  - Defers Costly Grid Updates
  - Provides Price Stability

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 Technologies

- Electric Generation Equipment
  - Reciprocating Engines
  - Turbines
  - Fuel Cells
- Cooling Equipment
  - Mechanical Chillers
  - Absorption Chillers
  - Desiccant Dehumidification
- Heating

Reciprocating Engines

- Four-Stroke Reciprocating Engine:
  - One of the Most Reliable Technologies Available
  - Used in Small to Medium-Sized Plants
- Reciprocating Engines Can Operate on:
  - Diesel
  - Natural Gas, or
  - Mixture of Both.
- Higher Emissions than Other Options Without Additional Emissions Reduction Equipment.

Reciprocating Engines

- Diesel Engines
  - Leading Prime Movers in the Range Up to 5 MW_e
    - Lower Initial Cost
    - Established of Technology.
- Gas Engines
  - Increasing in Popularity
    - Lower Emissions
    - Newer Technologies

Reciprocating Engines Advantages & Disadvantages

+ Run Well on Part Loads
+ Suitable for Start-Stop Operations
+ Can be Sized for Lower Electrical Loads

- Emissions
- Efficiency
- Noise

Combustion Turbines

- Established Technology
- Wide Range of Sizes
  - Mainly Used Above 1 MW_e
  - Up to hundreds of MW_e
- Utilize
  - Natural Gas
  - Petroleum Based Fuels
  - Dual-Fuel Mode

Combustion Turbines

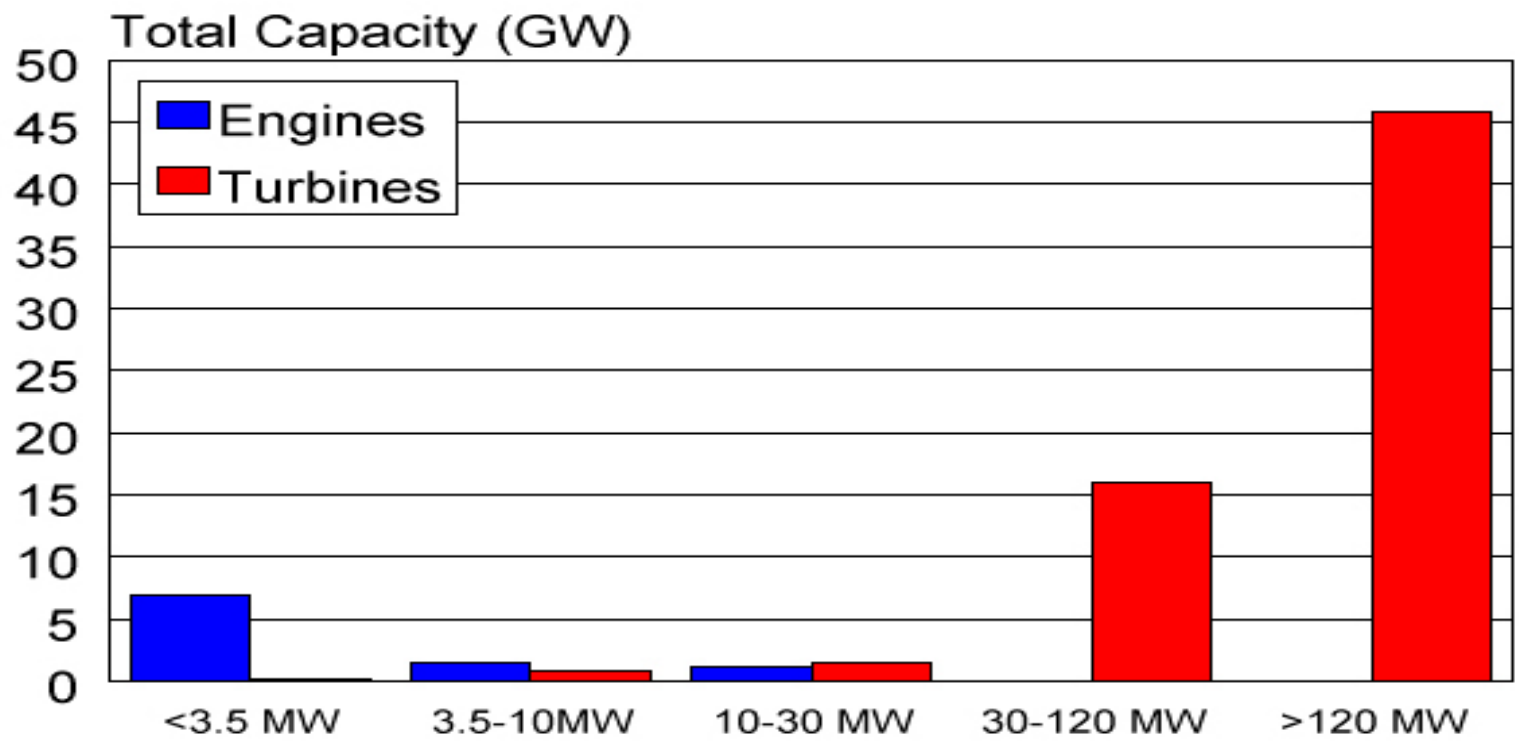
- Best Operated at Full Load
  - Low Flow Rates
    - Excessive vibration
    - Noise
    - Performance Degradation
- Decrease Emissions by:
  - Dry Combustion
  - Injection of Water or Steam
  - Exhaust Treatment

Combustion Turbines Advantages & Disadvantages

+ Reliable Technology
+ High Efficiency
+ Low Maintenance Cost
+ High Quality Exhaust Heat

- Performance Degrades
  - Below Full Load
  - Inconsistent Load
- Not Suitable for Start-Stop Operation

Engines Versus Turbines



Engine & Turbine Capacity for Different Power Ranges

Microturbines

- Capacity Range: 25 to 300 kW_e
- Electrical Efficiency: 20% to 33%
- Capital Cost: $600 to $1,000 per kW_e
- Operating and Maintenance Cost: $0.003 to $0.01 per kWh
- MTBO: 40,000 hours +
- Heat Recovery Temp: ~500^oF
- Heat Recovery Rate: 12,000 Btu/kWh
- No_x emissions: <1 ppm

Microturbine Advantages/Disadvantages

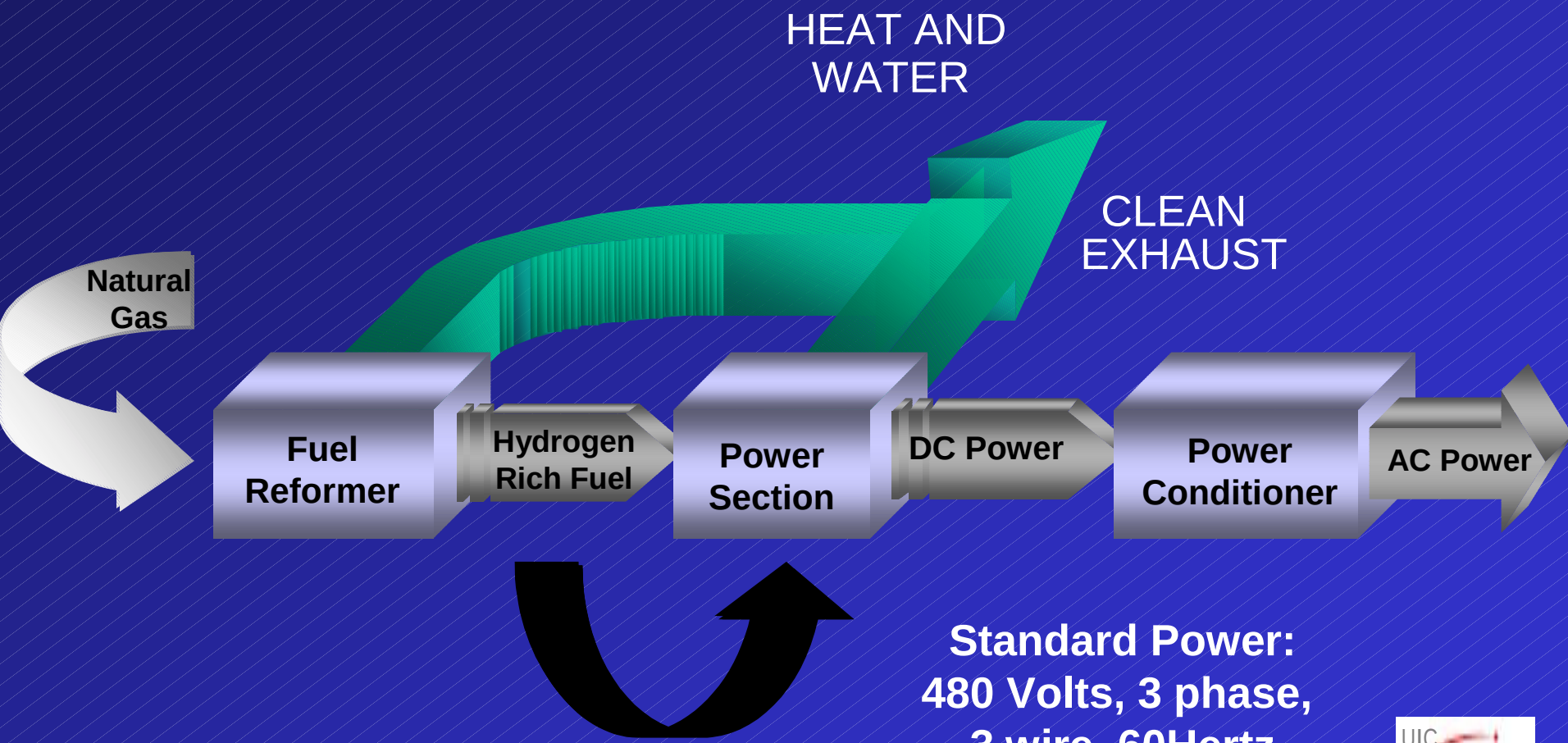
+ Compact and Modular Design
+ Lower Maintenance and Operating Costs
+ Low Emissions and Noise

- Requires High Pressure Gas
  - Compressor Reduces Net kW_e Output
- Not Able to Start Under Large Load or Follow Large Transients
- Problems Experienced
  - Recuperator Design and Gas Compressors
- Performance Sensitive
  - Inlet Air Temperature and Altitude

Fuel Cells

- Electrochemical Process
  - DC Electricity is Directly Generated
  - Usually Converted to AC
- Hydrogen Produced in Reformer
  - Hydrocarbon Fuel and Air
- Produces:
  - Electricity
  - Heat
  - Water

Fuel Cell System Scheme



Standard Power:
480 Volts, 3 phase,
3 wire, 60Hertz

Fuel Cells

- Capacity Range: 5 kW_e to 3 MW_e
- Electrical Efficiency: 36% to 60%
- Capital Cost: $1,500 to $3,000 per kW_e
- Operating and Maintenance Cost: $0.005 to $0.10 per kWh
- MTBO: 40,000 hours +
- Heat Recovery Temp: Depends on Type
- Heat Recovery Rate: 4,000 Btu/kWh
- No_x emissions: ~1 ppm

Fuel Cell Types

- Depends on the Electrochemical Process
- Classified as
  - Alkaline
  - Molten Carbonate (MCFC)
  - Phosphoric Acid (PAFC)
  - Proton Exchange Membrane (PEM)
  - Solid Oxide (SOFC)

Fuel Cell Advantages/Disadvantages

+ Reliability
+ Low Operating Cost
+ Constant Power Production
+ Computer Grade Power
+ Clean Emissions
+ Quiet Operations
+ High Efficiency
+ Choice of Fuels

- High Initial Cost
- Not a Firmly Established Technology
- Availability
- Poor Ability for Multiple Starts
- Poor Ability to Follow Large, Rapid Transients

Electric Generation Devices Cost Comparison

Technology Comparison	Diesel Engine	Gas Engine	Simple Cycle Gas Turbine	Microturbine	Fuel Cell
Product Rollout	Commercial	Commercial	Commercial	1999 – 2000	1996 – 2010
Size Range (kW)	20 – 10,000+	50 – 5,000+	1,000+	30 – 200	50 – 1000+
Efficiency (HHV)	36 – 43%	28 – 42%	21 – 40%	25 – 30%	35 – 54%
Genset Package Cost ($/kW)	125 – 300	250 – 600	300 – 600	350 – 750*	1500 – 3000
Turnkey Cost – no heat recovery ($/kW)	350 – 500	600 – 1000	650 – 900	600 – 1100	1900 – 3500
Heat Recovery Added Costs ($/kW)	n.a.	$75 – 150	$100 – 200	$75 – 350	incl.
O&M Cost ($/kWh)	0.005 – 0.010	0.007 – 0.015	0.003 – 0.008	0.005 – 0.010	0.005 – 0.010

*Commercial target price

Chillers

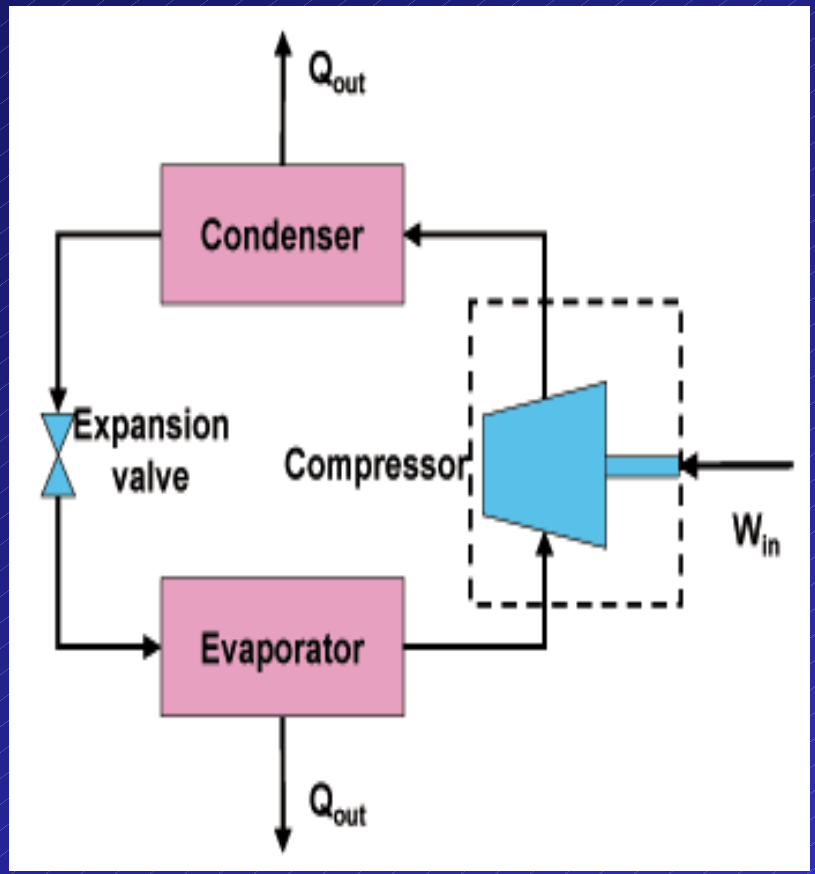
- Central HVAC Systems are Commonly Used in Most Large Buildings
  - Air Handlers with Chilled Water Coils Provide Cooling
- Supplied at ~ 44ºF and Returned at ~ 54ºF
- Reduced System Size
  - Produce Colder Air
  - Increase Temperature Difference

Chiller Types Classified By Compressor

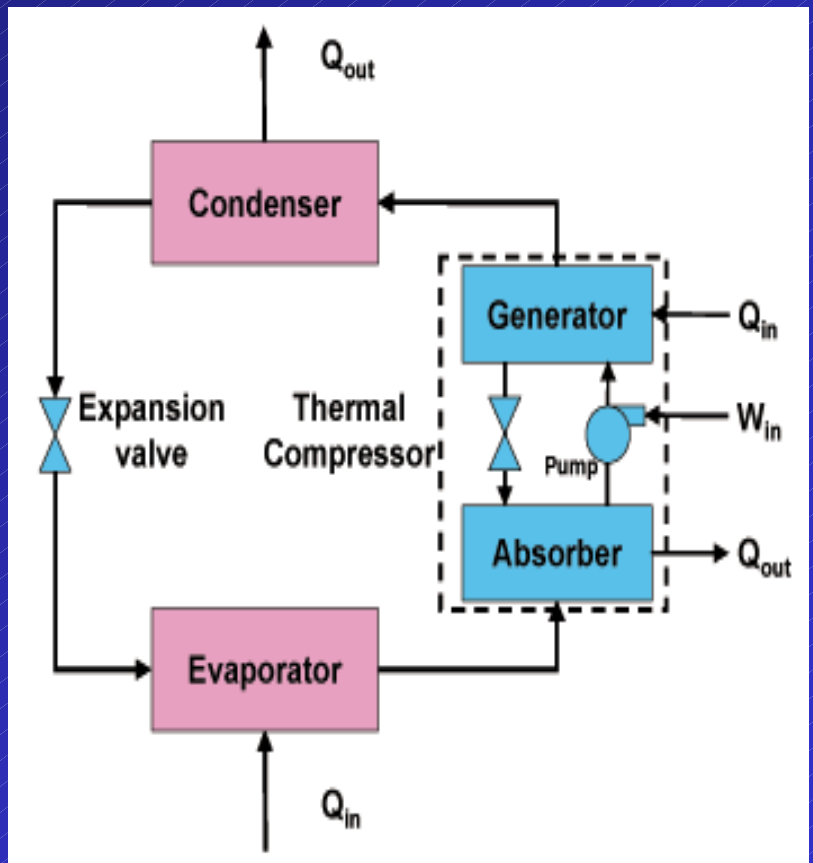
1. Mechanically Chillers
   - Referred to as Vapor-Compression Chillers
   - Compression Due to a Mechanical Cycle
2. Thermally Chillers
   - Referred to as Absorption Chillers
   - Chilling Due to a Absorption Cycle

Chiller Cycles

Mechanical Chiller



Thermal Absorption Chiller



Mechanical Compressor Drivers

- Drivers for Mechanical Compressors
  - Electric Motors
  - Reciprocating Engines
  - Combustion Turbines

Heat Recovery Can be Applied to Reciprocating Engines or Combustion Turbines Used as Mechanical Compressors

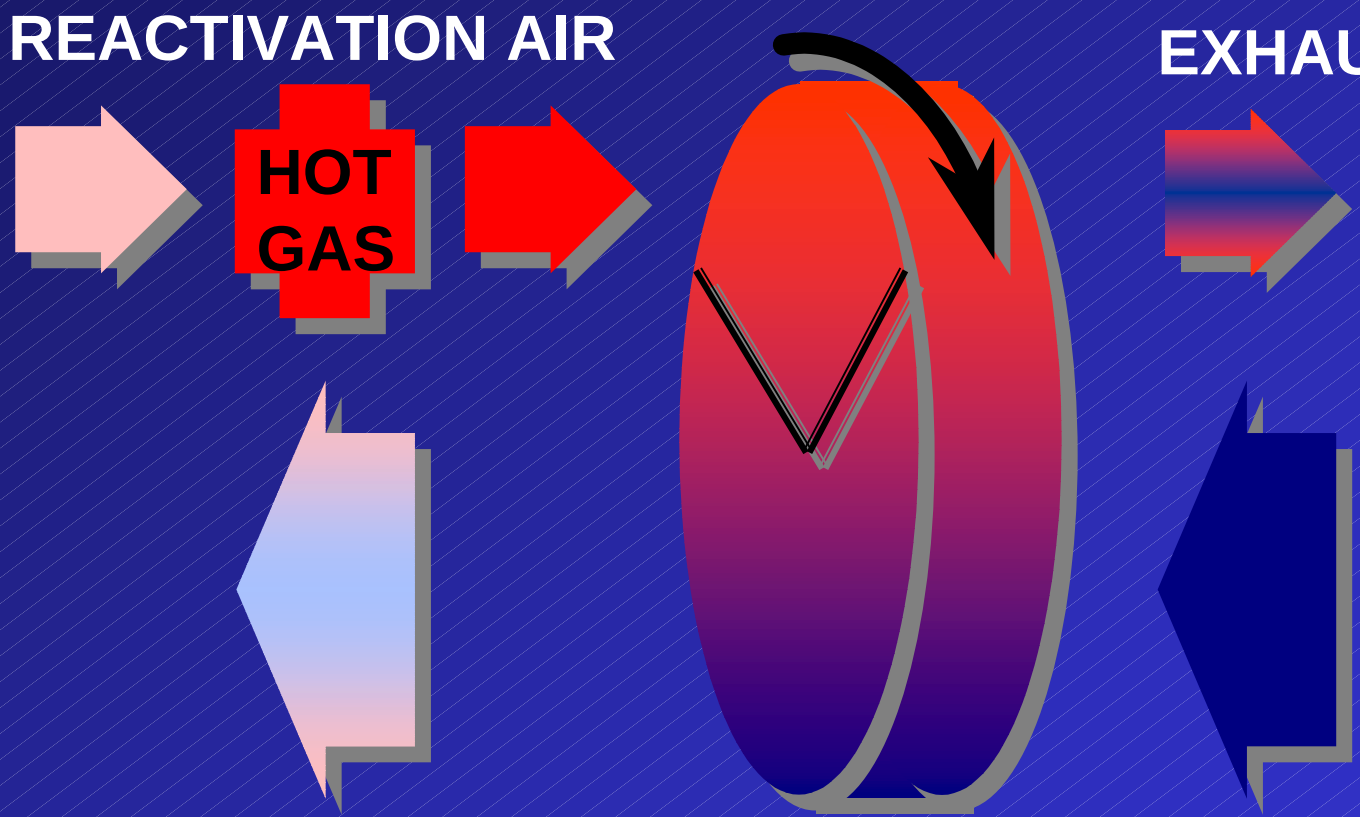
Chiller Pricing

- **Absorption Chillers**
  - **Single Stage**
    - **Steam or Hot Water Driven**
    - **$200/RT (Larger RT - Steam Driven) to $1,000 (Smaller RT – Hot Water Driven)**
  - **Double Stage**
    - **Steam Driven**
    - **$300/RT(Larger RT) to $500 (Smaller RT)**
  - **Recovery Cooling Capabilities**
    - **Gas Engine 0.22 to 0.28 RT/kW_e**
    - **Gas Turbine 0.28 to 0.33 RT/kW_e**
- **Electric Chillers**
  - **$180/RT (Larger RT) to $300/RT (Smaller RT)**

Heat-Activated Dehumidification using Desiccants

- Reduces Demands on Air Cooling Systems by Removing Latent (Humidity) Load
- Improves Indoor Air Quality
  - Reduces Mold Growth
  - Reduces “Over Cooling”
  - Allows Higher Make-Up Air Rates for Same Energy Usage
    - Conventional AC Loses Humidity Control at Higher Outdoor Air Make-Up Levels

Desiccant Dehumidification



Applications to Consider CHP

- **High Electric and Thermal Consumption**
- **Electric and Thermal Loads Occur Concurrently**
  - **Hottest Day/Highest Occupancy**
- **High Electric Demand and Peak Energy Usage Charges**
  - Higher Peak Load Energy and Demand Rates
  - Higher Summer Rates

What Makes CHP Favorable?

- High Occupancy Rates/Operating Hours
- High Quality or Back-Up Power
- New Construction or Major Renovation
- Central Heating/Cooling Facilities

Energy Prices
Where are We?

Electricity Rates

- EIA Electrical Price Predictions
  - Decline from 6.9¢/kWh to 6.3¢/kWh in 2005,
  - Rise to 6.9¢/kWh by 2020 Because of Increasing Natural Gas Prices
- Restructuring Contributes to Declining Prices Due to Reductions in:
  - Operating and Maintenance Costs
  - Administrative Costs
  - Other Costs

Electricity Pricing In Illinois

- 6.98¢/kWh ($20.45/Mbtu)
  (Average across all customer classes in 1999)
- Ranks it 17th Highest in the Nation
- Permits Renegotiated Rates When *"Uneconomic Bypass of the Utility's System Would be Avoided"*

Electric Rates

Example: Commonwealth Edison (Illinois' Largest Utility)

	Commercial	Large User (>1 MWe)	
Demand			
Summer	$14.24/kWe	$16.41/kWe	(1st 10 MWe)
		$ 6.51/kWe	(Above 10 MWe)
Winter	$11.13/kWe	$12.85/kWe	(1st 10 MWe)
		$ 5.03/kWe	(Above 10 MWe)
Usage			
Peak	5.599¢/kWh	5.022¢/kWh	
Off-Peak	2.341¢/kWh	2.123¢/kWh	

Standby Rates in Illinois

Example: Commonwealth Edison

- Standby Rate 18
- Applicable to All Self-Generators
- Detailed and Complicated
- Highly Performance Based
  - Based on 12-Month Rolling Peak Demand of Standby Usage @ $2.99 per kW_e
  - Can Result in Decreased Savings

Natural Gas Prices

- High Natural Gas Prices
  - Negative Effects on the CHP Market
  - Those of Winter 2000/2001 Not Anticipated to Recur
- EIA Expects Natural Gas Prices Around $3 per MMBTU by 2020

Natural Gas Prices in Illinois

- Commercial Customers
  - $5.76 per 1000 ft^3
- Industrial
  - $4.66 per 1000 ft^3
- Average City Gate
  - $3.16 per 1000 ft^3

EIA State Average Prices February 2002

State Level Policy Issues

- Significant to CHP Deployment
  - Access and Interconnection Rules
  - Status of Deregulation
  - Emerging Legislation
  - Exit Fees
  - Standby Charges

Access and Interconnection Rules in Illinois

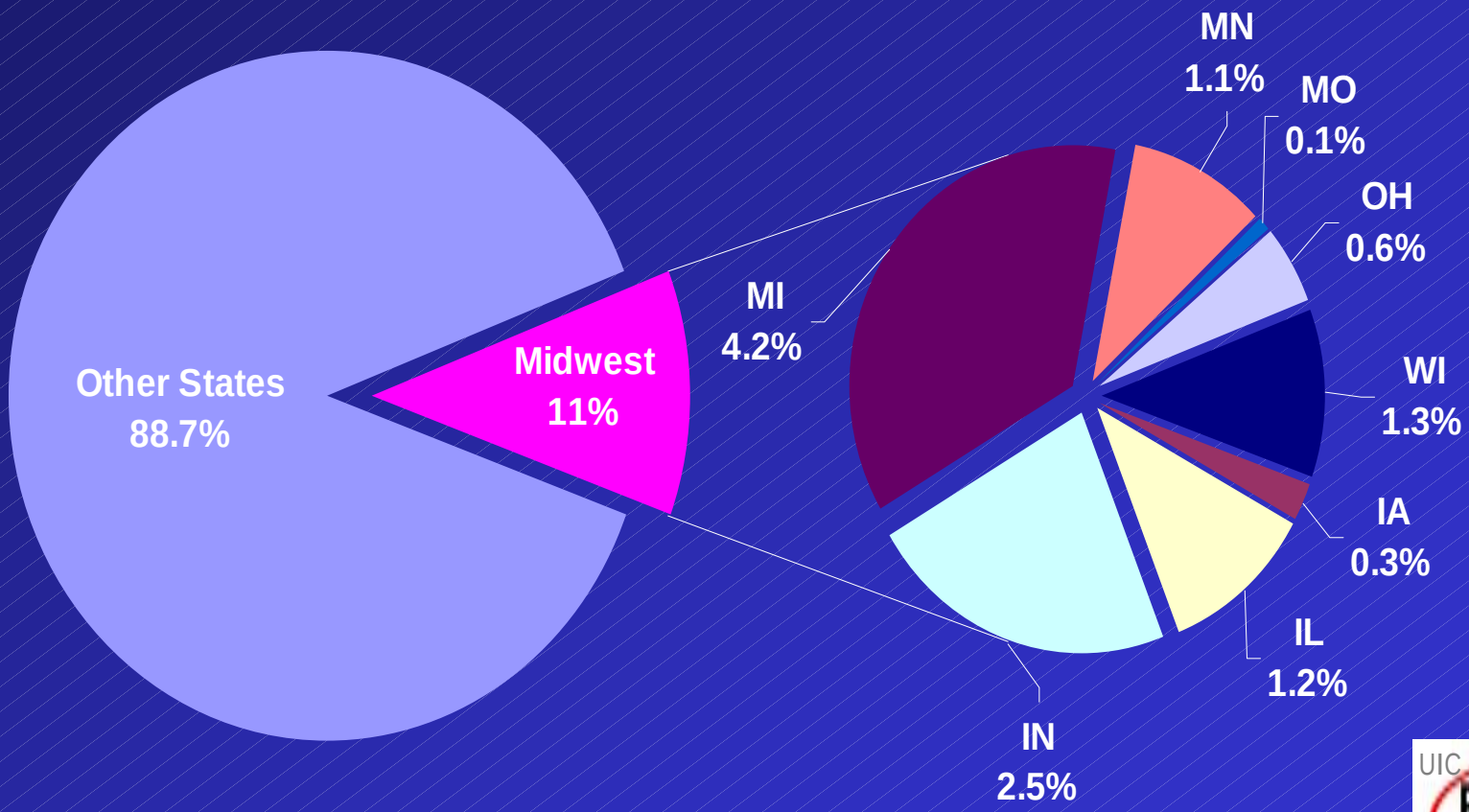
- No State Standard for Interconnection Process and Fees
- ComEd Interconnection Requirements
  - "Blue Book" Recently "Simplified" for Distributed Generation
  - Requirements Remained Unchanged
  - Protective of T&D System
- ComEd Interconnection Study Fees are Variable and Potentially Cost Prohibitive

Status of Electric Deregulation in Illinois

- Illinois Electric Service Customer Choice and Rate Relief Law (1997)
  - Non-Residential Phased 1998 thru 2000
  - Residential Customers May 2002

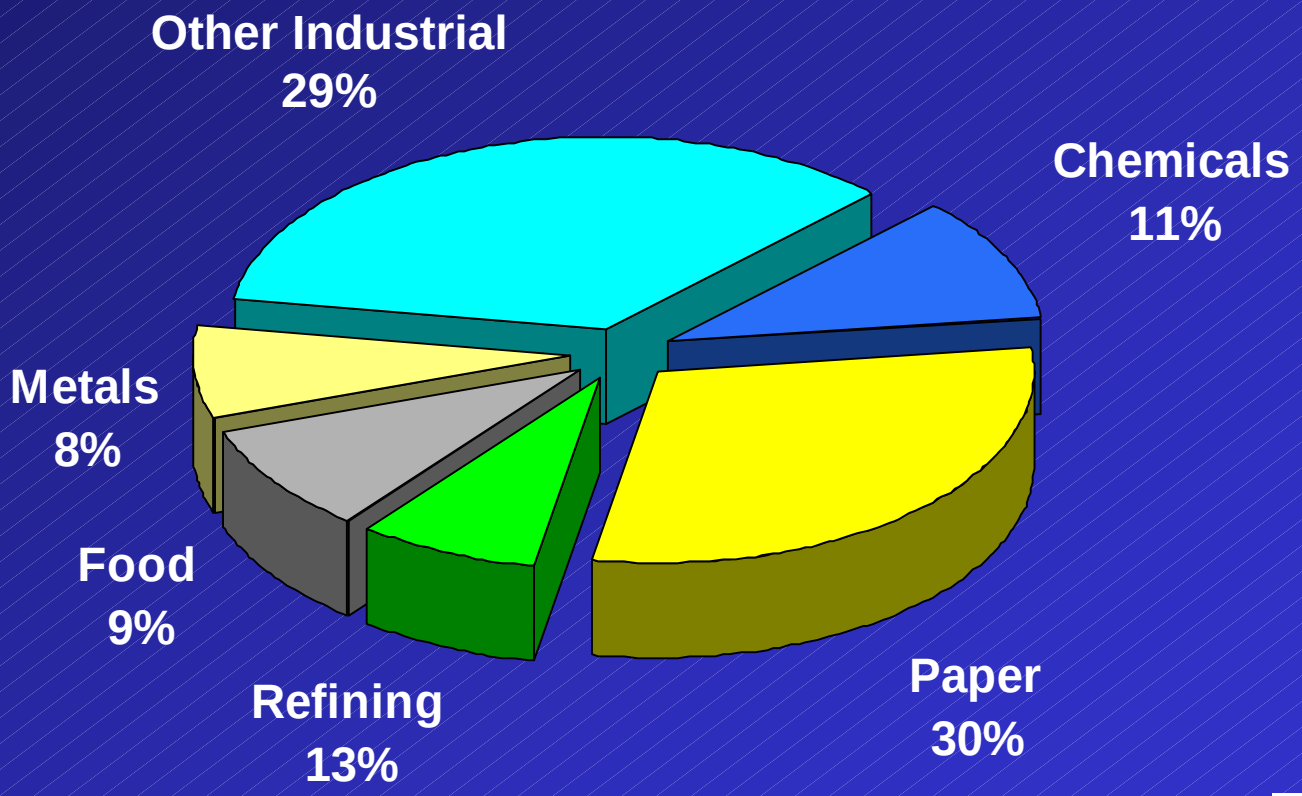
Existing Industrial CHP (Midwest)

5.2 GW (11.3% of Total U.S. Installed – 45.5 GW)



Potential for Industrial CHP is Large

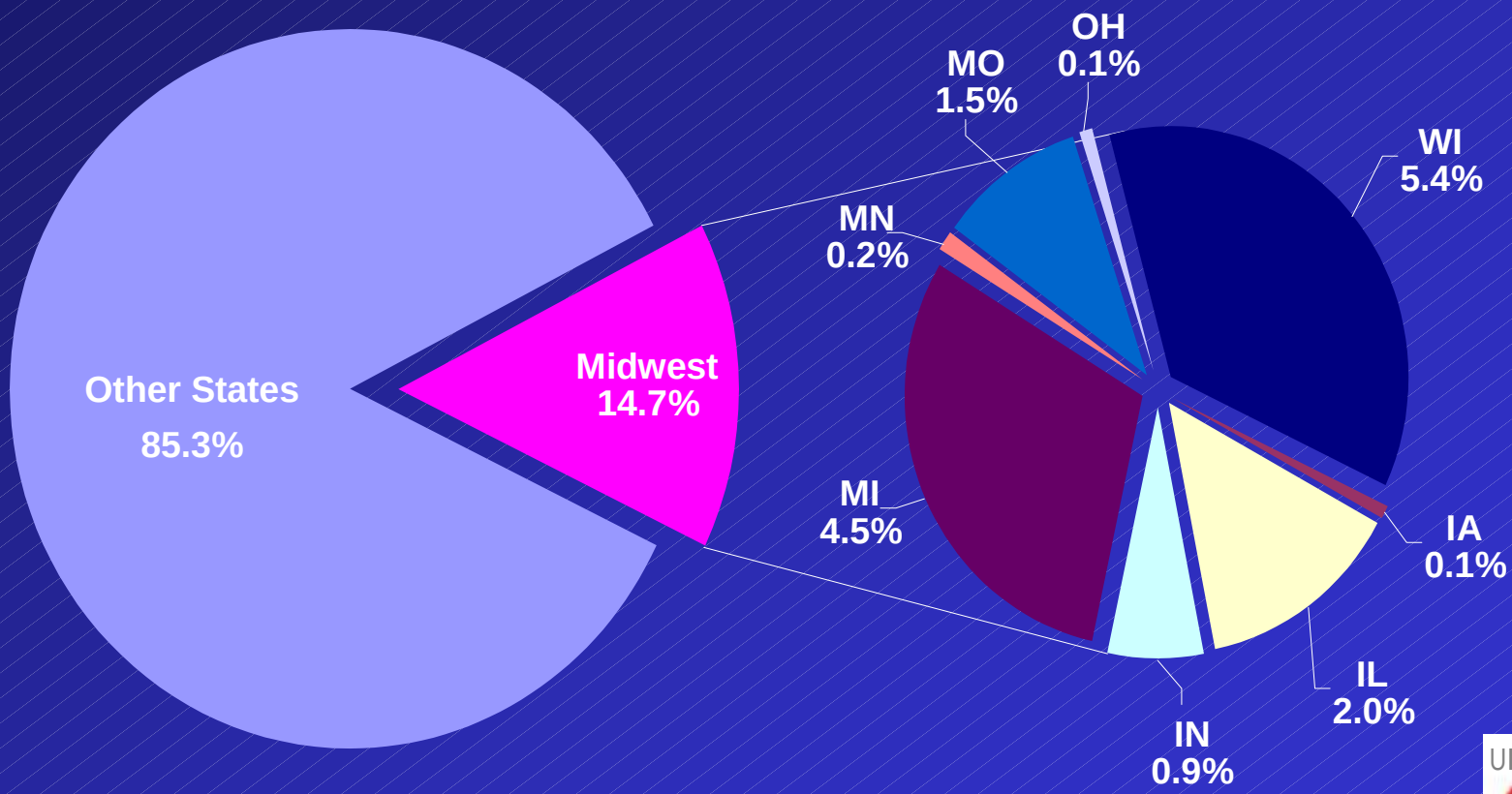
Estimated CHP Potential: 88 GW



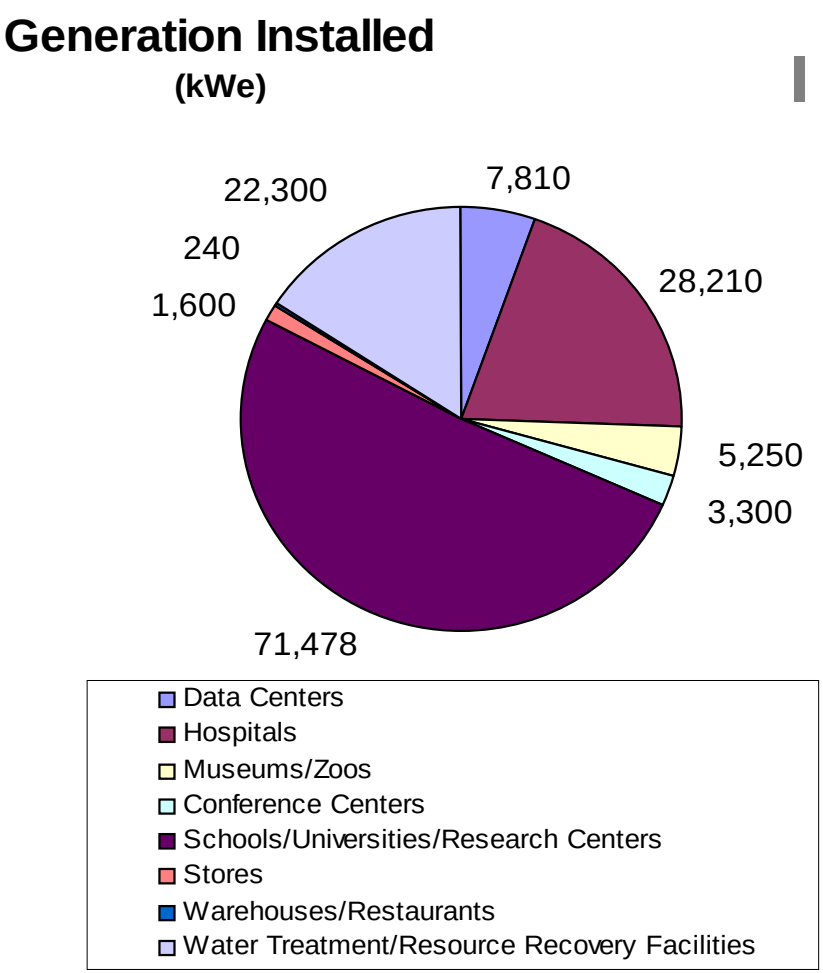
Source: Nexus

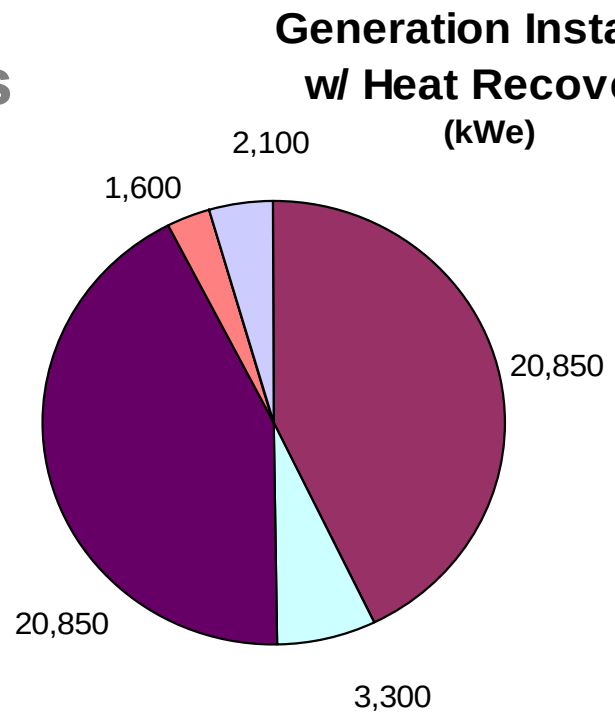
Existing Commercial CHP (Midwest)

0.7 GW (14.7% of Total U.S. Installed – 4.93 GW)



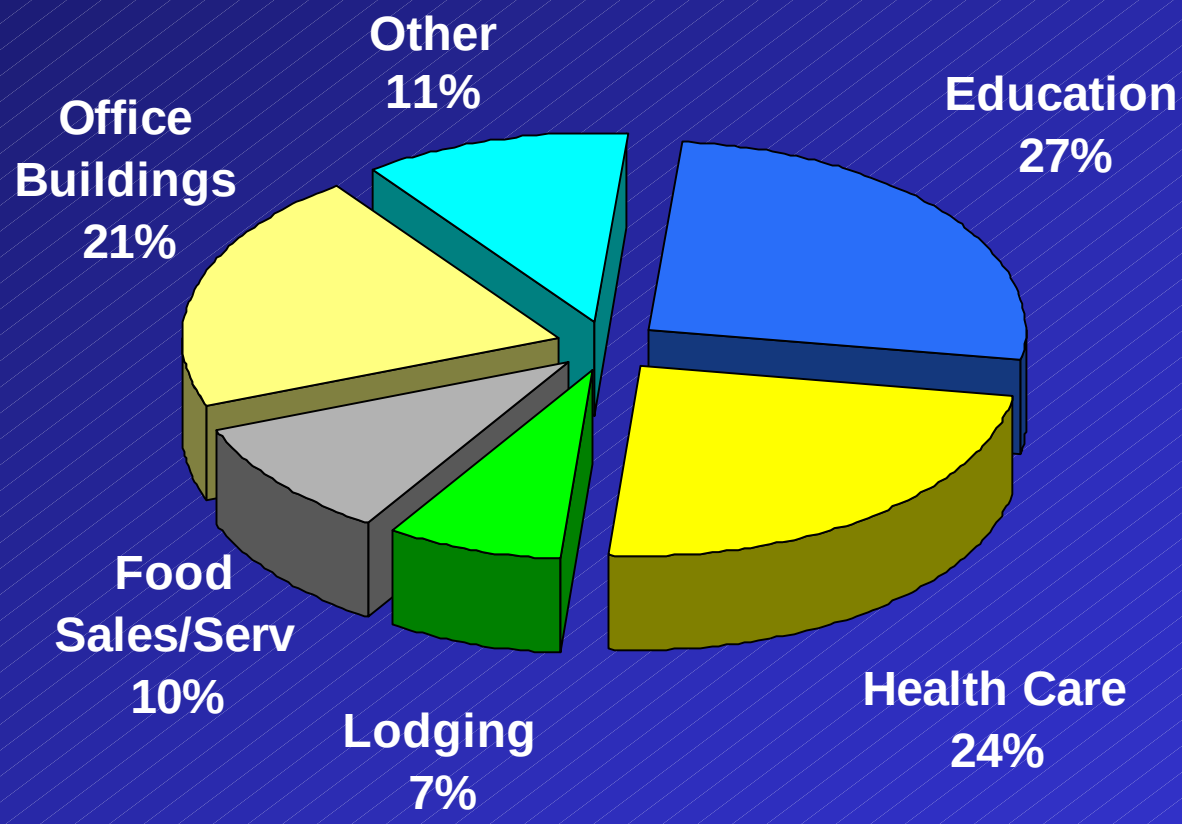
DG/CHP Installed in Illinois





Potential for Commercial CHP is Large

Estimated CHP Potential: 75 GW



Source: Nexus

Desirability Study for Packaged CHP Systems Showed

- Illinois Ranked 5th best State
- Chicago Ranked 3rd best City
- Best Applications *(In Order)*
  - Hospitals
  - Hotels
  - High Schools
  - Small Supermarkets
  - Full-Service Restaurants
  - Nursing Homes
  - Grade Schools

UIC/ERC and GTI Study, May 2002

Conclusions for Illinois

- Good Interest Level
- Moderate Current Installation Level
- Barriers
  - Lack of Interconnection Standards and Fees
  - Standby Charges and Rates
  - Operating Costs
  - Capital Costs and Payback
- Favorable Characteristics
  - Open Access
  - Favorable Alliances
  - Reasonable Market Potential

Questions?