Opportunities for Reducing Energy Costs, Meeting Climate Goals, and Increasing Resiliency

Combined Heat and Power (CHP) for Illinois Universities, Colleges and Schools (K-12)

IL APPA Conference

March 23, 2018

ERC ENERGY RESOURCES CENTER

UIC THE UNIVERSITY OF ILLINOIS AT CHICAGO

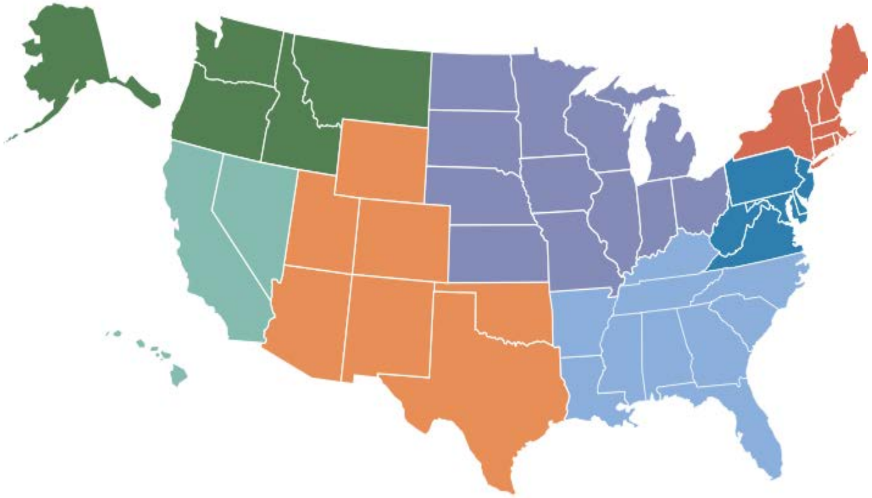
U.S. Department of Energy
CHP Technical Assistance Partnerships
MIDWEST

Agenda

- CHP Concepts, Technologies, Benefits
- CHP Market Opportunities – Universities, Colleges, Schools (K-12)
- CHP Project Snapshots
- CHP Project Development Resources
- CHP Project Incentives

DOE CHP Technical Assistance Partnerships (CHP TAPs)

- **End User Engagement**
  Partner with strategic End Users to advance technical solutions using CHP as a cost effective and resilient way to ensure American competitiveness, utilize local fuels and enhance energy security. CHP TAPs offer fact-based, non-biased engineering support to manufacturing, commercial, institutional and federal facilities and campuses.
- **Stakeholder Engagement**
  Engage with strategic Stakeholders, including regulators, utilities, and policy makers, to identify and reduce the barriers to using CHP to advance regional efficiency, promote energy independence and enhance the nation’s resilient grid. CHP TAPs provide fact-based, non-biased education to advance sound CHP programs and policies.
- **Technical Services**
  As leading experts in CHP (as well as microgrids, heat to power, and district energy) the CHP TAPs work with sites to screen for CHP opportunities as well as provide advanced services to maximize the economic impact and reduce the risk of CHP from initial CHP screening to installation.



www.energy.gov/chp

DOE CHP Technical Assistance Partnerships (CHP TAPs)

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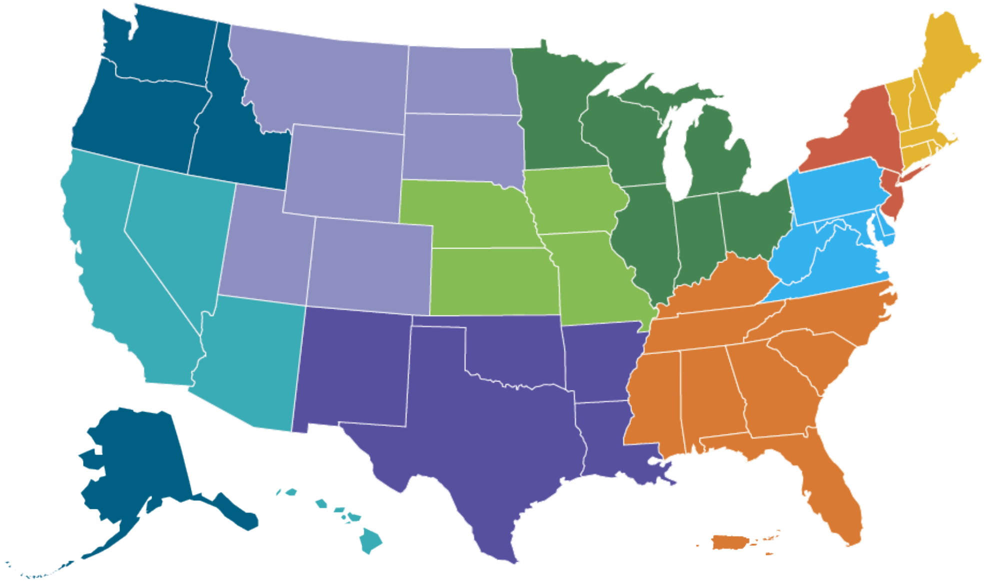

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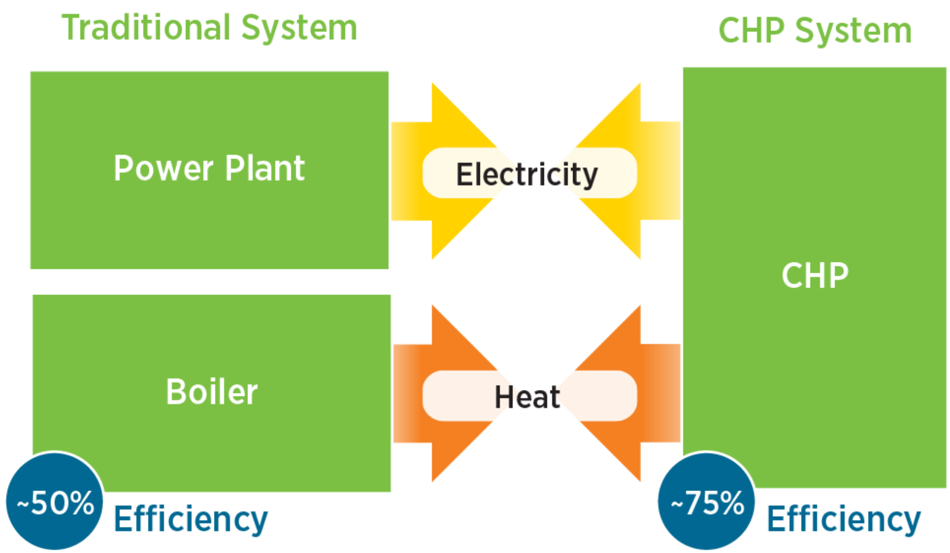
CHP Concepts and Technologies

CHP: A Key Part of Our Energy Future

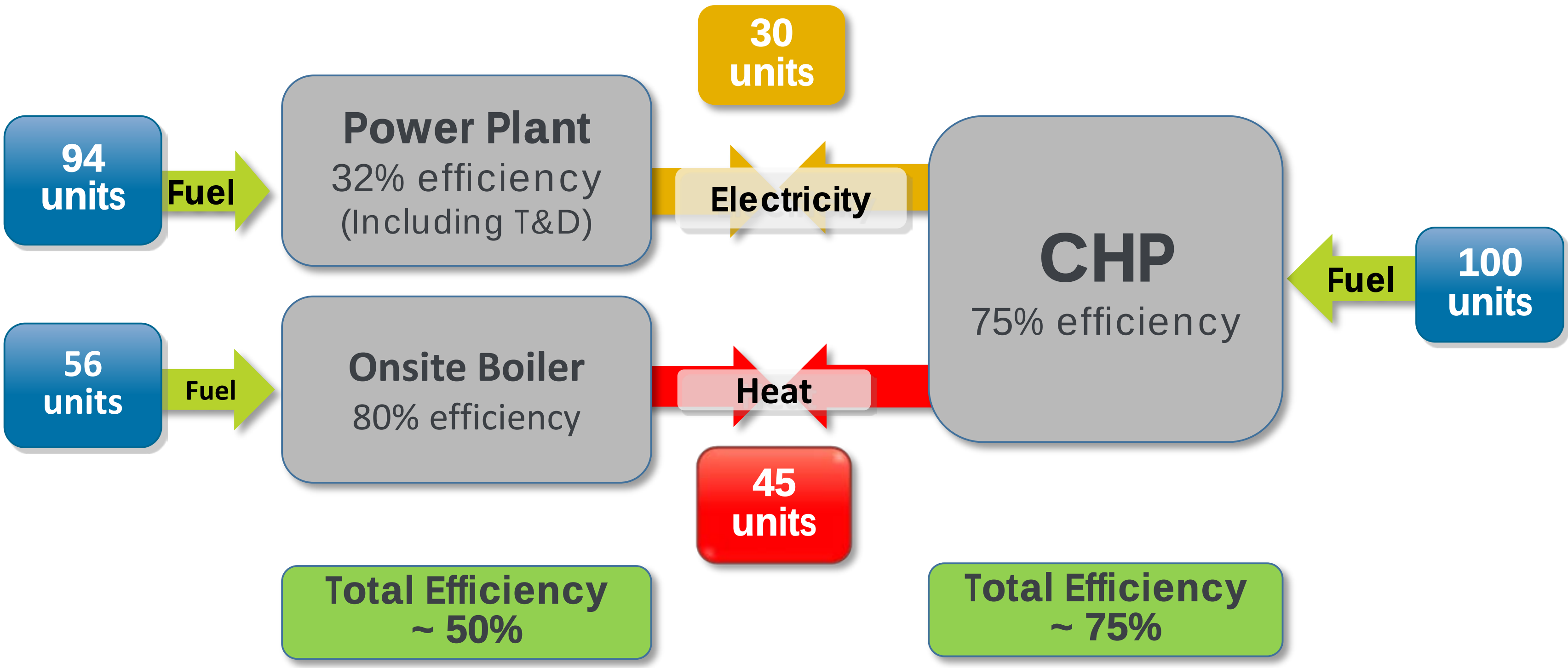
- Form of Distributed Generation (DG)
- An integrated system
- Located at or near a building / facility
- Provides at least a portion of the electrical load and
- Uses thermal energy for:
  - Space Heating / Cooling
  - Process Heating / Cooling
  - Dehumidification

Source: http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf



CHP provides efficient, clean, reliable, affordable energy – today and for the future.

CHP Recaptures Heat of Generation, Increasing Energy Efficiency, and Reducing GHGs



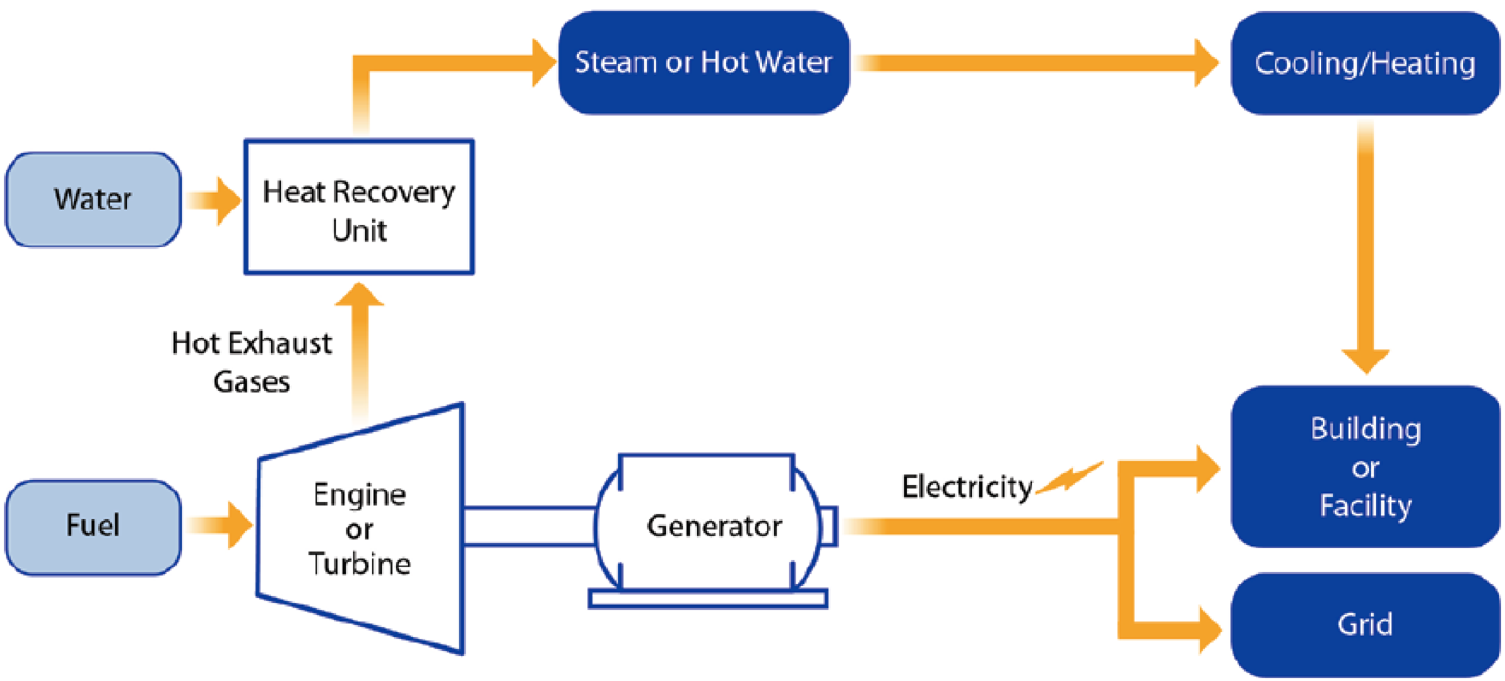
30 to 55% less greenhouse gas emissions

Defining Combined Heat & Power (CHP)

The on-site simultaneous generation of two forms of energy (heat and electricity) from a single fuel/energy source

Conventional CHP

(also referred to as Topping Cycle CHP or Direct Fired CHP)



Separate Energy Delivery:

- **Electric generation – 33%**
- **Thermal generation - 80%**
- **Combined efficiency – 45% to 55%**

CHP Energy Efficiency (combined heat and power)
70% to 85%

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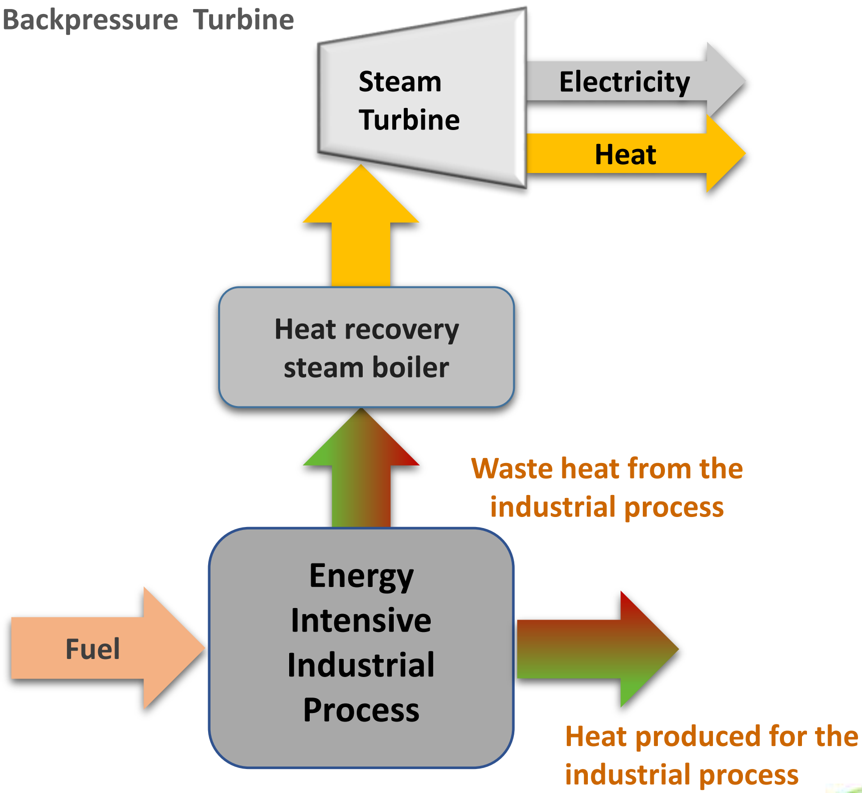
Defining Combined Heat & Power (CHP)

The on-site simultaneous generation of two forms of energy (heat and electricity) from a single fuel/energy source

Waste Heat to Power CHP

(also referred to as Bottoming Cycle CHP or Indirect Fired CHP)

HRSG/Steam Turbine
Organic Rankine Cycle
Backpressure Turbine



- Fuel first applied to produce useful thermal energy for the process
- Waste heat is utilized to produce electricity and possibly additional thermal energy for the process
- Simultaneous generation of heat and electricity
- No additional fossil fuel combustion *(no incremental emissions)*
- Normally produces larger amounts electric generation *(often exports electricity to the grid; base load electric power)*

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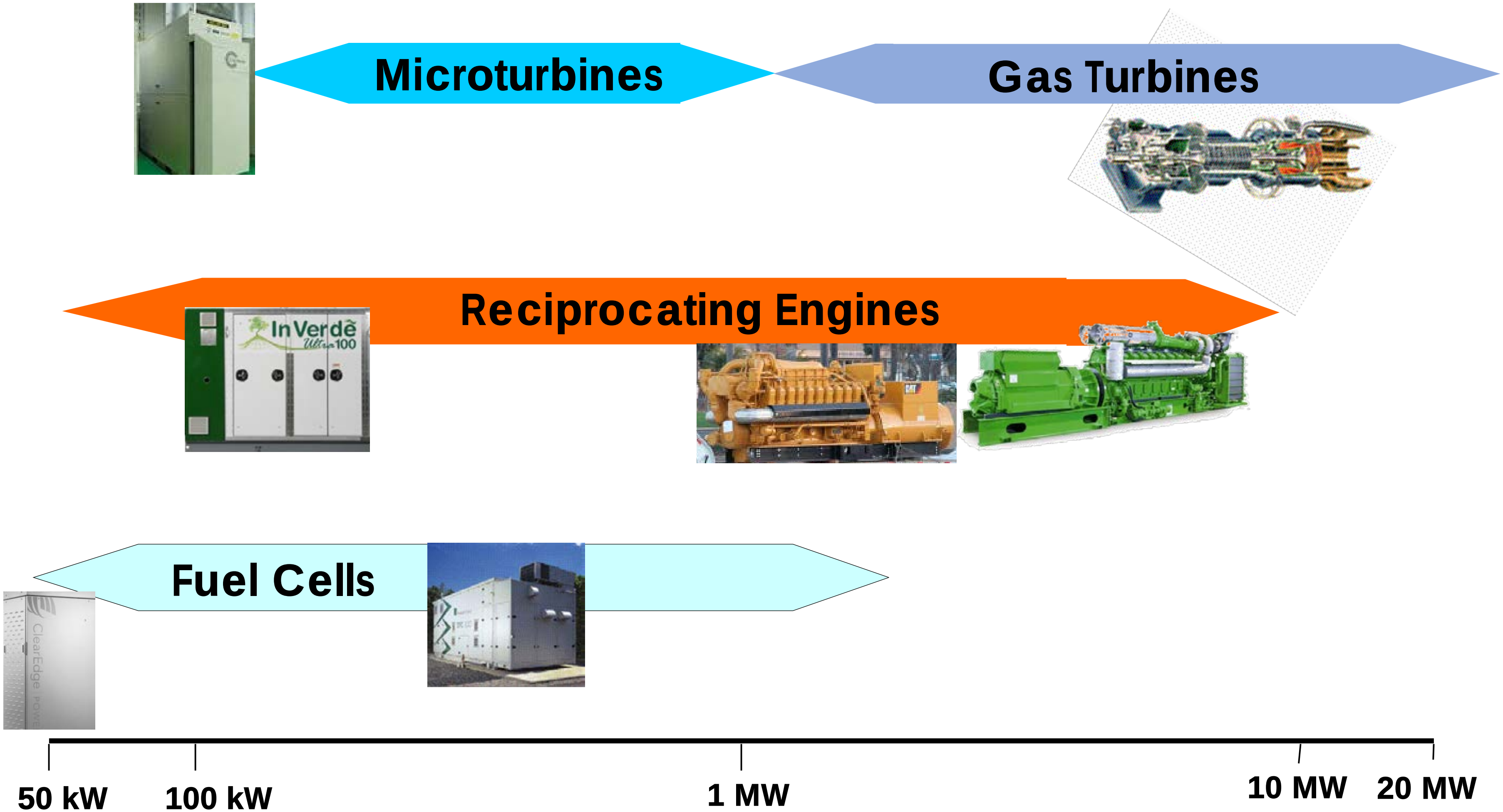
Common CHP Technologies and Generating Capacity Ranges



Heat Recovery

- Heat Exchangers
  - Recover exhaust gas from prime mover
  - Transfers exhaust gas into useful heat (steam, hot water) for downstream applications
  - Heat Recovery Steam Generators (HRSG) the most common
- Heat-Driven Chillers
  - Absorption Chiller
    - Use heat to chill water
    - Chemical process (not mechanical)
  - Steam Turbine Centrifugal Chiller
- Dessiccant Dehumidifiers
  - Separates Latent from Sensible Load
  - Reduces Humidity and Reduces AC Load

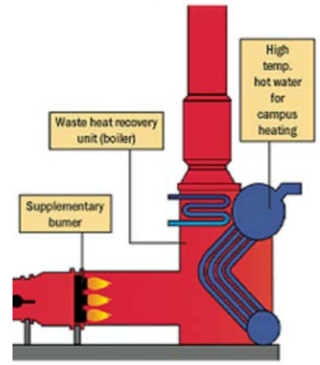


Image Source: University of Calgary

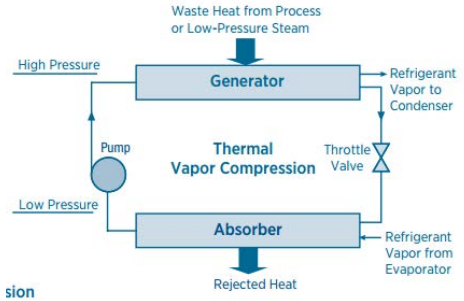
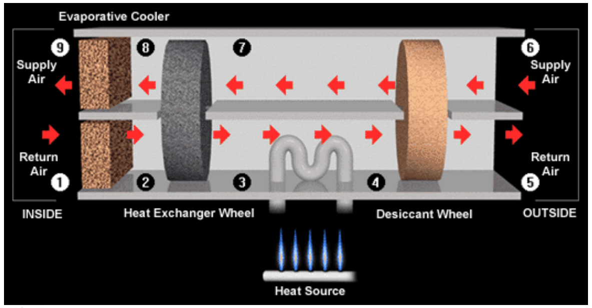


Image Source: DOE - EERE



What Are the Benefits of CHP?

- CHP is *more efficient* than separate generation of electricity and heat
- Higher efficiency translates to *lower operating cost,* (but requires capital investment)
- Higher efficiency *reduces emissions of all pollutants*
- CHP can also *increase energy reliability and enhance power quality*
- On-site electric generation *reduces grid congestion and avoids distribution costs*

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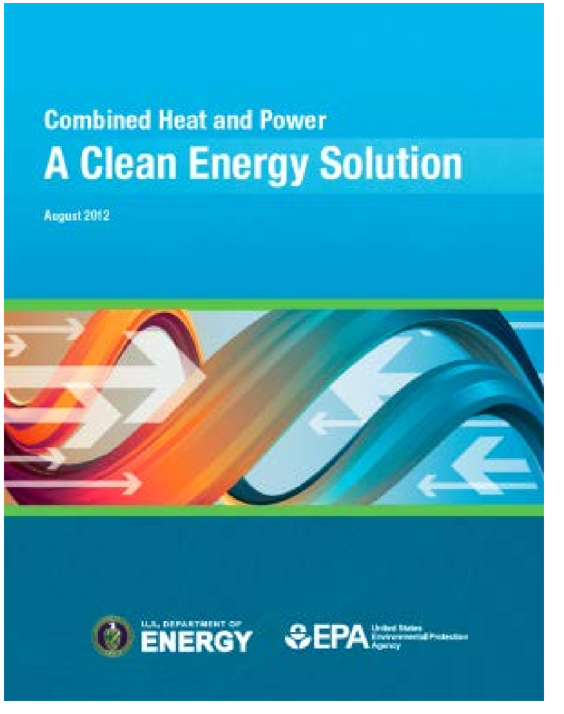
Emerging Drivers for CHP

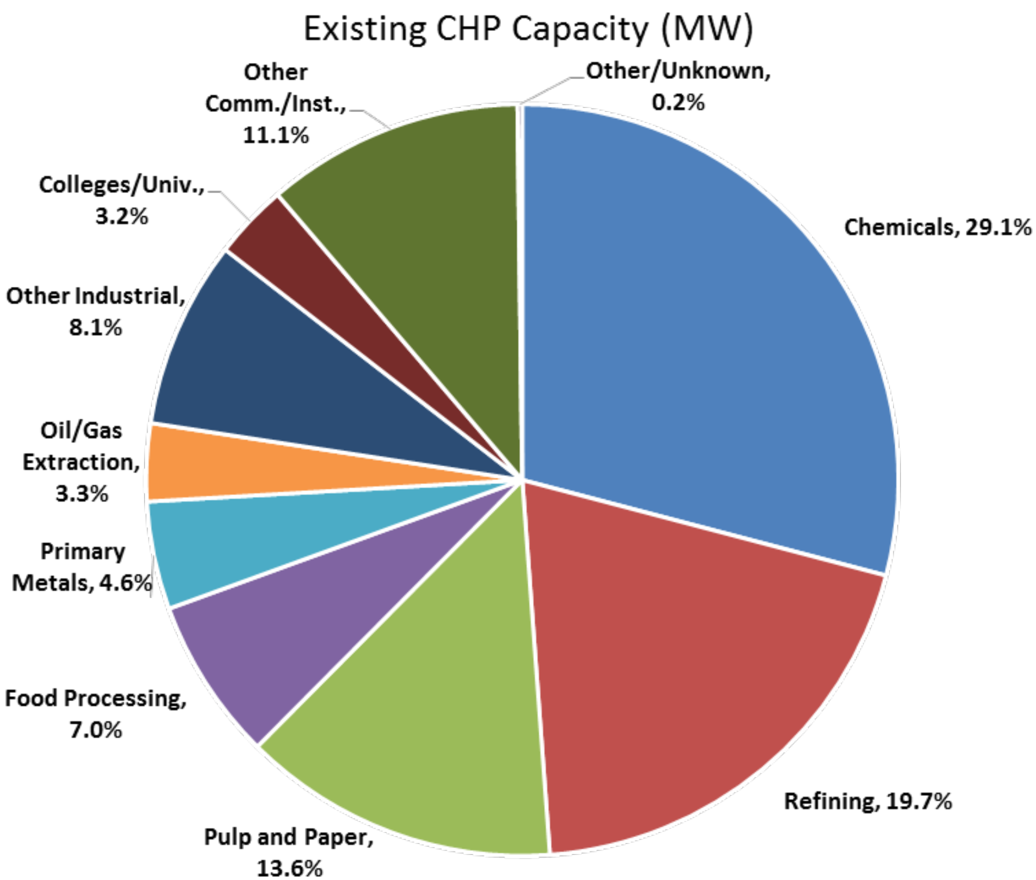
- Benefits of CHP recognized by policymakers
  - State Portfolio Standards (RPS, EEPS, Tax Incentives, Grants, standby rates, etc.)
  - CHP recognized as an energy efficiency technology in some states (e.g. Illinois, Minnesota, Ohio)
- Favorable outlook for natural gas supply and price in North America
- Opportunities created by environmental drivers
- Utilities finding economic value
- Energy resiliency and critical infrastructure

DOE / EPA CHP Report (8/2012)



Source: www.energy.gov/chp

CHP Today in the United States



- **82.6 GW** of installed CHP at nearly 4,400 industrial and commercial facilities
- 8% of U.S. Electric Generating Capacity; 14% of Manufacturing
- Avoids more than **1.8 quadrillion Btus** of fuel consumption annually
- Avoids **241 million metric tons of CO_2** compared to separate production

Source: DOE CHP Installation Database (U.S. installations as of December 31, 2016)

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CHP at Universities, Colleges, Schools (K-12)

Market Sector: Colleges/Universities

272 U.S. CHP Sites = 2,763.9 MW Generating Capacity

- Due to large thermal loads and desire for reliable power, CHP is a good fit for colleges and universities
- Number of college and universities use CHP to provide steam and some power to key campus facilities
- 72% of existing CHP for colleges and universities is natural gas-fired, and most institutions use a boiler/steam turbine or gas turbines.
- Many college and university CHP systems have been designed to be able to run independently of the grid

Table: CHP System Size

Fuel Type	Sites	MW
< 1 MW	109	35.4
1 – 4.9 MW	72	170.4
5 – 19.9 MW	54	495.4
20 – 49.9 MW	5	157.7
50 – 99.9 MW	1	55.0
100 – 499.9 MW	1	102.2
Total	272	2,653.9

Sources:

- The Opportunity for CHP in the United States, American Gas Association, May 2013
- DOE CHP Installation Database (U.S. CHP Installations as of December 2016)

Energy & Sustainability Trends at Universities

Energy efficiency and sustainability is moving well beyond the LEED building to systems and institution-wide strategies, driven by both environmental and financial stewardship.

- Campuses approach energy efficiency and sustainability planning holistically
- New tone to energy efficiency and sustainability conversations: it's no longer to do the right thing or to be a leader, it's institutional survival; resource consumption on campus, reduction of energy costs, etc.
- Greater focus on energy efficiency and sustainability as part of financial sustainability
- On the campus level, there's a gathering storm to move off the grid and aim toward zero impact
- Building efficiency and energy management are emerging as the key sustainability initiatives

Source: "Report on Trends in Higher Education Planning 2014", SCUP Academy Council
http://www.scup.org/asset/75087/ReportOnTrendsInHigherEducationPlanning2014

Midwest Universities with CHP Systems

49 University and Comm. Colleges = 1,086 MW capacity

University of Cincinnati
Kent State University
College of Medicine and Life Sciences, The University of Toledo
Indiana State University
Purdue University
University of Notre Dame
Western Michigan University
CMU Central Michigan University
University of Michigan
Michigan State University
Loyola Medicine
UIC
Northeastern Illinois University
Illinois Institute of Technology
Illinois, University of Illinois at Urbana-Champaign
SIU Southern Illinois University Carbondale
Wisconsin, University of Wisconsin-Madison
University of Wisconsin Whitewater
University of Minnesota
The University of Iowa
University of Northern Iowa
Iowa State University
Southeast Missouri State University · 1873
Mizzou University of Missouri
Kansas State University
University of Nebraska Lincoln

Source: www.energy.gov/eere/amo/chp-deployment (facilities with >2 MW capacity displayed)

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Market Sector: Schools (K-12)

254 U.S. CHP Sites = 66.4 MW Generating Capacity

- CHP systems are increasingly common in schools
- These CHP systems are small, typically less than 1 MW systems
- 84% of school CHP capacity is natural gas
- Most schools use reciprocating engines
- Since schools often serve as places of refuge for the community during storm events, CHP systems have become increasingly popular due to their ability to allow for the school to have lighting and other services during power outages

Table: Hospitals by CHP System Size

Fuel Type	Sites	MW
< 1 MW	240	44.0
1 – 4.9 MW	14	22.5
5 – 19.9 MW	0	0.0
20 – 49.9 MW	0	0.0
50 – 99.9 MW	0	0.0
100 – 499.9 MW	0	0.0
Total	254	66.4

Sources:
- The Opportunity for CHP in the United States, American Gas Association, May 2013
- DOE CHP Installation Database (U.S. CHP Installations as of December 2016)

CHP Snapshots

Project Snapshot:

University District Energy CHP System

University of Illinois at Chicago
Chicago, Illinois

Application/Industry: University Campus
Capacity: 21 MW
Prime Mover: Combustion Turbines (3)
Fuel Type: Natural Gas
Thermal Use: Heating, cooling, hot water
Installation Year: 2001
Energy Savings: $5 to $7 million annually

Testimonial: *"The CHP system provides reliable and efficient power and steam to the university. The duct firing capabilities of the combustion turbines enable the CHP system to supply 100% of the required steam to the UIC West Campus."*
- Robert Roman, Director, UIC Utilities

UIC West Campus CHP Facility

7.0 MW Solar Taurus Turbine Generator

Source: http://www.midwestchptap.org/profiles/ProjectProfiles/UIC_West_Campus.pdf

Project Snapshot:

Replacing Outdated Coal-fired Boiler House

Kent State University

Kent, OH

KENT STATE UNIVERSITY

Application/Industry: University

Capacity (MW): 12 MW

Prime Mover: Gas Turbine

Fuel Type: Natural Gas

Thermal Use: Heating and cooling

Installation Year: 2003, 2005

Emissions Savings: Reduces CO_2 emissions by 37,000 tons/year

Testimonial: *"It is a very clean technology, and it is an economic saving for us. By using steam and electricity, we are able to offset the costs for heating the campus. It's kind of like recycling."*

- Thomas Dunn, Associate Director for Campus Environment and Operations

Source: https://mysolar.cat.com/cda/files/2111485/7/dschp-ksu.pdf

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Project Snapshot:
Interactive CHP System

Washtenaw Community College
Ann Arbor, MI

Application/Industry: College

Capacity (MW): 130 kW

Prime Mover: Microturbine

Fuel Type: Natural Gas

Thermal Use: Hot Water, Cooling

Installation Year: 2014

Energy Savings: >$60,000/year

Highlights: The microturbine CHP system at Washtenaw Community College is equipped with a FlexSet control system. The web-based system allows facility managers to monitor the system on computers or cell phones. The system's designer, GEM Energy, also donated an additional microturbine to the school for the training of future energy professionals.

Washtenaw Community College

Source: http://www.gemenergy.com/wp-content/uploads/2014/10/CHP-Washtenaw-102814.pdf

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Project Snapshot:
Energy Savings

MEDINA CITY SCHOOLS
RECOGNIZING POTENTIAL MAXIMIZING ACHIEVEMENT

Medina High School

Medina, OH

Application/Industry: High School

Capacity (MW): 125 kW

Prime Mover: Reciprocating Engine

Fuel Type: Natural Gas

Thermal Use: Heating, Hot Water

Installation Year: 2014

Energy Savings: $82,944/year

Highlights: The engine at Medina High School will be able to run 48,000 hours before needing replacement and has an eight year payback. It will offset the 1 million kilowatts of electricity the school purchases each year.

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Source:
http://www.cleveland.com/medina/index.ssf/2014/02/medina_city_school_district_tu.html


Princeton University, NJ


Stony Brook Univ, NY


Fairfield, CT


Ewing, NJ

Resilient University Microgrids in Superstorm Sandy

- The College of New Jersey (NJ) – 5.2 MW CHP
  - "Combined heat and power allowed our central plant to operate in island mode without compromising our power supply." - *Lori Winyard, Director, Energy and Central Facilities at TCNJ*
- Fairfield, University (CT) – 4.6 MW CHP
  - 98% of the Town of Fairfield lost power, university only lost power for a brief period at the storm's peak
  - University buildings served as area of refuge for off-campus students
- Stony Brook University (LI, NY) – 45 MW CHP
  - < 1 hour power interruption to campus of 24,000 students (7,000 residents)
- NYU Washington Square Campus (NY, NY) – 13.4 MW CHP
- Princeton University (NJ) – 15 MW CHP
  - CHP/district energy plant supplies all heat and hot water and half of the electricity to campus of 12,000 students/faculty
  - "We designed it so the electrical system for the campus could become its own island in an emergency. It cost more to do that. But I'm sure glad we did." – *Ted Borer, Energy Manager at Princeton University*

CHP Project Development Resources from US DOE

CHP TAP Role: Technical Assistance

Screening and Preliminary Analysis

Quick screening questions with spreadsheet payback calculator; Advanced technical assistance to explore equipment or operational scenarios.

Feasibility Analysis

Perform 3rd Party Reviews of site Feasibility Assessments: Estimates on savings, installation costs, simple paybacks, equipment sizing, and type.

Investment Grade Analysis

Performa 3rd Party reviews of Engineering Analysis. Review equipment sizing and choices.

Procurement, Operations, Maintenance, Commissioning

Review specifications and bids.

DOE TAP CHP Screening Analysis

- High level assessment to determine if site shows potential for a CHP project
  - Quantitative Analysis
    - Energy Consumption & Costs
    - Estimated Energy Savings & Payback
    - CHP System Sizing
  - Qualitative Analysis
    - Understanding project drivers
    - Understanding site peculiarities

Annual Energy Consumption		
	Base Case	CHP Case
Purchased Electricty, kWh	88,250,160	5,534,150
Generated Electricity, kWh	0	82,716,010
On-site Thermal, MMBtu	426,000	18,872
CHP Thermal, MMBtu	0	407,128
Boiler Fuel, MMBtu	532,500	23,590
CHP Fuel, MMBtu	0	969,845
Total Fuel, MMBtu	532,500	993,435
Annual Operating Costs		
Purchased Electricity, $	$7,060,013	$1,104,460
Standby Power, $	$0	$0
On-site Thermal Fuel, $	$3,195,000	$141,539
CHP Fuel, $	$0	$5,819,071
Incremental O&M, $	$0	$744,444
Total Operating Costs, $	$10,255,013	$7,809,514
Simple Payback		
Annual Operating Savings, $		$2,445,499
Total Installed Costs, $/kW		$1,400
Total Installed Costs, $/k		$12,990,000
Simple Payback, Years		**5.3**
Operating Costs to Generate		
Fuel Costs, $/kWh		$0.070
Thermal Credit, $/kWh		($0.037)
Incremental O&M, $/kWh		$0.009
Total Operating Costs to Generate, $/kWh		**$0.042**

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Favorable Characteristics for CHP Applications

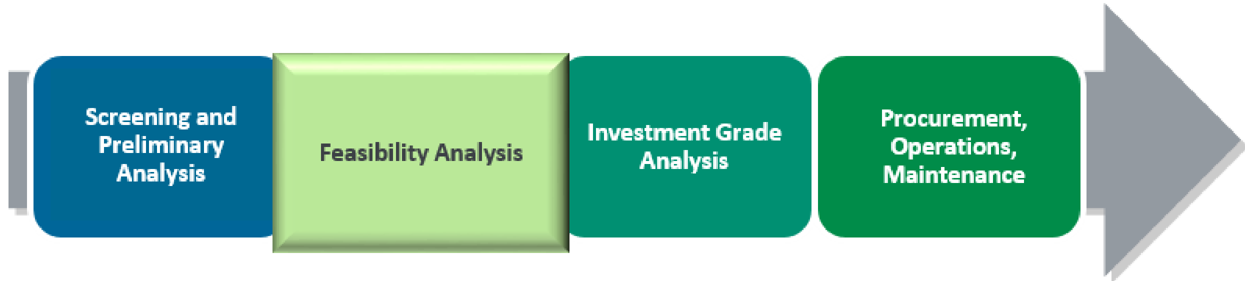
Important

- Concern about energy costs
- Concern about power reliability
- Concern about sustainability and environmental impacts
- Long hours of operation
- Concurrent thermal loads or Storage
- Central heating and cooling distribution system

Helpful

- Future central plant replacement and/or upgrades
- Future facility expansion or new construction projects
- EE measures already implemented
- Access to nearby renewable fuels
- Facility energy champion

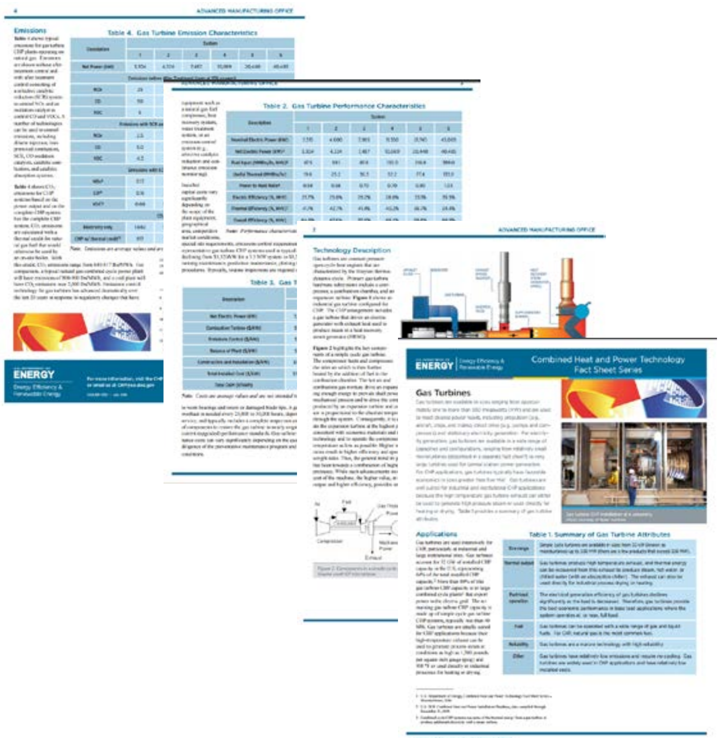
A Feasibility Analysis Typically Involves:



- Electrical load profiling
- Thermal load profiling
- Unit sizing
- Thermal use determination (what to do with the heat)
- Installation cost estimations
- Financial calculations (simple payback, ROI, etc.)
- Cost/savings information compared to what your facility would pay if the CHP system were not installed

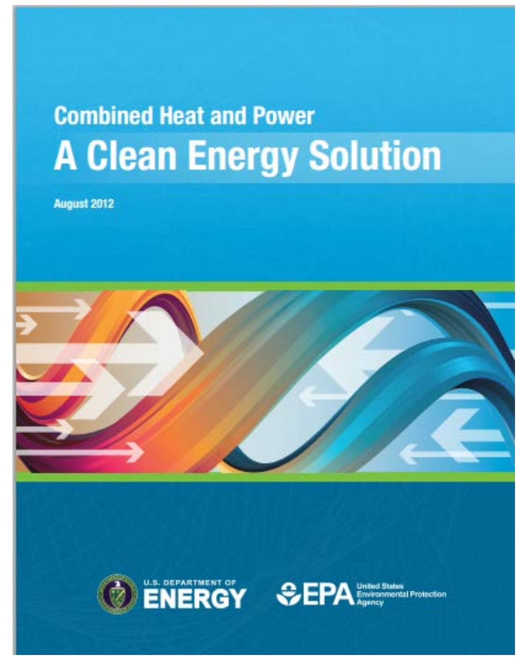
CHP Project Resources

DOE CHP Technologies Fact Sheet Series



www.energy.gov/chp-technologies

Good Primer Report



www.eere.energy.gov/chp

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CHP Project Resources

DOE Project Profile Database
(100+ case studies)

energy.gov/chp-projects

DOE Database of Incentives & Policies (DSIRE)

www.dsireusa.org

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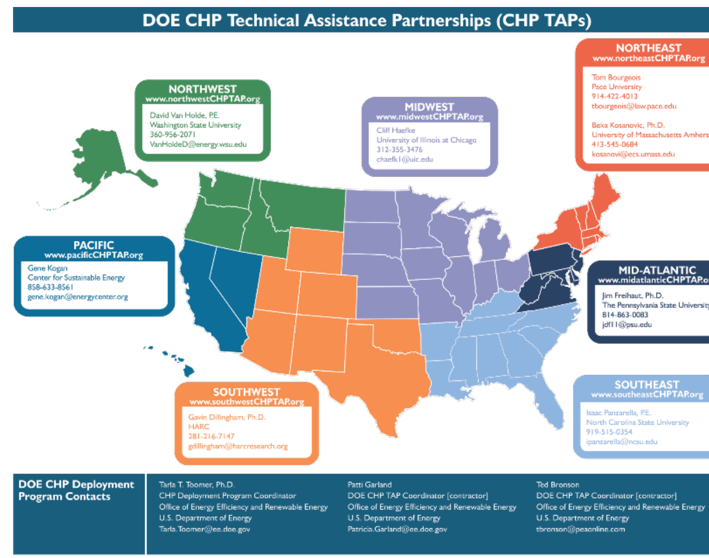
CHP Project Resources

DOE CHP Installation Database
(List of all known
CHP systems in U.S.)

energy.gov/chp-installs

Low-Cost CHP Screening and Other Technical Assistance from the CHP TAP



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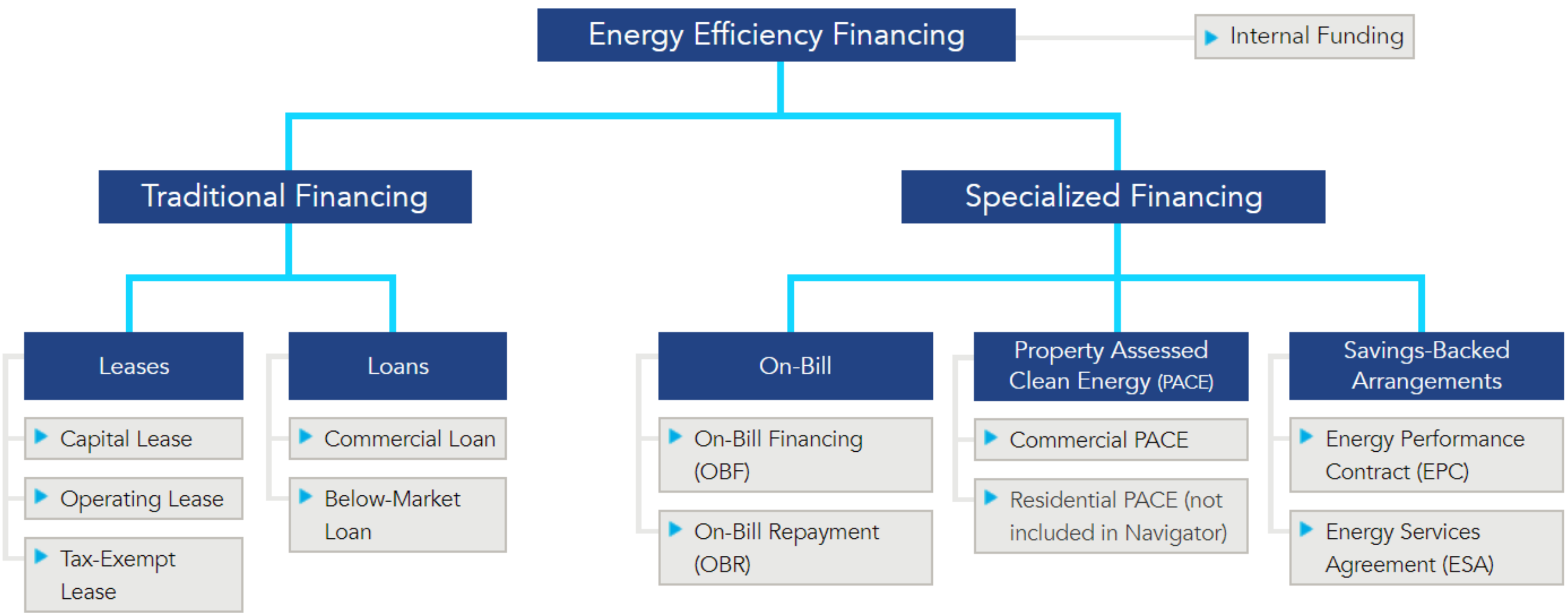
Better Buildings Financing Navigator

Energy Efficiency Financing Landscape



Source: https://betterbuildingssolutioncenter.energy.gov/financing-navigator

CHP Utility Incentives

Utility Incentives and Tax Credits

- Federal
  - 10% Investment Tax Credit for CHP systems (extended to 2022)
- ComEd
  - Up to $25k or 50% of feasibility studies
  - $0.07/kWh for electricity savings
- Ameren
  - Up to $20k for feasibility studies
  - $0.06/kWh for electric savings, $1.25/therm for natural gas savings
- Gas Companies
  - Nicor Gas – up to $12.5 k or 25% of feasibility studies, $1/therm Custom Program incentive for natural gas savings
  - Peoples – $1/therm Custom Program incentive for natural gas savings

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Illinois TRM – CHP Energy Savings That are Eligible for CHP Incentives

CHP Efficiency (HHV)	Electric & Gas		Electric Only		Gas Only	
	% $Elec_{CHP}$	% $NG_{thermal}$	% $Elec_{CHP}$	% $NG_{thermal}$	% $Elec_{CHP}$	% $NG_{thermal}$
60%	65.0%	0.0%	65.0%	0.0%	0.0%	0.0%
65%	70.0%	0.0%	70.0%	0.0%	0.0%	12.5%
70%	70.0%	12.5%	75.0%	0.0%	0.0%	25.0%
75%	70.0%	25.0%	80.0%	0.0%	0.0%	37.5%
80%	70.0%	37.5%	85.0%	0.0%	0.0%	50.0%
85%	70.0%	50.0%	90.0%	0.0%	0.0%	62.5%

$Elec_{CHP}$ = Useful annual electricity output produced by the CHP system (generation minus parasitic load)
$NG_{thermal}$ = Boiler natural gas use before CHP installation (useful thermal output divided by on-site boiler efficiency)

http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_2_C_and_I_020817_Final.pdf
See pages 280-287

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Summary

- CHP is a proven technology providing energy savings, reduced costs, and opportunities for resiliency
- Emerging drivers are creating new opportunities to evaluate CHP today
- Universities and community colleges are excellent candidates for CHP
- Resources are available to assist in developing CHP Projects
- Incentives are also available for CHP projects in Illinois, for both electricity and natural gas savings, along with federal tax credits
- Contact us to learn more about available CHP Incentives or for more information about technical assistance from the US DOE Midwest CHP TAP.

Thank You

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