U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

FEMP FIRST THURSDAY SEMINARS

What you need to know...online, live, and anytime.

Combined Heat and Power for Energy Resource Optimization

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Bob Slattery, Oak Ridge National Laboratory
FEMP Expert: David Catarious

FEMP Federal Energy Management Program

Objectives/Competency Development

After completing this seminar, the learner will be able to:

- Define CHP for on-site power generation
- Discuss potential benefits of CHP for the learner's site or facility including whether the site has characteristics that make CHP cost-effective
- Discuss "prime mover" and "thermally activated technologies," including the advantages and limitations of specific technology options
- Conduct a feasibility analysis to inform the technical feasibility and cost effectiveness of implementing a CHP project
- Understand best practices and lessons learned from CHP projects in the Federal government
- Consider the potential financing vehicles including CHP as part of an ECM in ESPCs, UESCs, and PPAs

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Combined Heat and Power

Definition and Concept

What Is Combined Heat and Power?

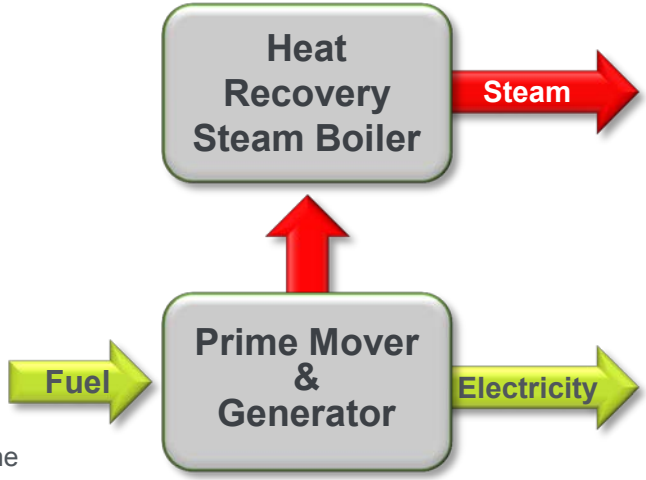
CHP is an ***integrated energy system*** that:

- is located at or near a facility
- generates electrical and/or mechanical power
- recovers waste heat for
  - heating
  - cooling
  - dehumidification
- can utilize a variety of technologies and fuels
- is also referred to as cogeneration

Defining Combined Heat and 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 Cycled CHP or Direct Fired CHP)



- Simultaneous generation of heat and electricity
- Fuel is combusted/burned for the purpose of generating heat and electricity
- Normally sized for thermal load to max. efficiency – 70% to 80%
- HRSG can be supplementary fired for larger steam loads
- Normally non export of electricity
- Low emissions – natural gas

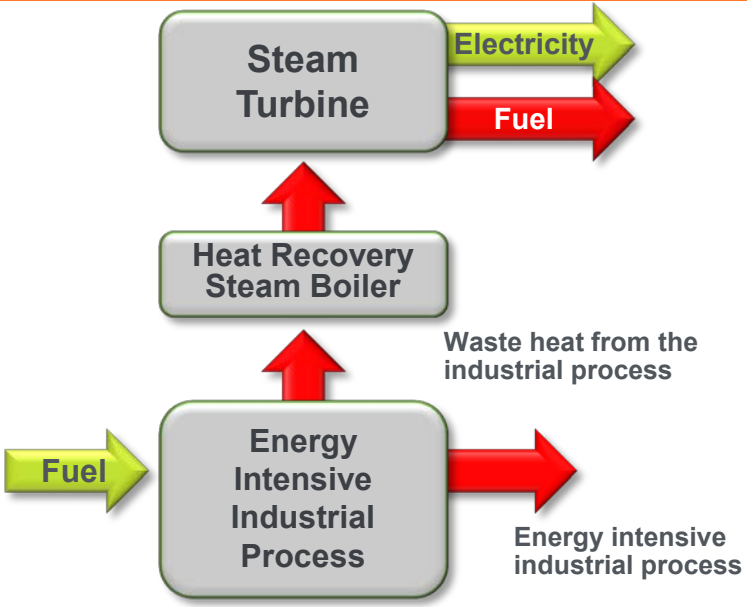
Recip. Engine
Gas Turbine
Micro-turbine
Fuel Cell
Boiler/Steam Turbine

Source: Midwest Clean Energy Application Center

Defining Combined Heat and 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)



- 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 of electric generation (often exports electricity to the grid; base load electric power)
- Normally requires high temperature (>800ºF) (low hanging fruit in industrial plants)

Source: Midwest Clean Energy Application Center

CHP Is Based on Proven Technologies and Practices

What Are the Benefits of CHP?

Benefits to Federal Facility	National Benefits
Reduced energy costs	Low-cost approach to new electricity generation capacity
Reduced risk of electric grid disruptions and greater grid security	Lessens need for new T&D infrastructure
Stability related to uncertain electricity prices	Enhances US manufacturing competitiveness
Immediate path to increased energy efficiency and reduced GHG emissions	Uses abundant, domestic energy sources
	Uses highly skilled local labor and U.S. technology

Regulatory Drivers for CHP

Federal Drivers

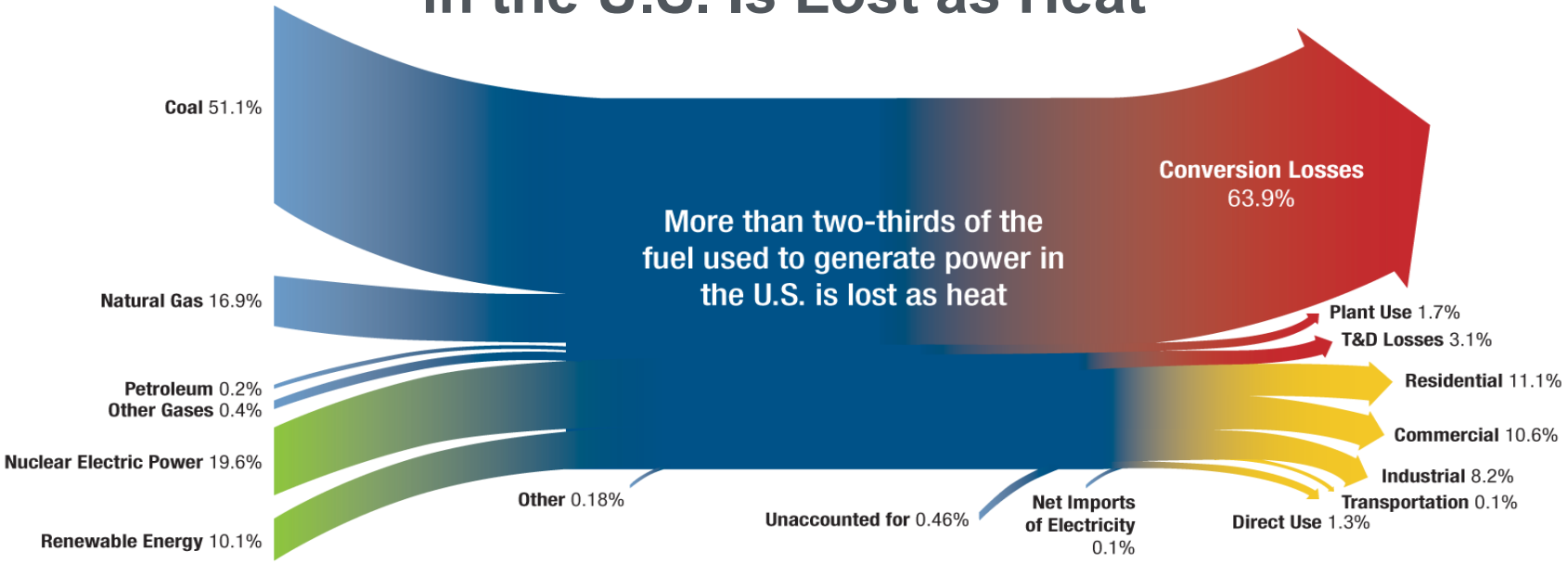
- EISA 2007
- EPAct 2005
- E.O. 13424 and 13514

Also:

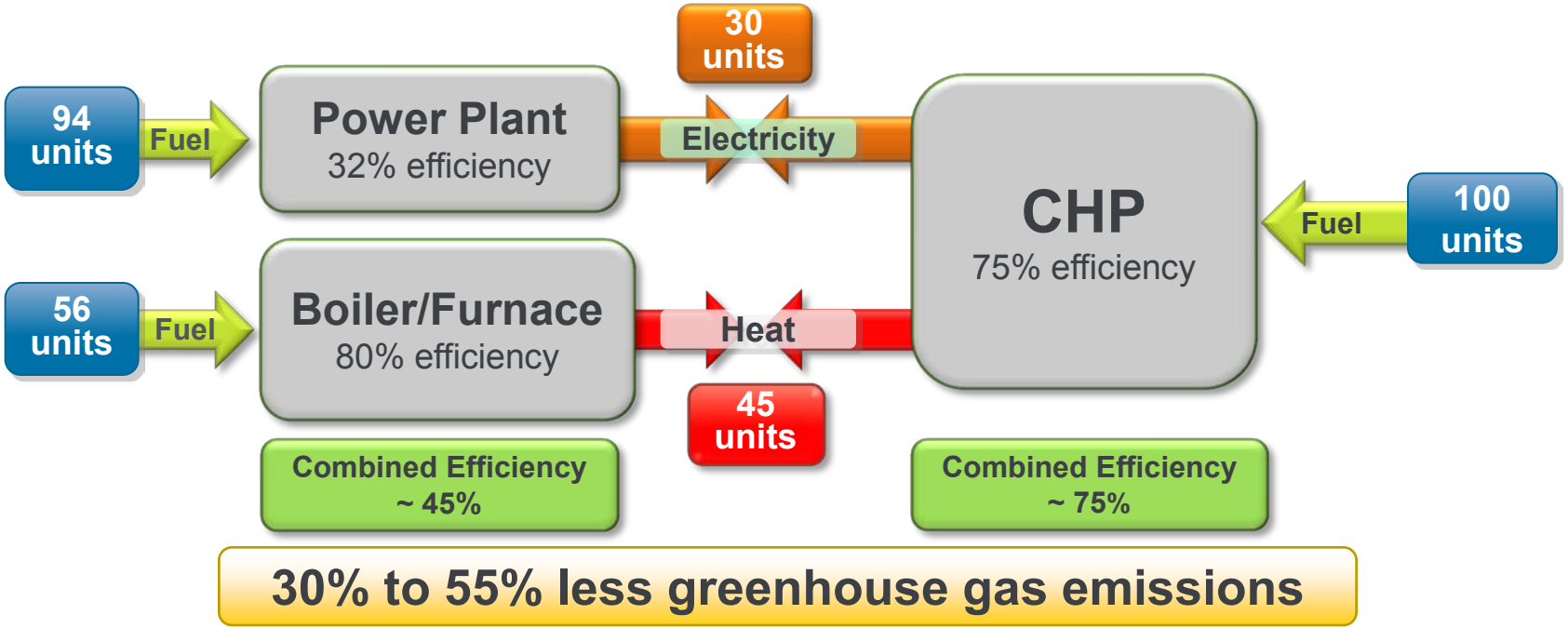
Executive Order of August, 2012
Accelerating Investment In Industrial Energy Efficiency

Recognizing the benefits of CHP and its current underutilization as an energy resource in the United States, the Obama Administration is supporting a new National goal to achieve 40 gigawatts (GW) of new, cost-effective CHP by 2020

Over Two-Thirds of the Fuel Used to Generate Power in the U.S. Is Lost as Heat



CHP Recaptures Much of that Heat, Increasing Overall Efficiency of Energy Services



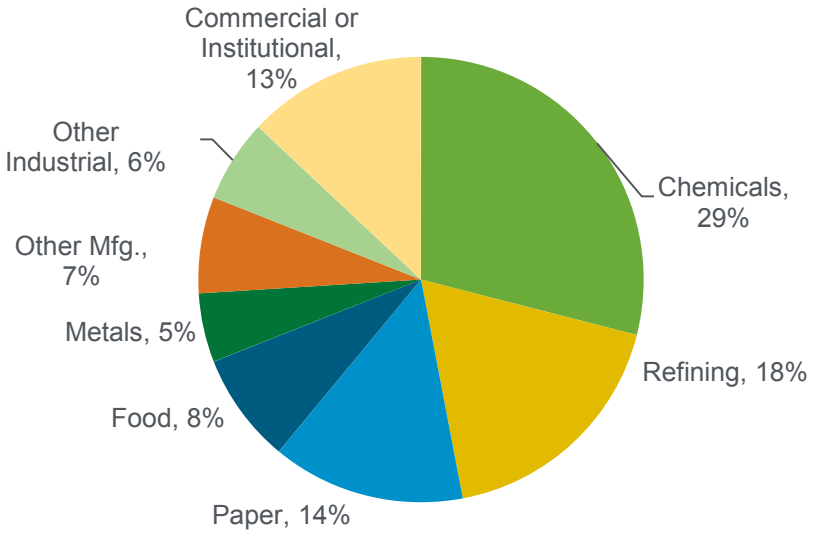
30% to 55% less greenhouse gas emissions

CHP's Higher Efficiency Results in Energy and Emissions Savings

Category	10 MW CHP	10 MW PV	10 MW Wind	10 MW NGCC
Annual Capacity Factor	85%	22%	34%	70%
Annual Electricity	74,446 MWh	19,272 MWh	29,784 MWh	61,320 MWh
Annual Useful Heat Provided	103,417 MWh_t	None	None	None
Footprint Required	6,000 sq ft	1,740,000 sq ft	76,000 sq ft	N/A
Capital Cost	$20 million	$60.5 million	$24.4 million	$10 million
Annual Energy Savings, MMBtu	308,100	196,462	303,623	154,649
Annual CO_2 Savings, Tons	42,751	17,887	27,644	28,172
Annual NOx Savings	59.9	16.2	24.9	39.3

Source: Combined Heat and Power A Clean Energy Solution: August 2012: DOE and EPA

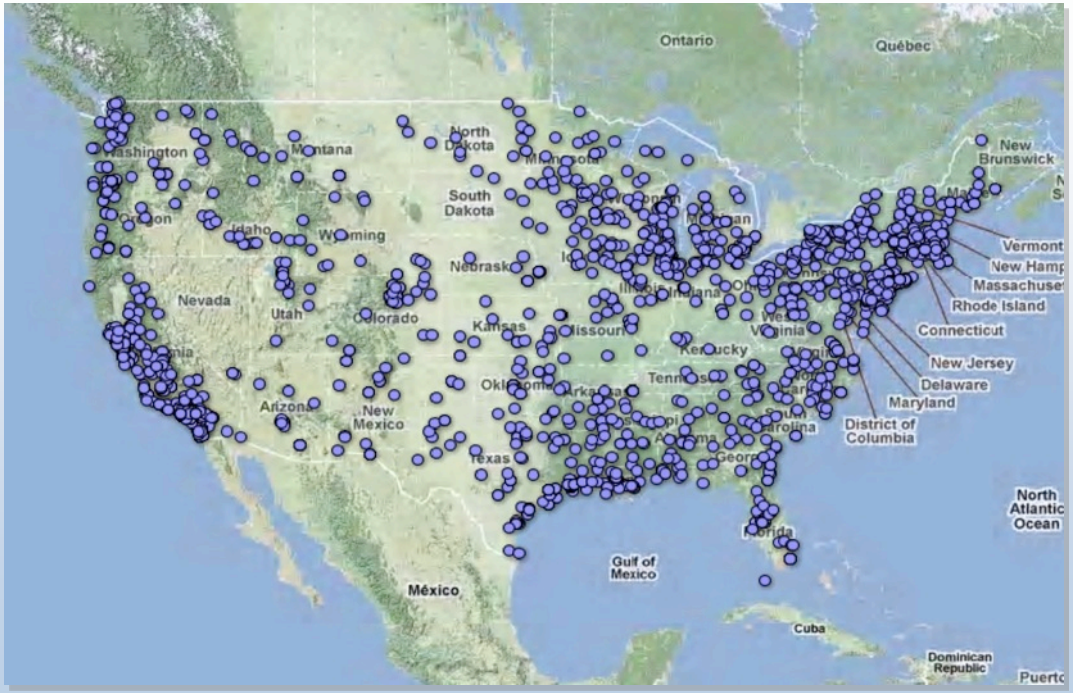
CHP Is Already an Important Natural Resource



Source: Combined Heat and Power A Clean Energy Solution: August 2012: DOE and EPA

- 82 GW of installed CHP at almost 4,000 industrial and commercial facilities (2011)
- Avoids more than **1.8 quadrillion Btus** of fuel consumption annually
- Avoids **241 million metric tons of CO_2** as compared to traditional separate production
- CO_2 reduction equivalent to eliminating **forty 1,000 MW coal power plants**

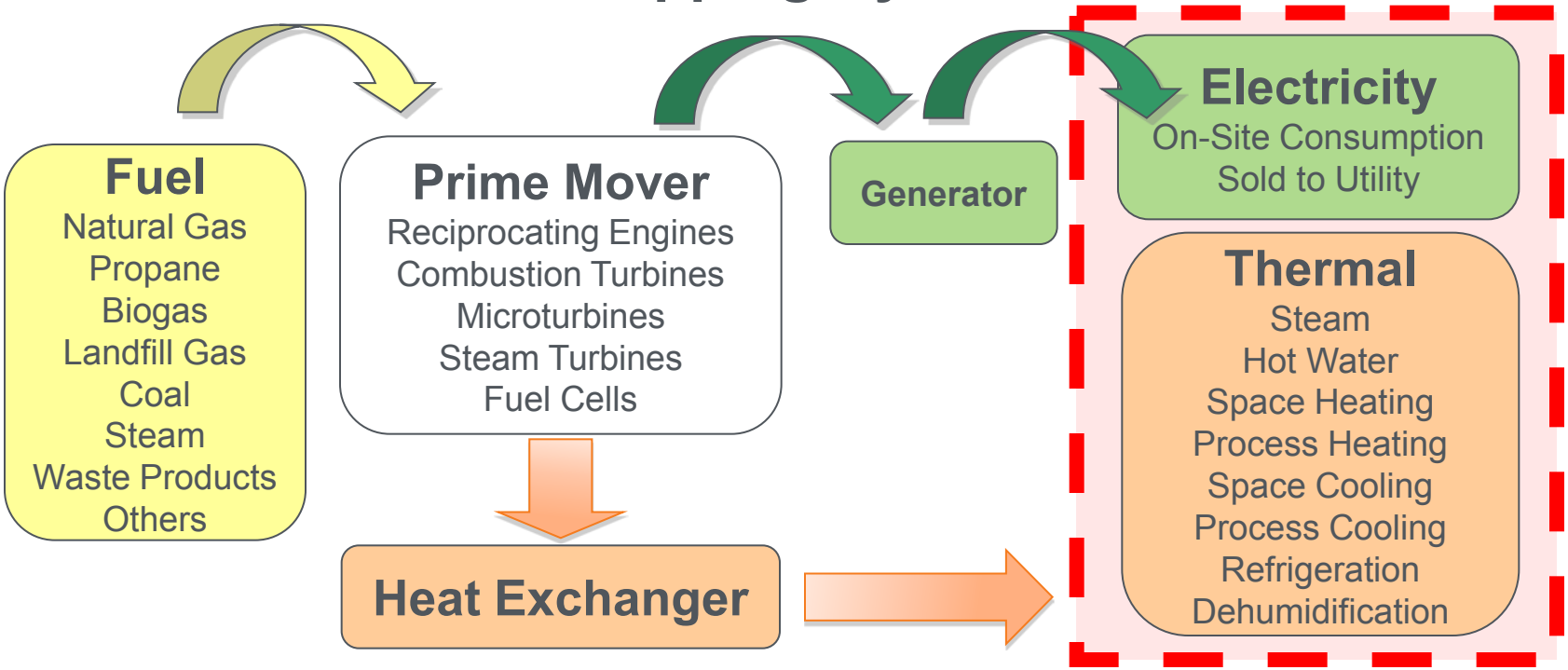
CHP is Used at the Point of Demand

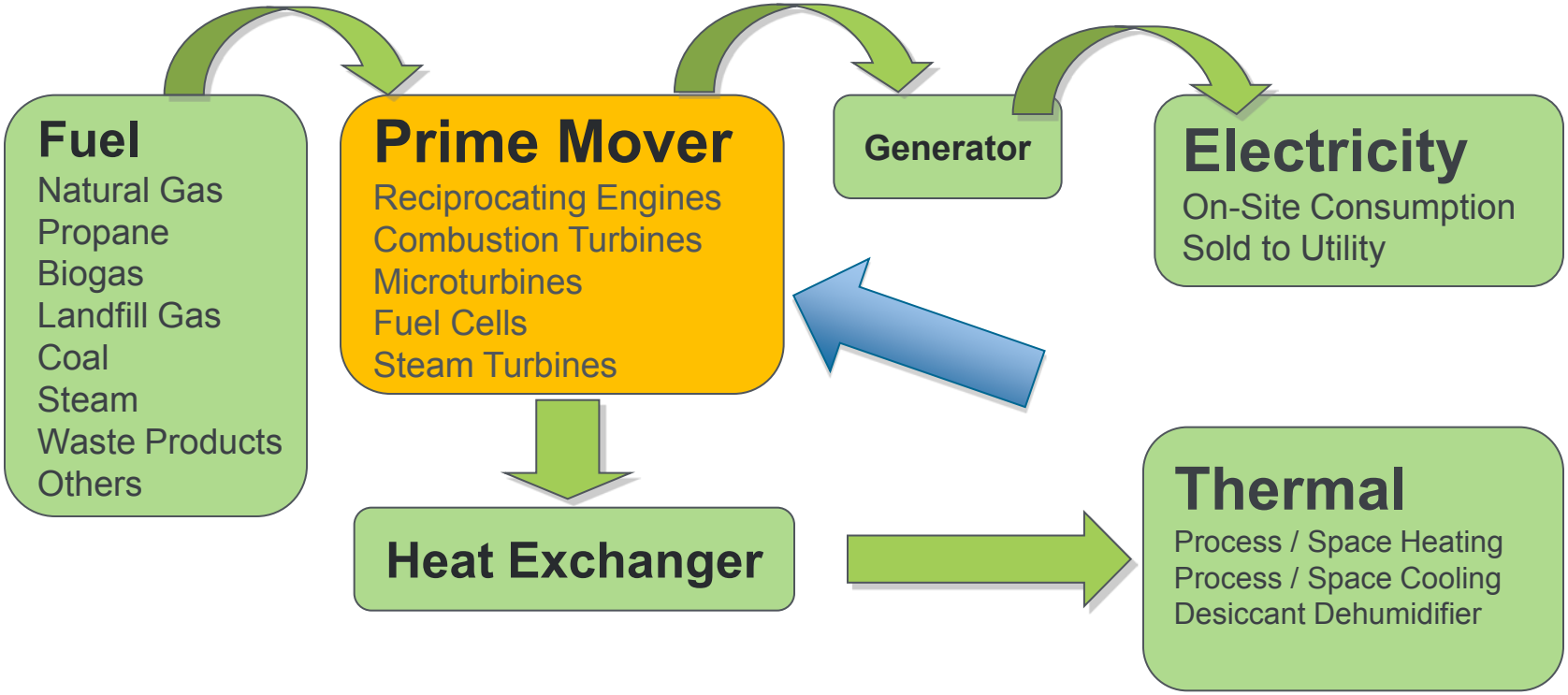


Source:
ICF/CHP
Installation
Database

Combined Heat and Power *Technologies*

Topping Cycle




Fuel
Natural Gas
Propane
Biogas
Landfill Gas
Coal
Steam
Waste Products
Others
Prime Mover
Reciprocating Engines
Combustion Turbines
Microturbines
Fuel Cells
Steam Turbines
Generator
Electricity
On-Site Consumption
Sold to Utility
Heat Exchanger
Thermal
Process / Space Heating
Process / Space Cooling
Desiccant Dehumidifier

Prime Mover

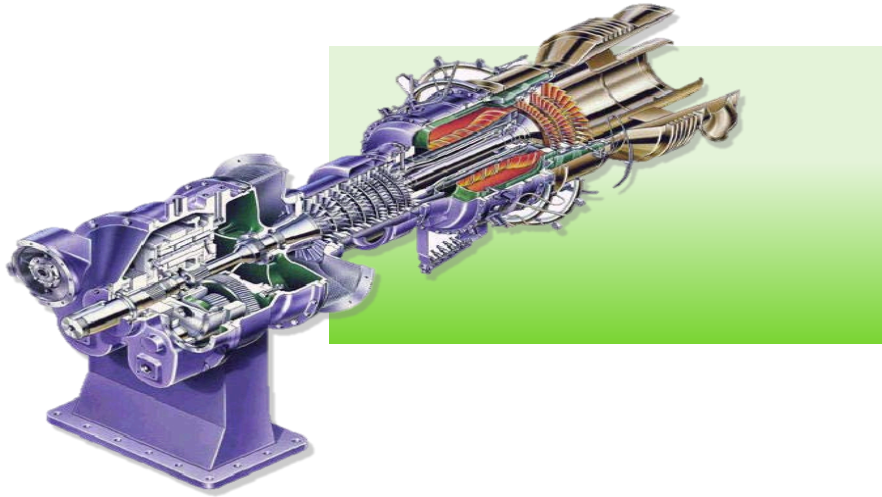
Reciprocating Engines

- 5 kW – 10 MW
- Excellent part-load operation
- Waste heat recovered from engine exhaust, engine jacket and oil coolant
- Low set-up cost, fast start-up
- Emissions signature has improved significantly
  - Lean-burn engines
  - Selective catalytic reduction (SCR)

Primer Mover

Combustion Gas Turbine

- 5 MW - 250 MW
- Same technology as a jet engine
- Best suited for base-load (24/7) operations
- Typically fueled by natural gas
- Produce high quality heat from exhaust



Primer Mover

Micro Turbines

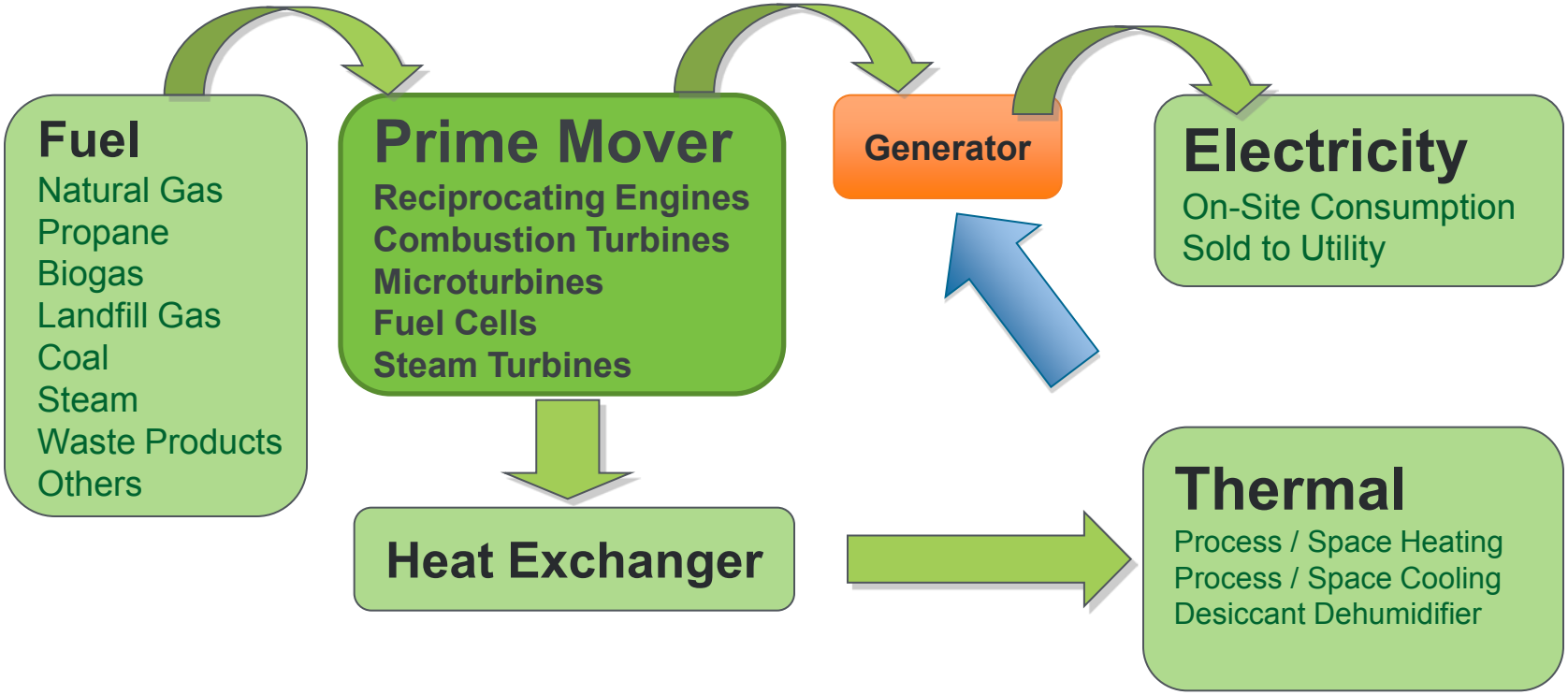
- Small turbines with recuperation
- 25 kW to 500 kW
- Efficiency range: 25% to 30% LHV
- Recoverable heat: gas exhaust @ approx. 500°F
- Fuel flexible
- Low emissions <0.49lbs/MWh or 9ppm

Primer Mover

Fuel Cells

- 5 kW – several MWs
- Generates power and heat through electrochemical reactions
- Very quiet, no combustion or shaft movement
- Environmentally cleanest CHP technology
- Different kinds:
  - Phosphoric acid
  - Solid oxide
  - Molten carbonate
  - Proton exchange membrane

Source: www.eere.energy.gov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On-Site Consumption
Sold to Utility
Heat Exchanger
Thermal
Process / Space Heating
Process / Space Cooling
Desiccant Dehumidifier

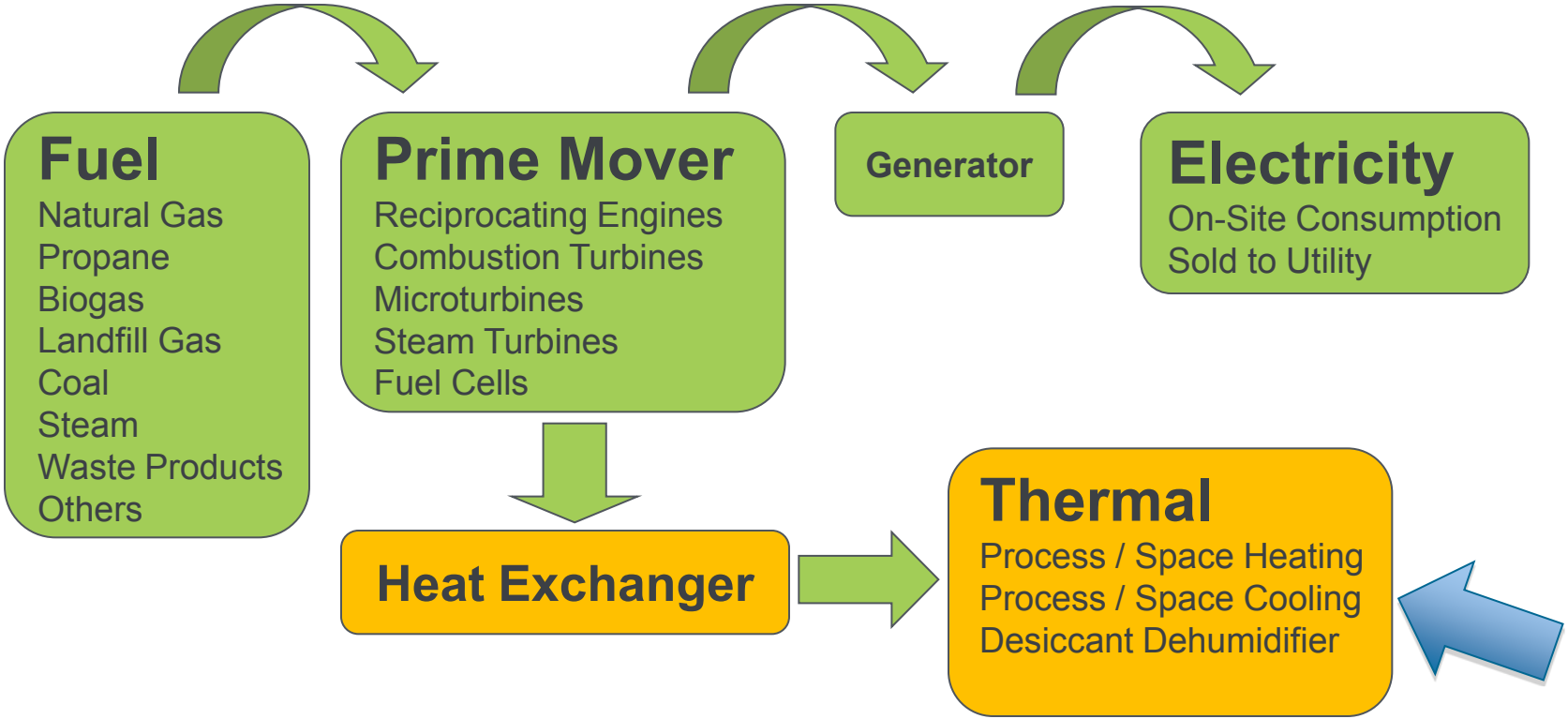
Two Types of Generators

Induction

- **Requires External Power Source to Operate (Grid)**
- Contributes to Poor PF
- **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)**
- Can Assist in PF Correction
- **CHP System can Continue to Operate thru Grid Outages**
- More Complicated & Costly to Interconnect (Safety)
- Preferred by CHP Customers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Desiccant Dehumidifier

Heat Capture: Converting Heat into Work

Heat Exchangers

- Recover exhaust gas generated by:
  - Gas turbine
  - Industrial processes
- Transfers exhaust gas into useful heat (e.g., steam) for downstream applications
- Heat recovery steam generator (HRSG) the most common

Heat Recovery Steam Generator (HRSG)

Heat Capture: Converting Heat into Work

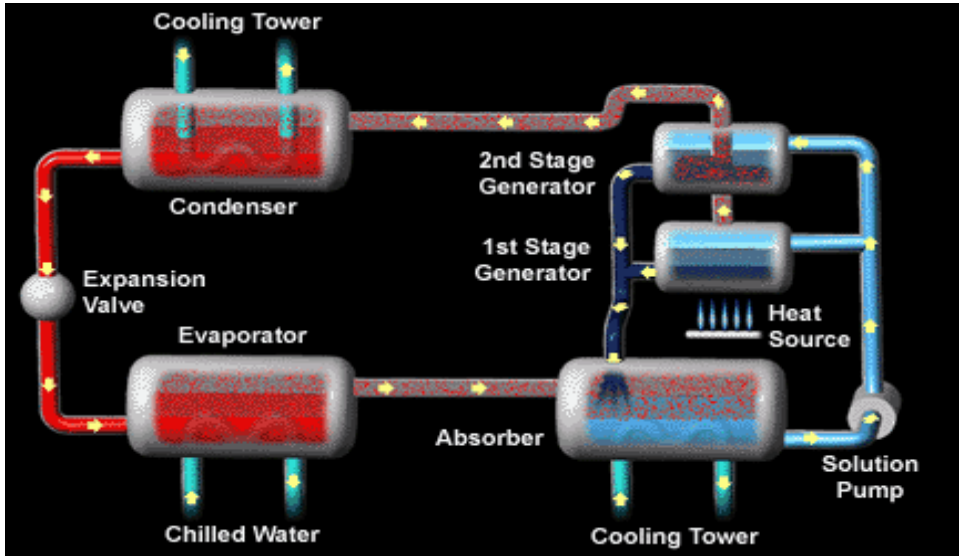
Heat-Driven Chillers (Absorption)

- Use "waste" heat to chill water for A/C, cooling machinery
- More efficient, fewer emissions vis-à-vis electric chillers

ABSORPTION CHILLERS

Use exhaust gas, hot water, or steam via thermal compressor to boil water vapor out of lithium bromide/ water solution and compress refrigerant to higher pressure; avoids CFCs/HCFCs

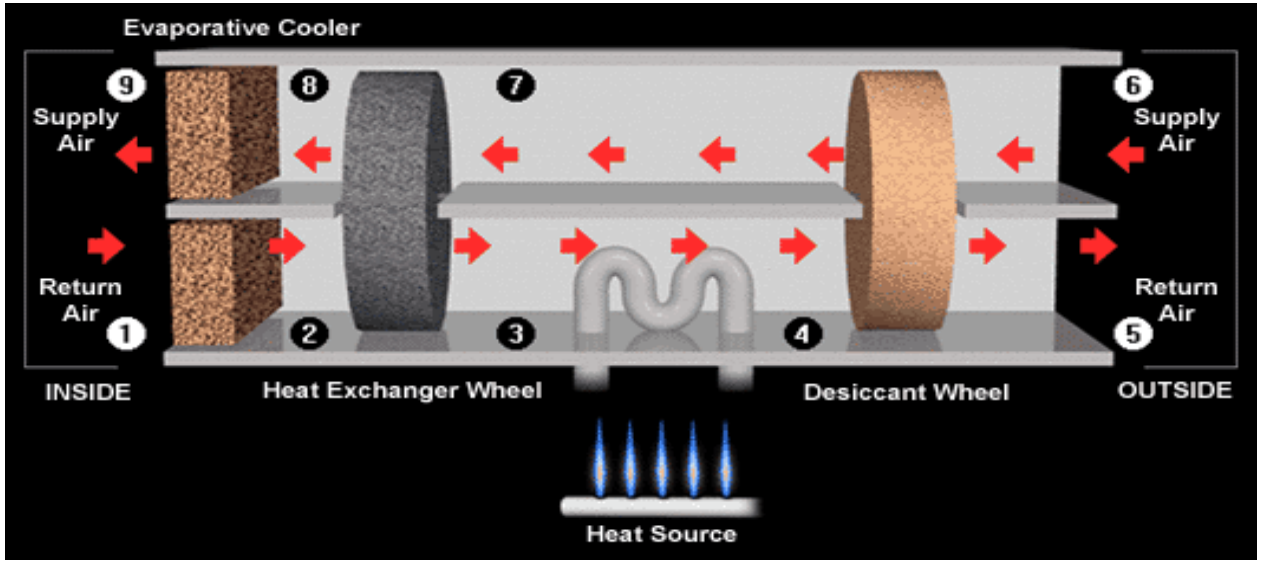
Range: 10-3,000 tons



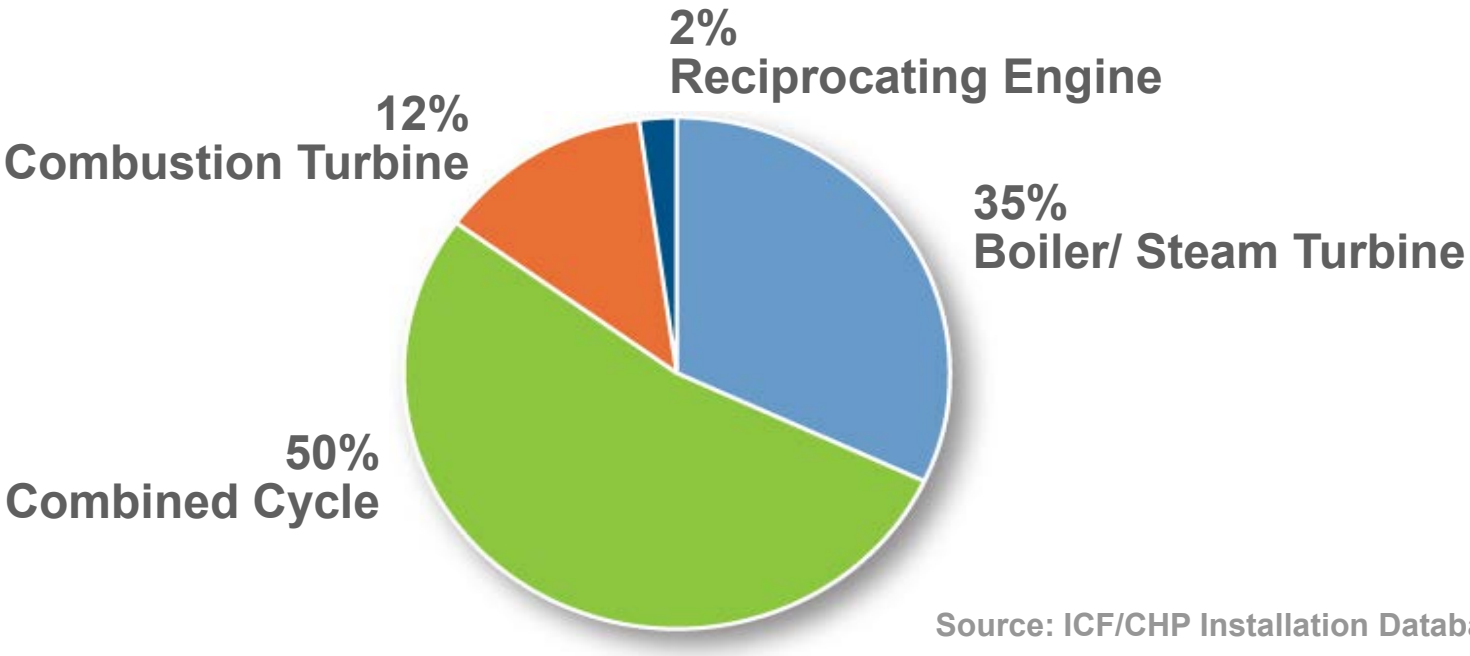
Heat Capture: Converting Heat into Work

Desiccant Dehumidifiers

- Separates Latent from Sensible Load
- Reduces Humidity and Reduces AC Load



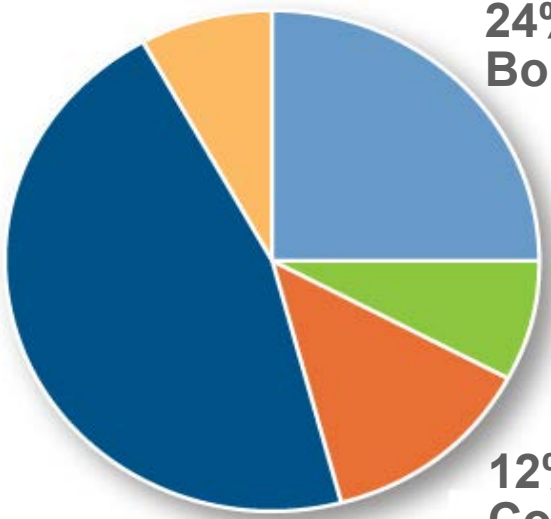
Existing CHP Capacity by Technology – 82 GW



Source: ICF/CHP Installation Database

CHP Technologies by Site

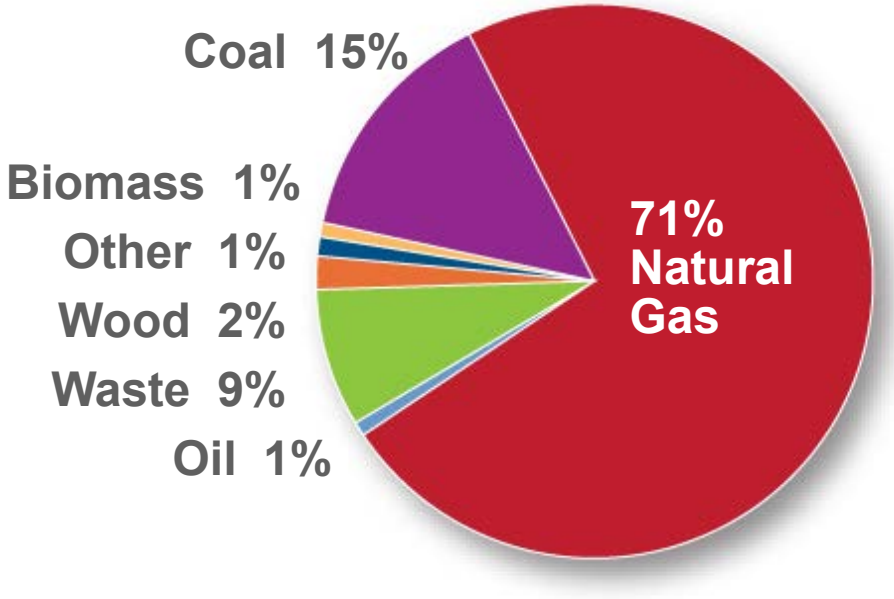
Existing CHP Sites by Technology



Source: ICF/CHP Installation Database

Natural Gas is the Preferred Fuel for Existing CHP

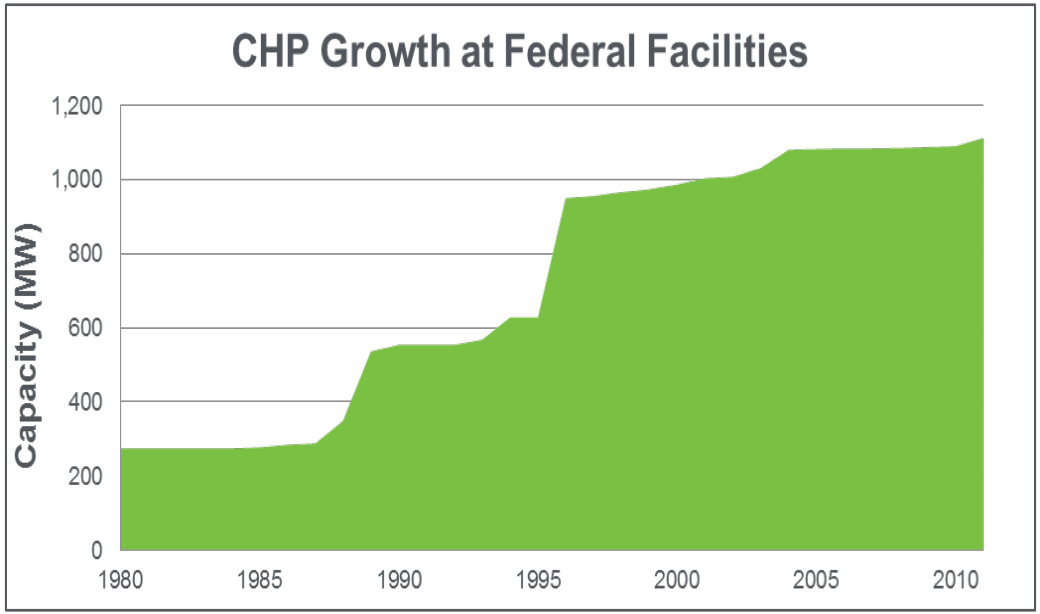
Existing CHP Capacity by Fuel – 82 GW



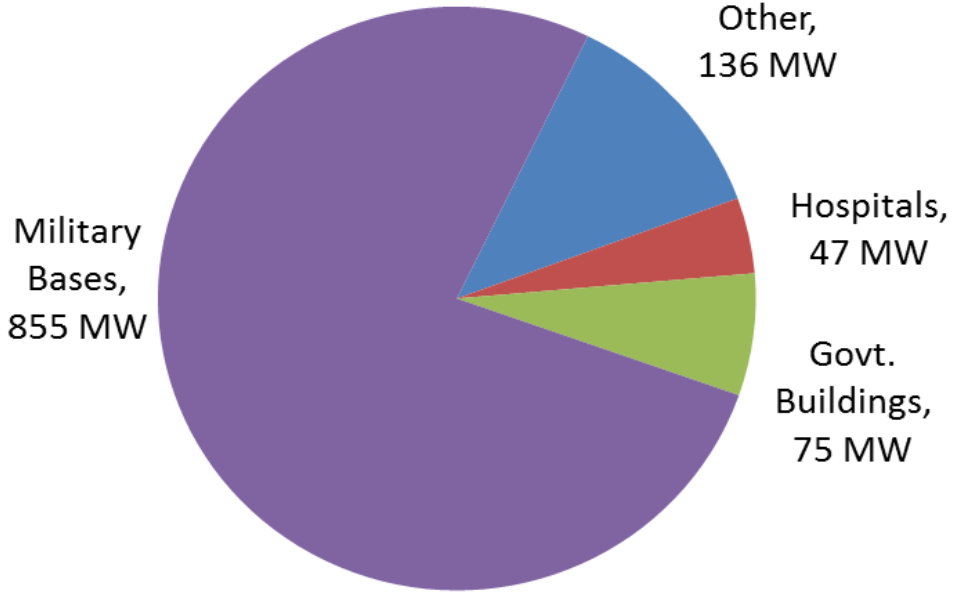
Source: ICF/CHP Installation Database

CHP at Federal Facilities

- 85 Federal facilities have CHP with 1,112 MW of operational capacity
- Represents 1.3% of US CHP capacity (81.8 GW)

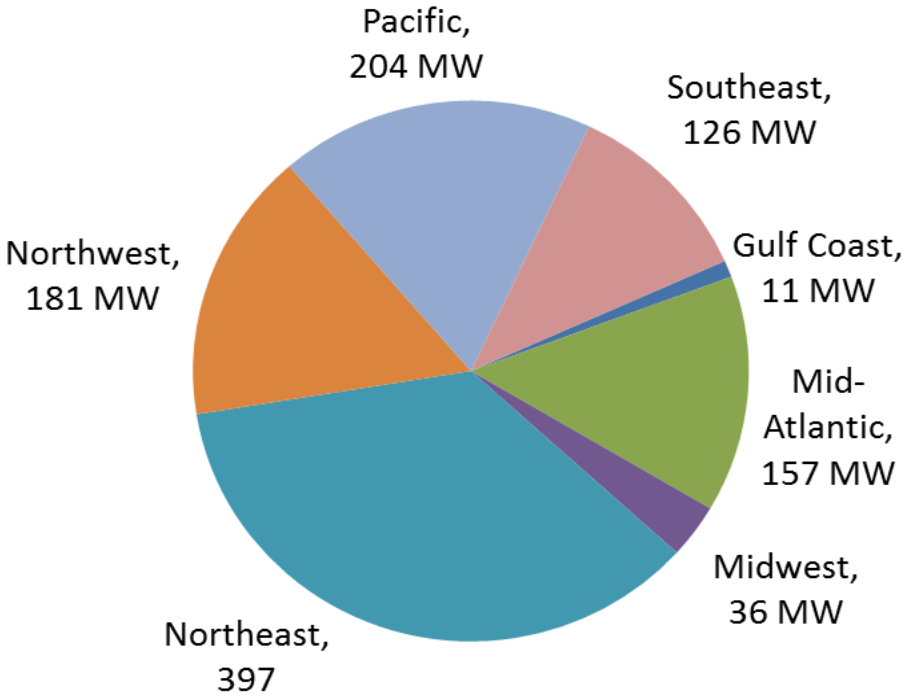


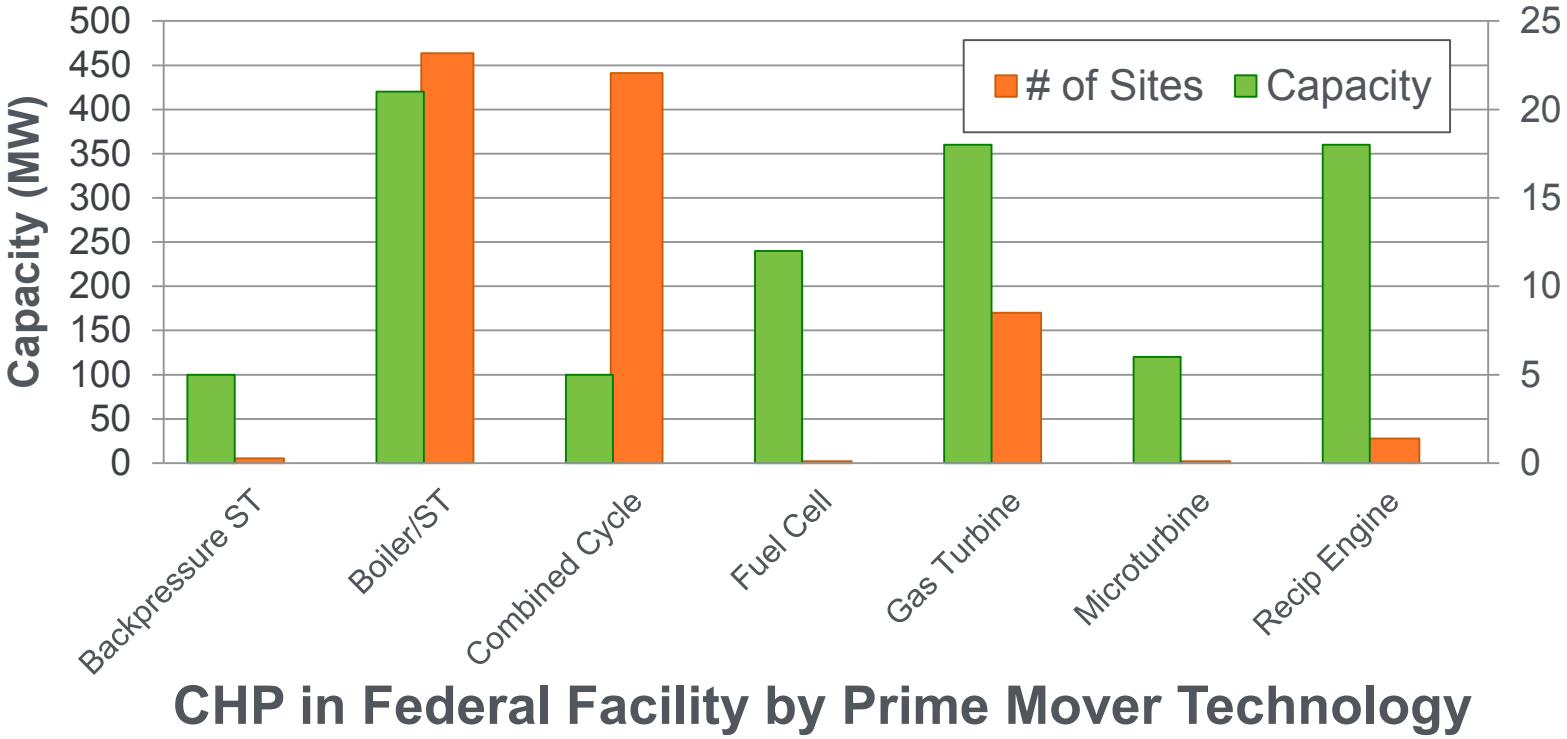
CHP in Federal Facilities by Application Type



*Other includes post offices, national labs, and other misc. government facilities

Federal Facilities with CHP by Region

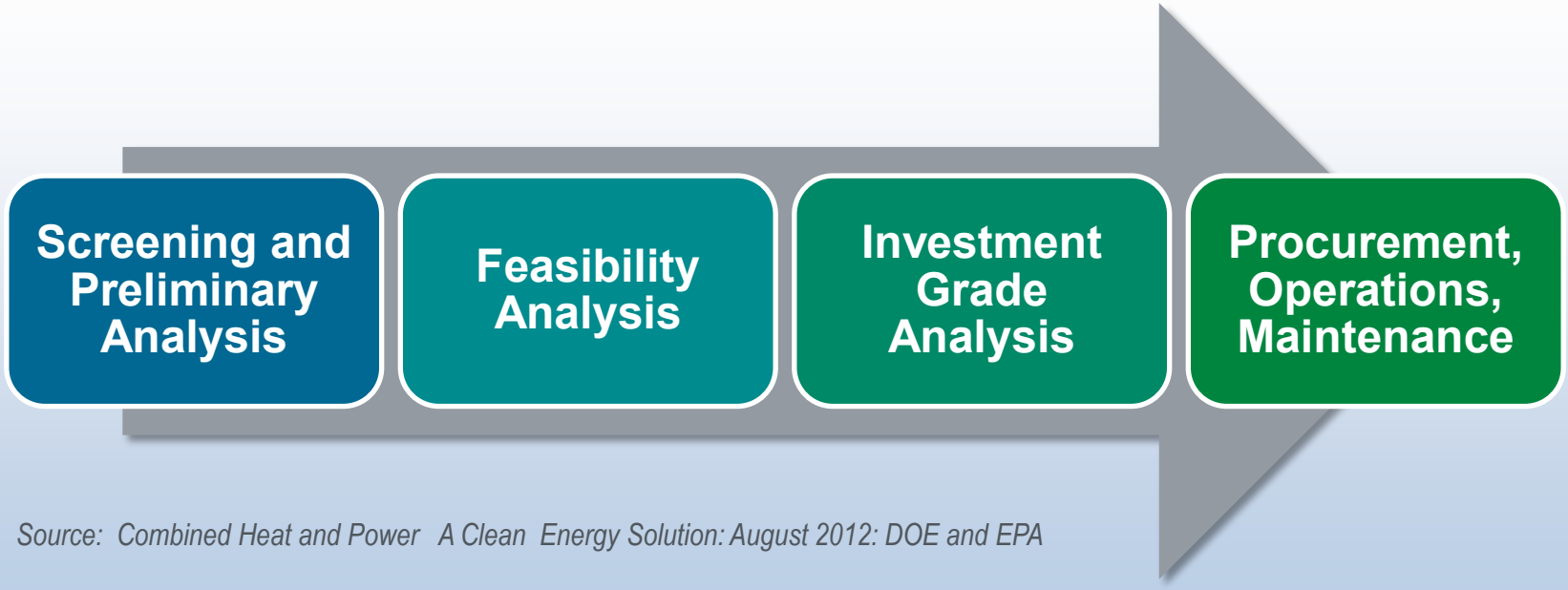




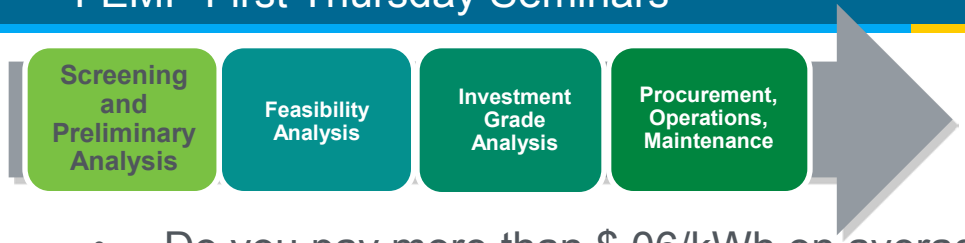
CHP in Federal Facility by Prime Mover Technology

CHP Project *Implementation*

CHP Project Process



Source: Combined Heat and Power A Clean Energy Solution: August 2012: DOE and EPA



Screening Questions

- Do you pay more than $.06/kWh on average for electricity (including generation, transmission and distribution)?
- Are you concerned about the impact of current or future energy costs on your operations?
- Are you concerned about power reliability?
  What if the power goes out for 5 minutes… for 1 hour?
- Does your facility operate for more than 3,000 hours per year?
- Do you have thermal loads throughout the year?
  (including steam, hot water, chilled water, hot air, etc.)

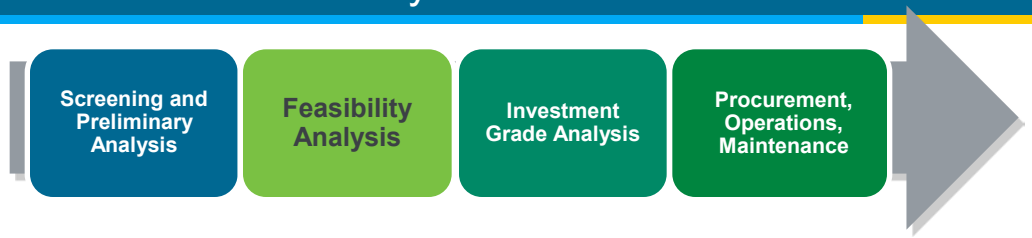
Source: Combined Heat and Power A Clean Energy Solution: August 2012: DOE and EPA

Screening Questions (cont.)

- Does your facility have an existing central plant?
- Do you expect to replace, upgrade, or retrofit central plant equipment within the next 3-5 years?
- Do you anticipate a facility expansion or new construction project within the next 3-5 years?
- Have you already implemented energy efficiency measures and still have high energy costs?
- Are you interested in reducing your facility's impact on the environment?
- Do you have access to on-site or nearby biomass resources? (i.e., landfill gas, farm manure, food processing waste, etc.)

Screening: Likely Candidates for CHP

- Traditional buildings with hydronic distribution systems (steam or hot water and chilled water)
- Key locations
  - Military installations
  - Office buildings
  - Hospitals
  - Labs and Data Centers
  - Prisons



A Feasibility Analysis typically involves

- Electrical load profiling
- Thermal load profiling
- New utility rate structure analysis
- Unit sizing
- Thermal use determination (what to do with the heat)
- Installation cost estimations

A Feasibility Analysis typically involves (cont).

- Permitting impacts
- Utility interconnection requirements
- Financial calculations (simple payback, ROI, etc.)
- Financing option availability
- Analysis of different ownership structures with recommendations as to project structure
- Discussion of design/construction models
- Cost/savings information can then compared to what your facility would pay if the CHP system were not installed

Example Challenges for CHP Projects

- Financial uncertainty
- CHP cost and performance uncertainty
- Regulatory uncertainty
- Utility uncertainty

Utility Partnership Considerations

Permitting, Tariffs, Rate Impacts

- Identify the state and local requirements for permitting a CHP plant early in the planning process.

- Identify potential impacts on utility rates under a CHP scenario – the availability, cost, and supply pressure of natural gas are issues that should be considered early in a feasibility study.

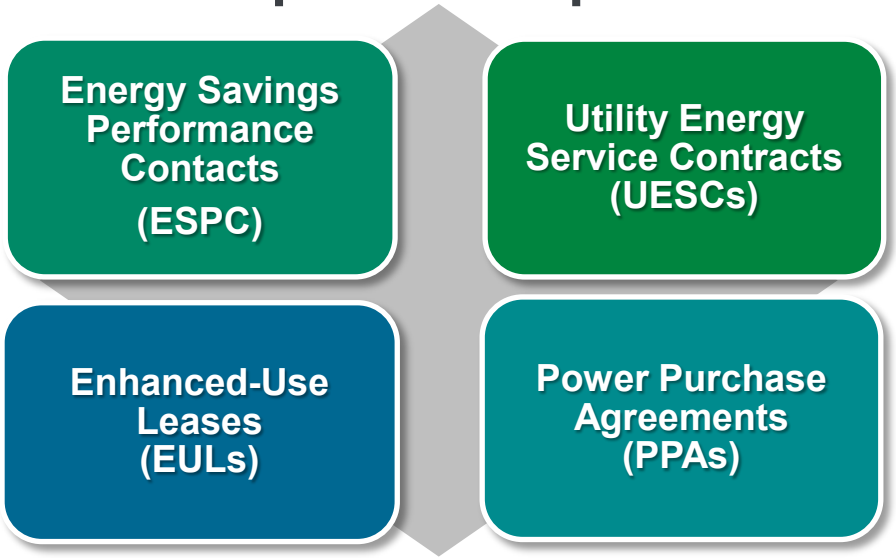
Investment Grade Analysis

- Generally involves contracting with a design engineering firm
- Results in design specs that can become part of an RFP
- Consider best technologies
- May include a utility required “interconnect study”
- Consider balance-of-plant items such as piping, stack breaching, platforms, electrical switchgear, steam piping, pumps, etc.
- For small projects, may use feasibility study rather than IGA

- Project financing (covered later in presentation)
- Permits – number and complexity vary
- Emissions – site vs. source considerations
- Interconnection – varies from state to state
- Operations and Maintenance: in-house, contractors, or both

Financing Options

Financing Vehicles Used to Get Energy Services/Improvements for Federal Facilities Without Up-Front Capital Costs



What are ESPCs?

ESPCs are contracts that allow Federal agencies to procure facility improvements with no up-front capital costs and are paid for over time.

ESCO

- Assesses the opportunities
- Incurs cost for implementing project
- Guarantees cost savings, equipment performance, standards of service

Agency

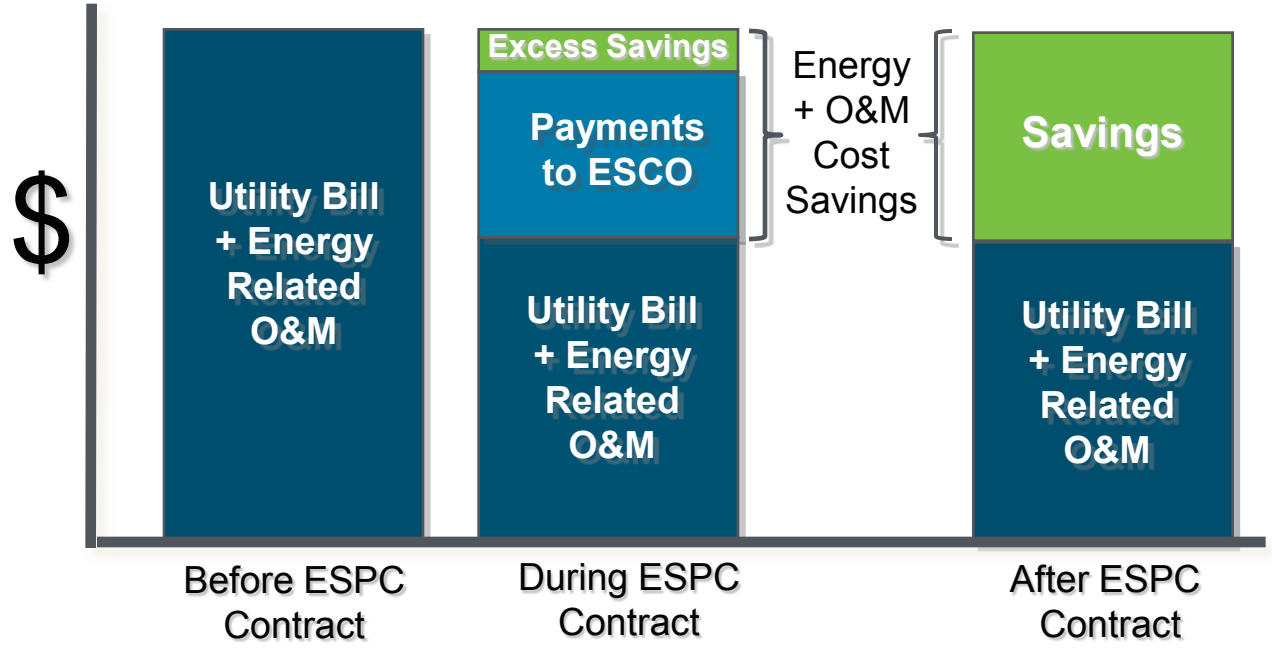
- Pays ESCO over term of contract from energy cost savings

ESPC Key Points

- Savings guarantees are mandatory
- Savings must exceed payments in each year
- Measurement and verification (M&V) is mandatory
- Contract term cannot exceed 25 years

ESPC Payments

- **Key:** ESPCs are budget neutral
- ESPCs are paid from savings – guaranteed

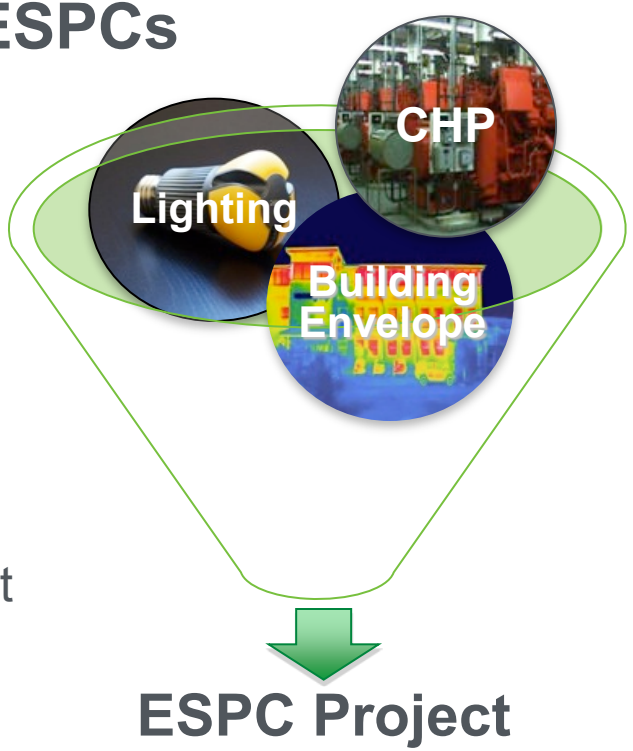


CHP Projects As Part of ESPCs

ESPC projects may consist of a wide range of possible Energy Conservation Measures (ECM)

Example:
DOE's ESPC program identifies 19 separate ECM technical categories

CHP may be a single ECM under an ESPC project or part of a larger multi-ECM energy project



What are UESCs?

Contracts that allow utilities to provide their Federal customer agencies with comprehensive energy and water efficiency improvements and demand-reduction services.

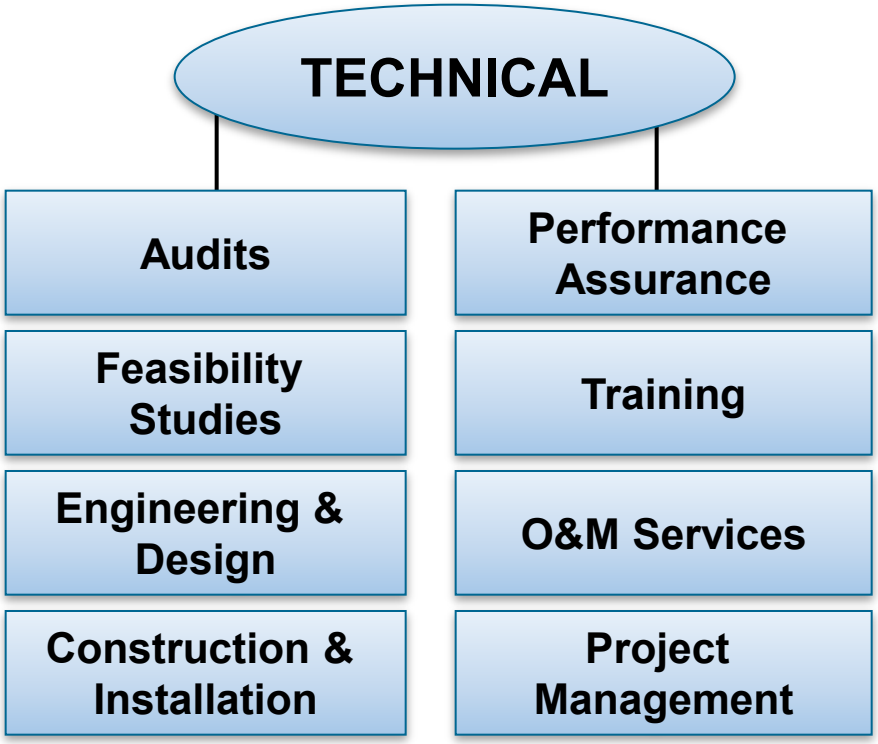
Utility

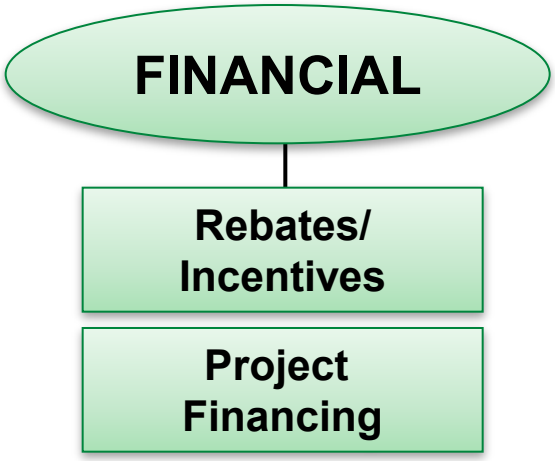
- **Fronts the capital costs, if needed**
- **Assesses the opportunities**
- **Assures equipment performance and standards of service**

Agency

- **Pays utility over term of contract from cost savings achieved**

A UESC is a Partnership





42 USC 8256 (EPAct 1992) authorizes the use of utility incentives

UESC Key Points

- A UESC can be any size
- A UESC can include a wide range of ECMs (depends on utility)
- UESCs may not be available to all facilities
- Utility may be new to this type of contracting
- Contract process and documents are not prescribed
- Agency's relationship with utility

Other Funding Options: Enhanced Use Lease (EUL)

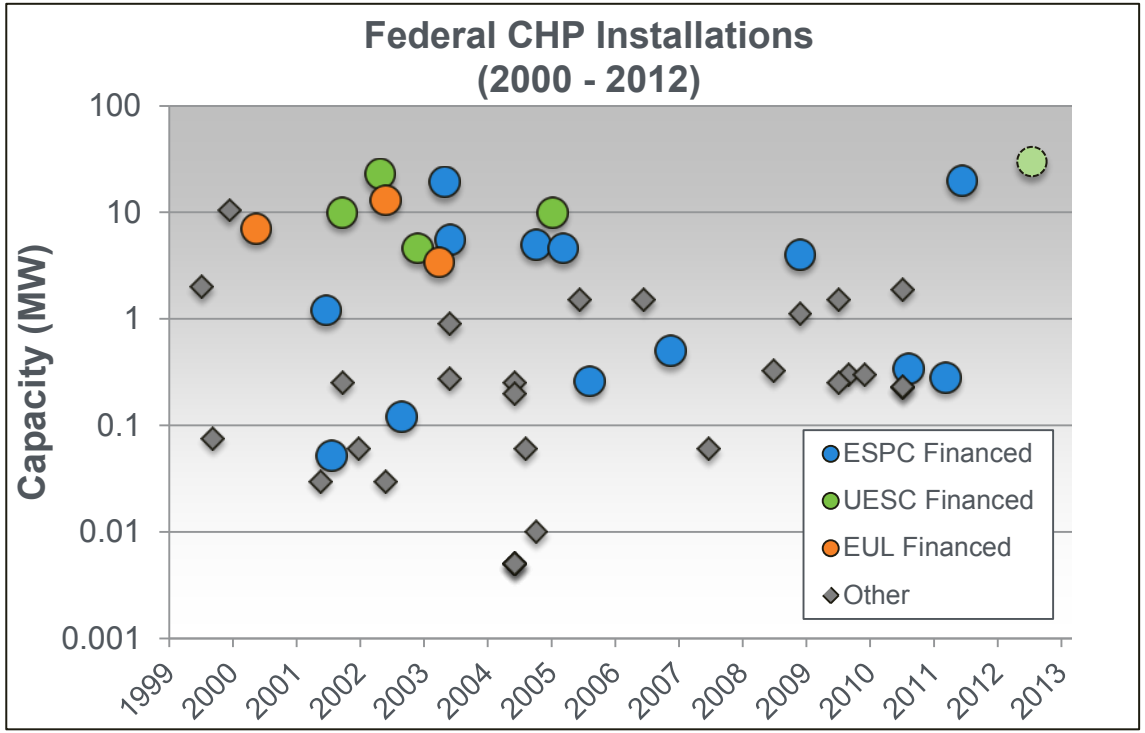
Under an EUL:

- a private developer leases underutilized property from the federal agency
- developer invests in equipment and improvements
- rent is paid by the developer in the form of in-kind services or cash
- A CHP based EUL might involve the lessee selling all or some of the power to the agency

Financing of CHP at Federal sites has been prevalent for several years and across a broad spectrum of system capacities.

Financing Vehicles utilized:

- **ESPC**
- **UESC**
- **EUL**



Case Studies
CHP and Financing Vehicles

Savannah River Biomass

CHP Technology

- (2) Biomass fueled fluidized bed steam boilers
- (1) 20MW Steam condensing turbine
- Biomass fuel: wood chips (forest residues)

Financing

- Energy Savings Performance Contract (ESPC)
- $795M contract /19 year performance term

Savannah River Biomass (*cont.*)

System Benefits

- Electric Capacity: 20MW
  (77MWh of "green" electricity generation)
- Thermal Capacity: 240,000 lb/hr of 850 psi steam
  (385 psi after turbine)
- Significant emissions reductions
  - 400 tons/yr particulate matter
  - 3,500 tons/yr SO2
  - 100,000 tons/yr of CO2
- 1,400,000 kgal/yr reduced water intake from the Savannah River

- **Contract value: $795M**
- **Annual Savings: $34.3M (energy and O&M)**

Veterans Administration: San Diego Medical Center

CHP Technology

- (1) 4.4MW Natural Gas Fired Turbine
- Heat Recovery Steam Generator (HRSG)
- Ultra lean premix combustion system (low NOx)
- 500 Ton Absorption Chiller

Financing

- Energy Savings Performance Contract (ESPC)
- $17M contract / 10 year performance term

4.4MW Solar Mercury 50 Turbine Generator

Veterans Administration: San Diego Medical Center (*cont.*)

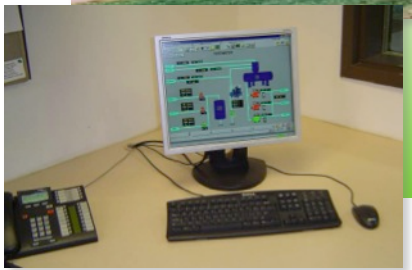
System Benefits

- Electric Capacity: 4.4MW (24MWh of electricity generation annually)
- Thermal Capacity: 11,000 lb/yr @ 130psig
- Ultra Low NOx emissions
  - Exceeds stringent air quality district emissions requirements
  - 40 tons/yr reduction

- **Estimated Annual Savings: $1.6M**

Jesse Brown VA Medical Center- Chicago, Illinois

- CHP Technology
  - 3.4 MW Natural Gas Turbine Generator
  - Heat Recovery Steam Generator
- Heat recovery applications
  - Building heat
  - Absorption cooling
  - Medical equipment sterilization
- Enhanced-Use Lease Financing



Jesse Brown VA Medical Center: CHP System Operation

- 24/7 Operation
- Load Following
- VA Hospital Purchases approximately 25 kilowatts from local utility (ComEd) when load following
- Supplies approximately 90% of entire electric demand
- Energy Independence
- Energy Reliability

Other FEMP case studies

FEMP Website: Project Funding

http://www1.eere.energy.gov/femp/financing/mechanisms.html

Video Case Studies

- Provides an overview of ESPC and UESC as financing vehicles
- Highlights deployment of CHP technologies within each contract type

FDA use of ESPC:

http://www1.eere.energy.gov/femp/financing/superespcs_fda.htmlvideo case studies

NIH use of UESC:

http://www1.eere.energy.gov/femp/financing/uescs_nih.html

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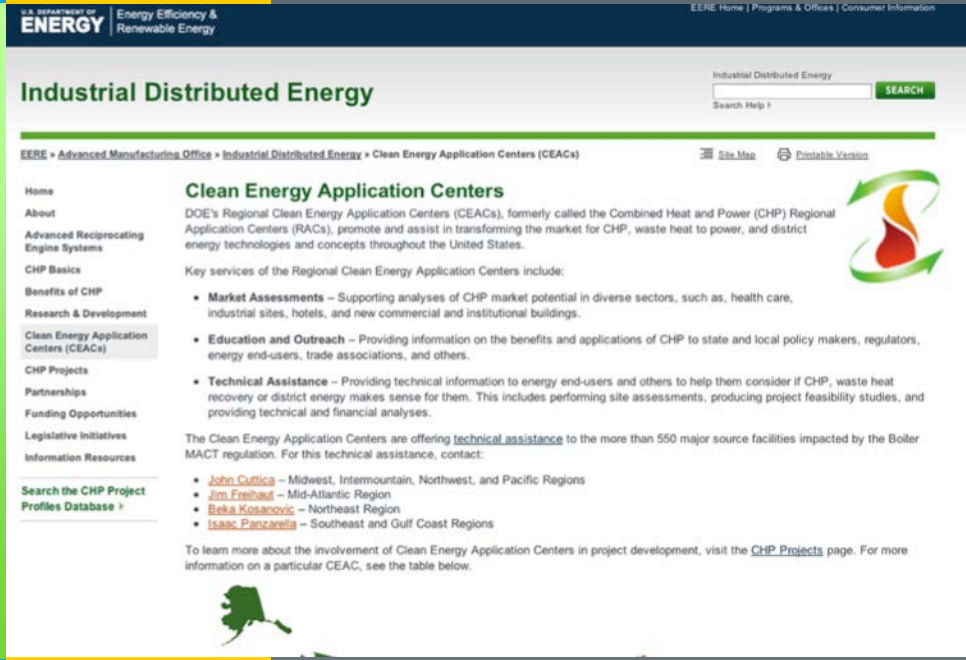
Resources for Pursuing CHP Projects



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Site Map | Printable Version

- Home
- About
- Advanced Reciprocating Engine Systems
- CHP Basics
- Benefits of CHP
- Research & Development
- Clean Energy Application Centers (CEACs)
- CHP Projects
- Partnerships
- Funding Opportunities
- Legislative Initiatives
- Information Resources

Search the CHP Project Profiles Database

Clean Energy Application Centers

DOE's Regional Clean Energy Application Centers (CEACs), formerly called the Combined Heat and Power (CHP) Regional Application Centers (RACs), promote and assist in transforming the market for CHP, waste heat to power, and district energy technologies and concepts throughout the United States.

Key services of the Regional Clean Energy Application Centers include:

- **Market Assessments** – Supporting analyses of CHP market potential in diverse sectors, such as, health care, industrial sites, hotels, and new commercial and institutional buildings.
- **Education and Outreach** – Providing information on the benefits and applications of CHP to state and local policy makers, regulators, energy end-users, trade associations, and others.
- **Technical Assistance** – Providing technical information to energy end-users and others to help them consider if CHP, waste heat recovery or district energy makes sense for them. This includes performing site assessments, producing project feasibility studies, and providing technical and financial analyses.

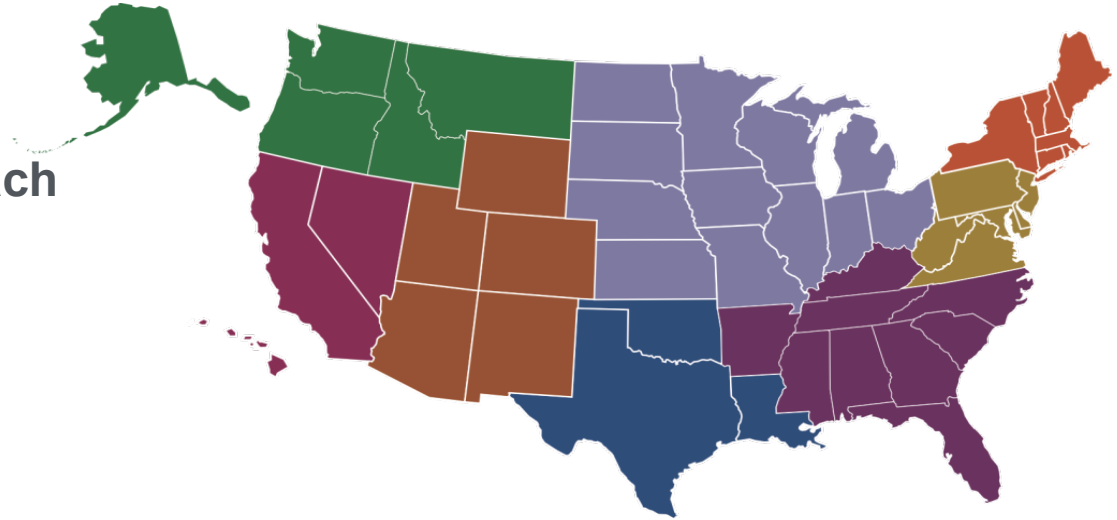
The Clean Energy Application Centers are offering technical assistance to the more than 550 major source facilities impacted by the Boiler MACT regulation. For this technical assistance, contact:

- John Cuttica – Midwest, Intermountain, Northwest, and Pacific Regions
- Jim Freihaut – Mid-Atlantic Region
- Beka Kosanovic – Northeast Region
- Isaac Panzarella – Southeast and Gulf Coast Regions

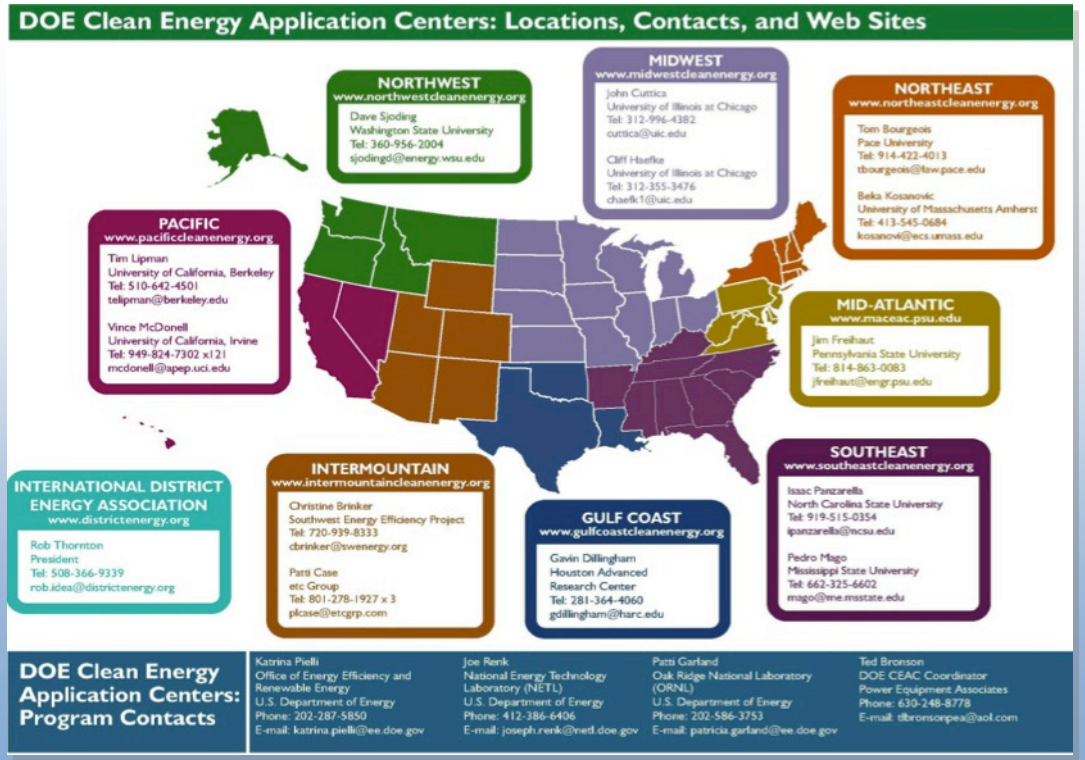
To learn more about the involvement of Clean Energy Application Centers in project development, visit the CHP Projects page. For more information on a particular CEAC, see the table below.

DOE CHP Assistance: Regional Clean Energy Application Centers (CEACs)

- Market Assessments
- Education and Outreach
- Technical Assistance



http://www1.eere.energy.gov/manufacturing/distributedenergy/ceacs.html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Combined Heat and Power Partnership

http://www.epa.gov/chp/

FEMP Resources

For Project Funding

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