Federal Utility Partnership Working Group
Spring 2013 – May 22-23
San Francisco, CA

Combined Heat & Power

Technology Overview and Federal Sector Deployment

Bob Slattery
Oak Ridge National Laboratory

Hosted by: Pacific Gas and Electric Company

Combined Heat and Power

Definition and Concept

What Is Combined Heat and Power?

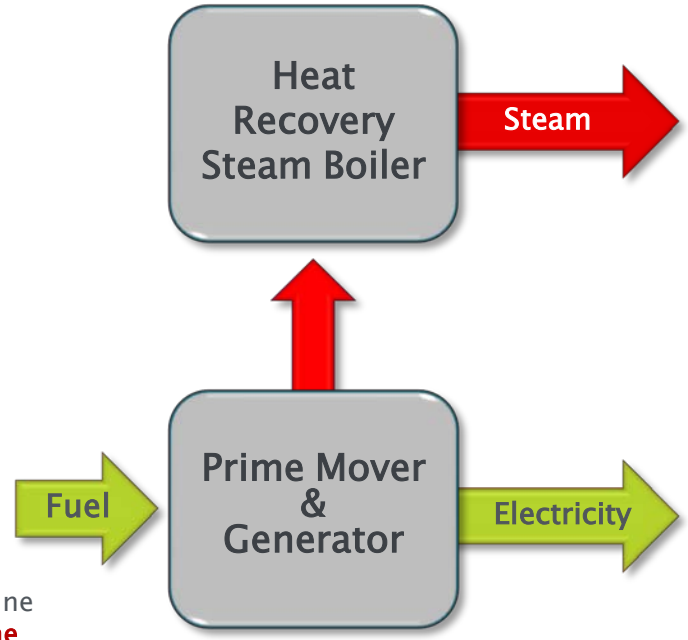
CHP is an ***integrated energy system*** that:

- 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

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

Defining Combined Heat and Power (CHP)

Conventional CHP
(also referred to as Topping Cycled CHP or Direct Fired CHP)



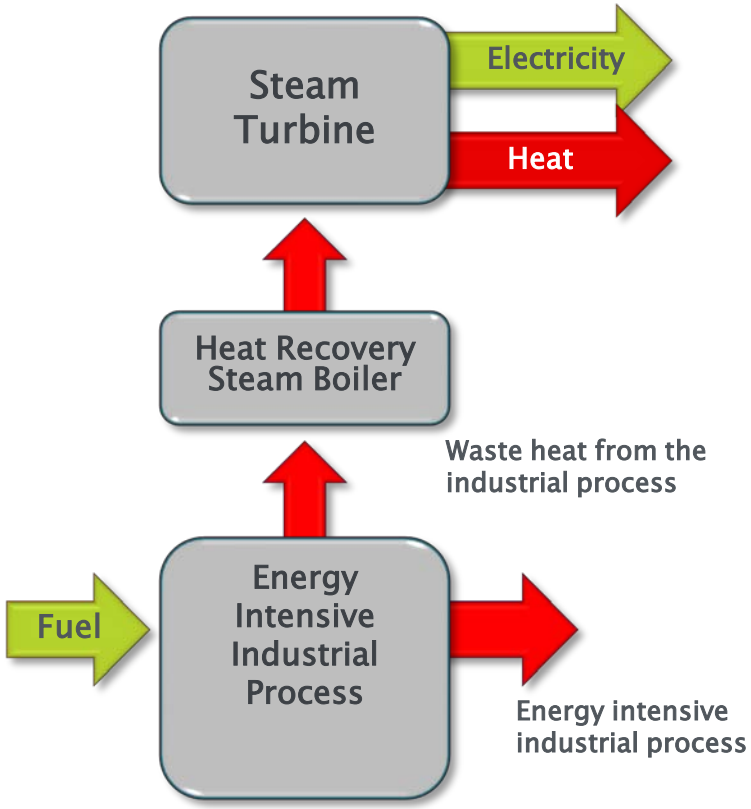
Recip. Engine
Gas Turbine
Micro-turbine
Fuel Cell
Boiler/Steam Turbine

- 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

Source: Midwest Clean Energy Application Center

Defining Combined Heat and Power (CHP)

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


Industrial


Institutional


Residential


Utility Scale


Commercial

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

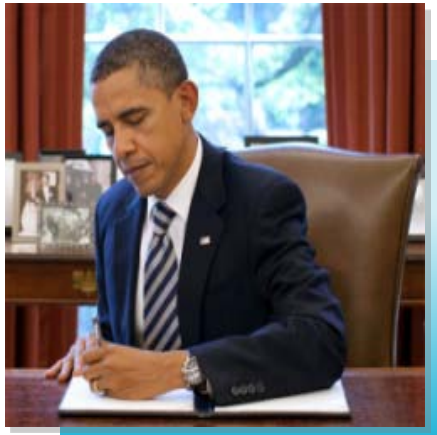
Regulatory Drivers for CHP

Federal Drivers

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

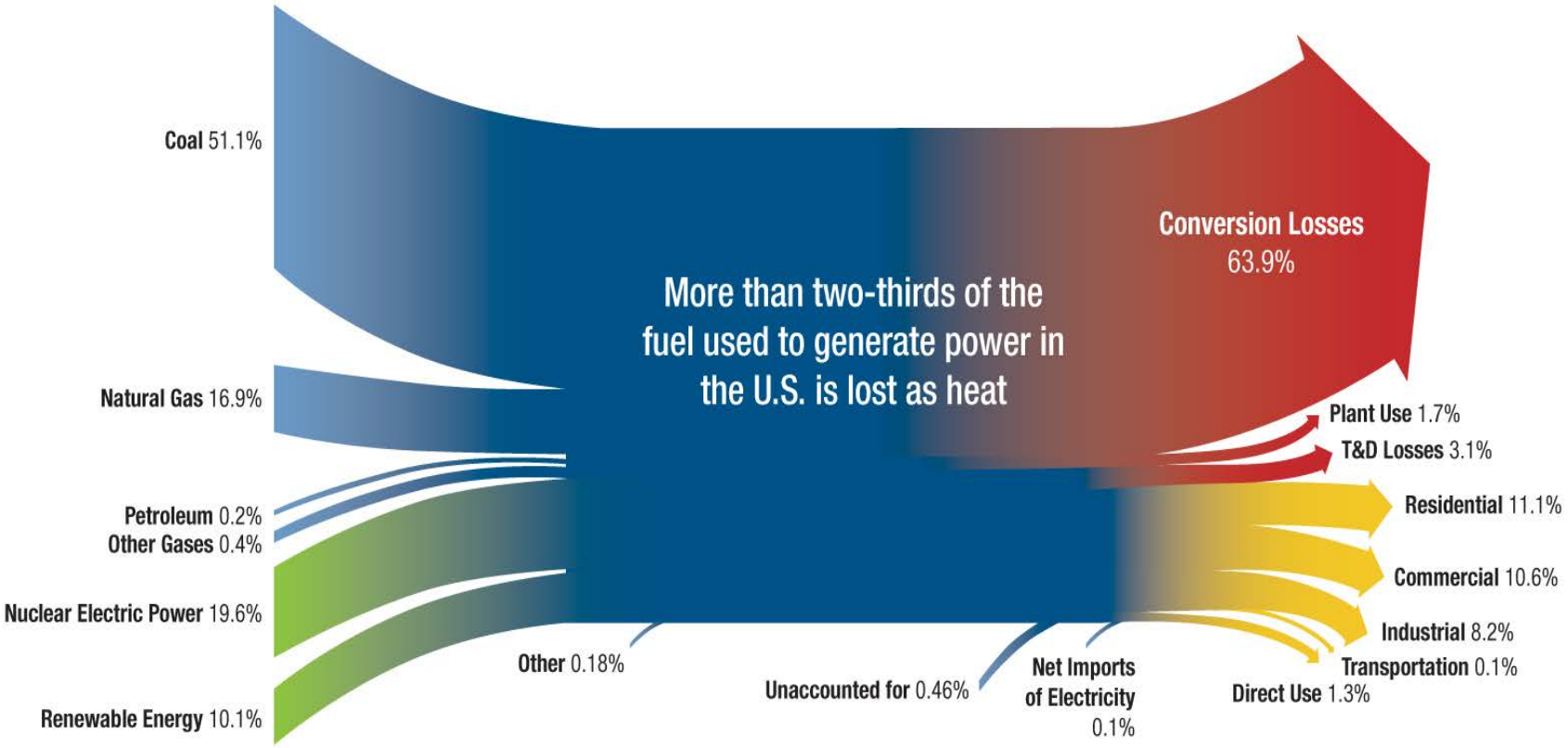
Also:

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

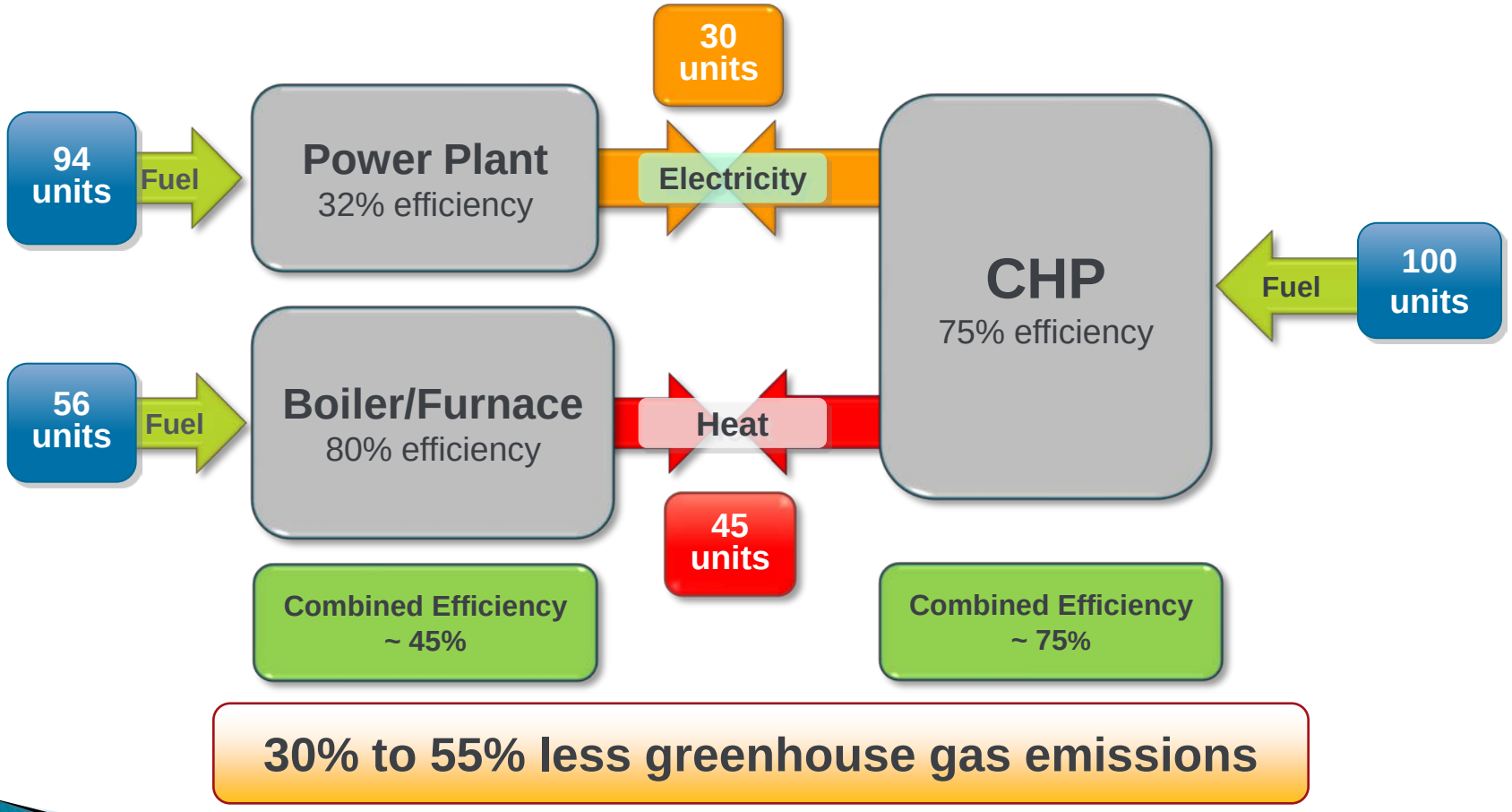


Recognizing the benefits of CHP and its current underutilization as an energy resource in the United States, the Obama Administration is supporting a new National goal to achieve 40 gigawatts (GW) of new, cost-effective CHP by 2020

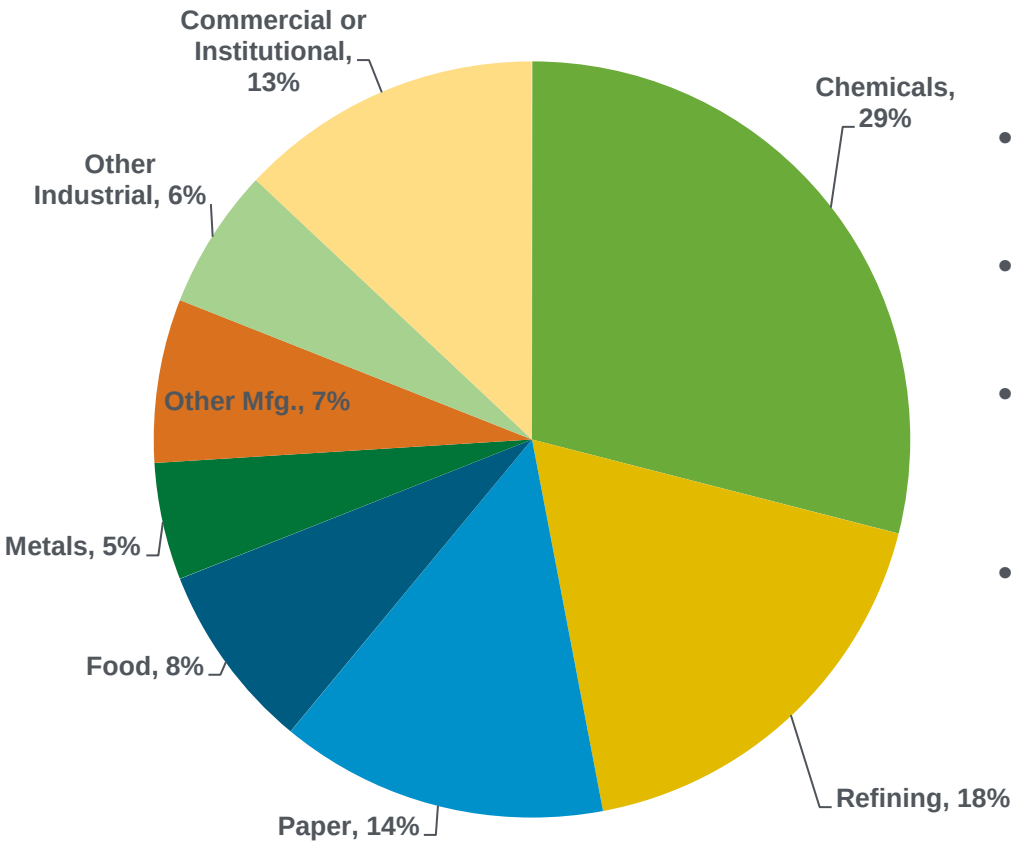
Over Two-Thirds of the Fuel Used to Generate Power in the U.S. Is Lost as Heat



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



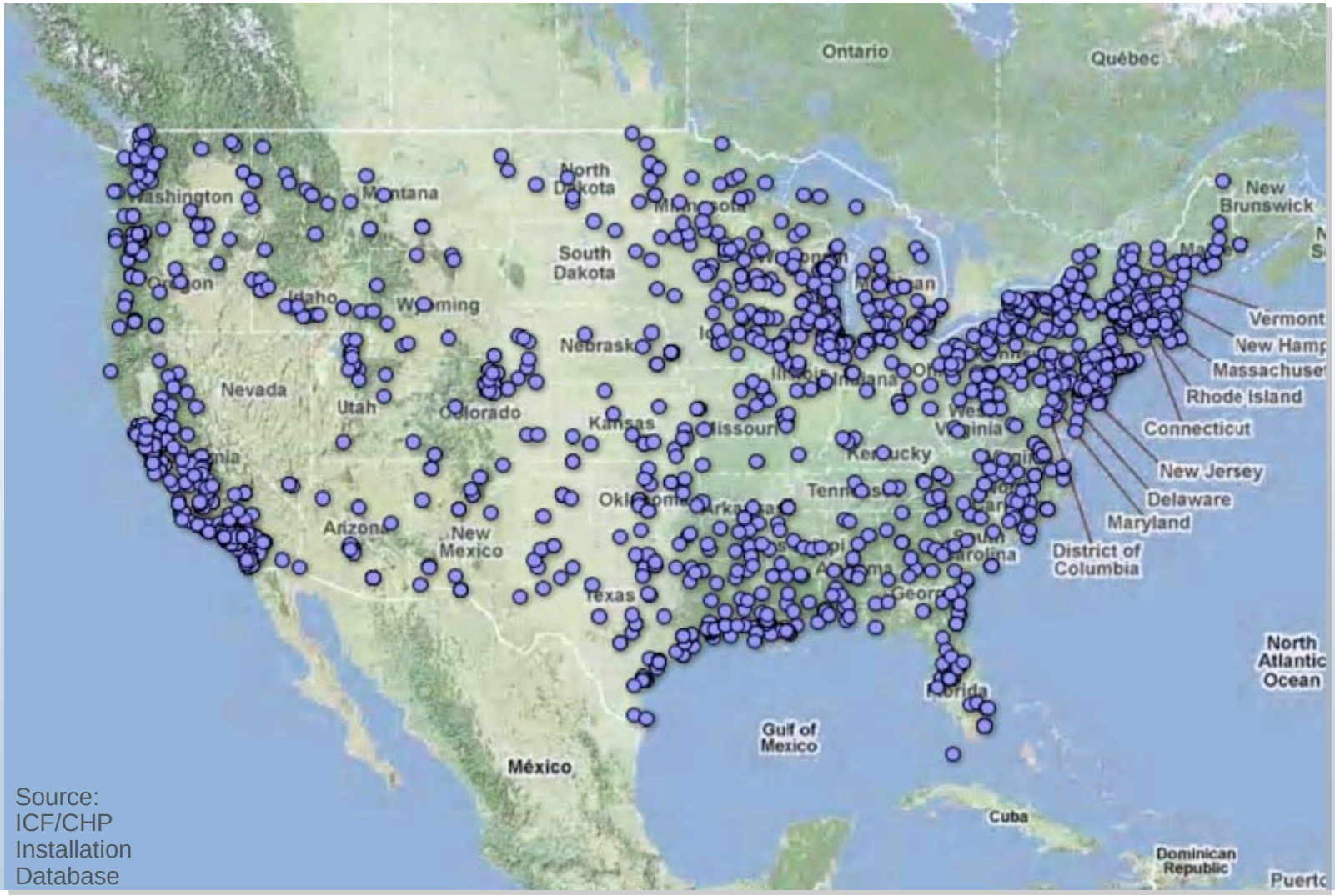
CHP Is Already an Important Natural Resource



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

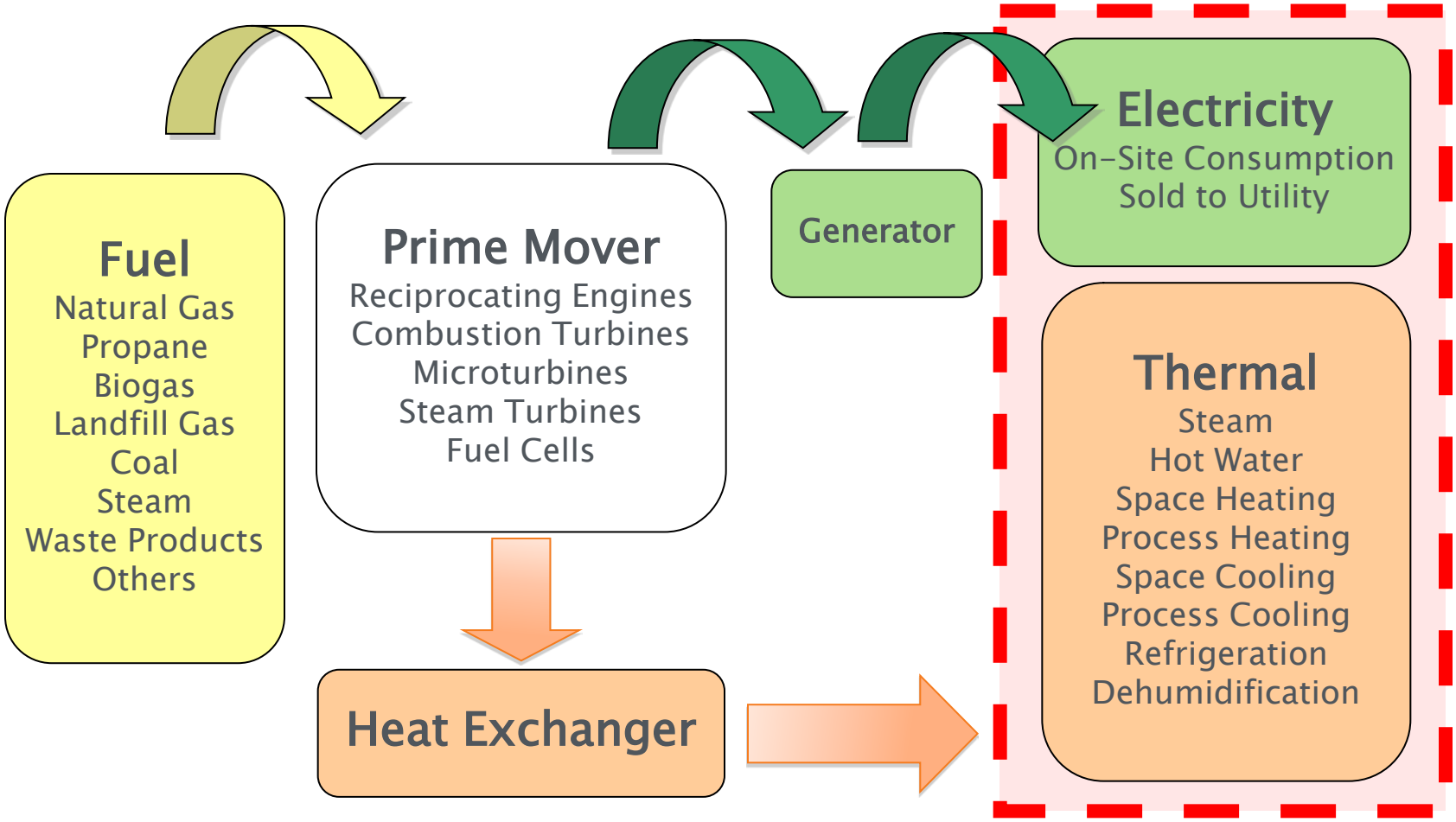


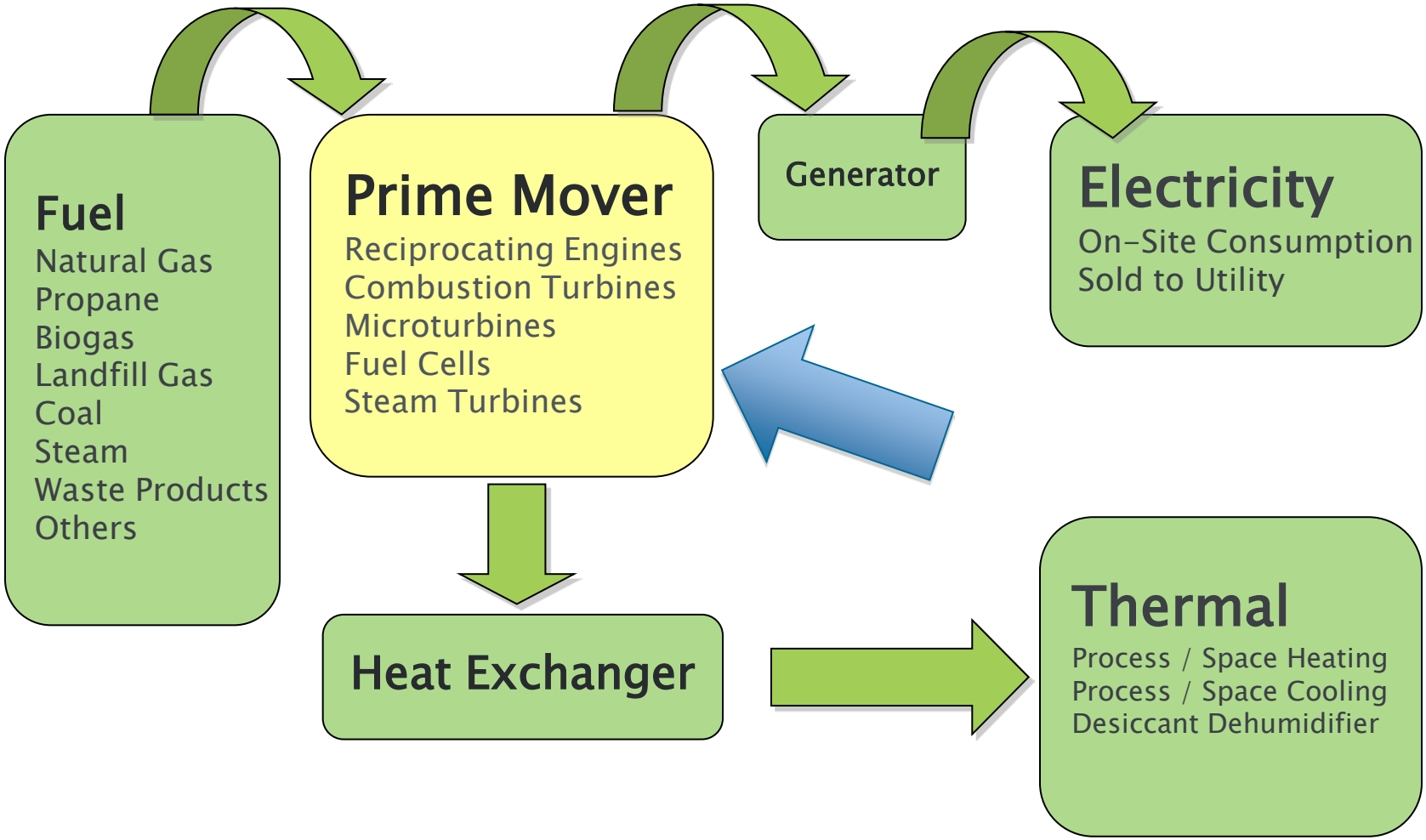
Source:
ICF/CHP
Installation
Database

Combined Heat and Power

Technologies

Topping Cycle

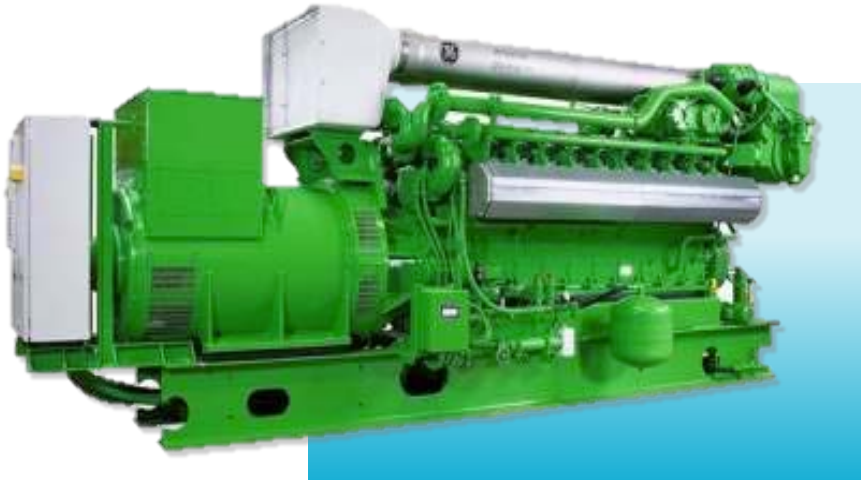



Fuel
Natural Gas
Propane
Biogas
Landfill Gas
Coal
Steam
Waste Products
Others
Prime Mover
Reciprocating Engines
Combustion Turbines
Microturbines
Fuel Cells
Steam Turbines
Generator
Electricity
On-Site Consumption
Sold to Utility
Heat Exchanger
Thermal
Process / Space Heating
Process / Space Cooling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

Prime Mover

Reciprocating Engines

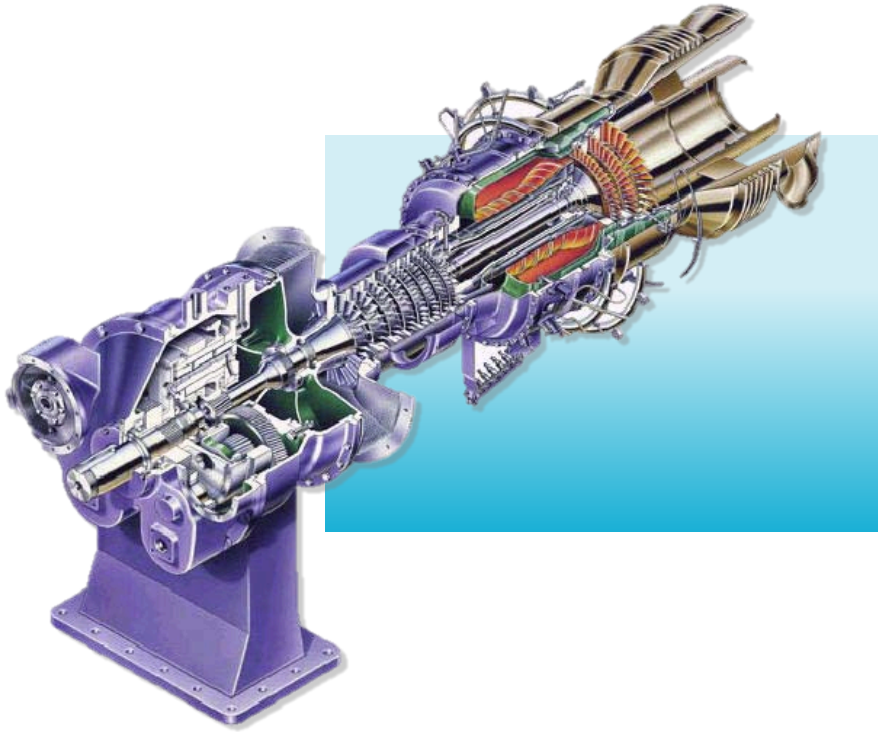
- 5 kW – 10 MW
- Excellent part-load operation
- Waste heat recovered from engine exhaust, engine jacket and oil coolant
- Low set-up cost, fast start-up
- Emissions signature has improved significantly
  - Lean-burn engines
  - Selective catalytic reduction (SCR)



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

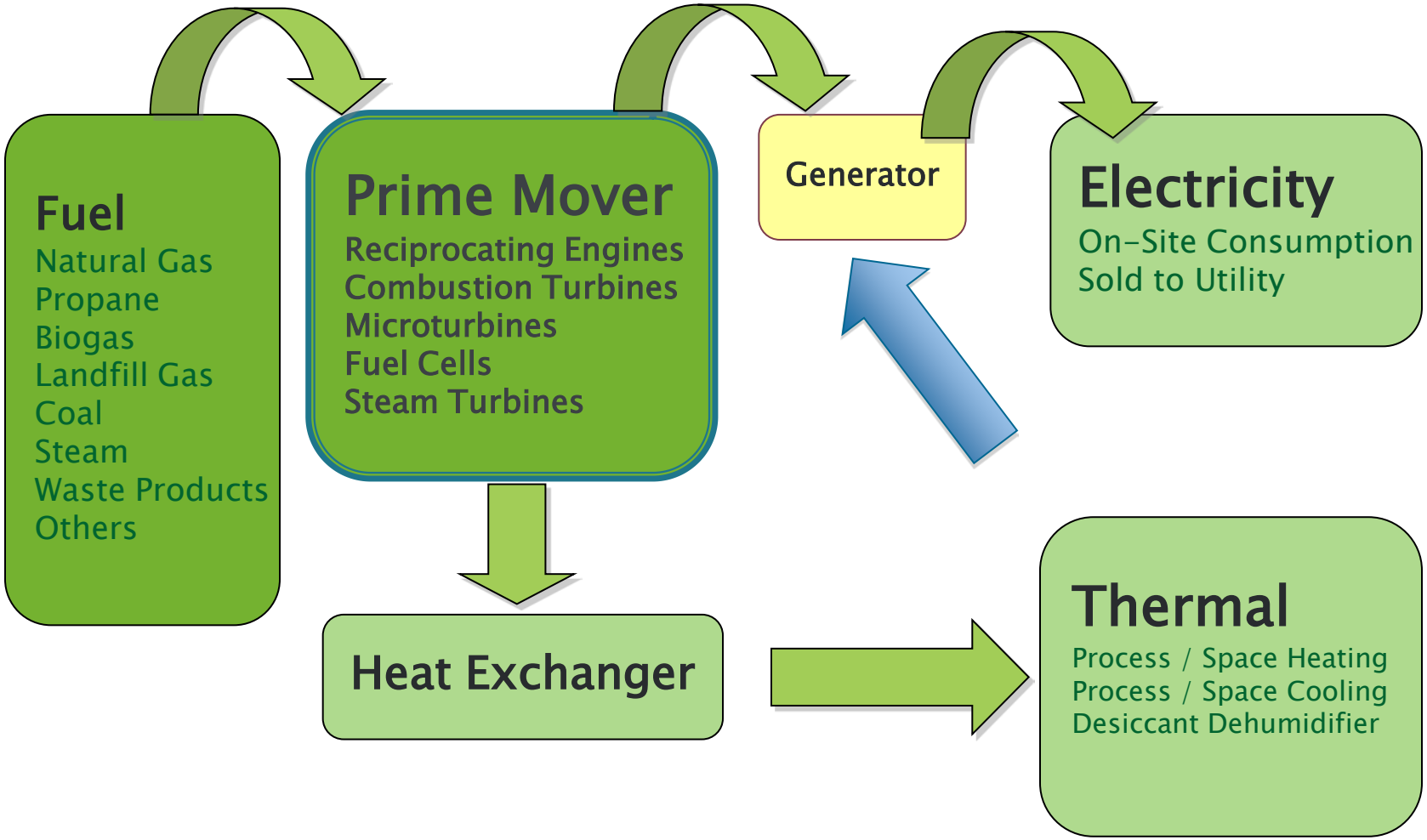
- Small turbines with recuperation
- 25 kW to 500 kW
- Efficiency range: 25% to 30% LHV
- Recoverable heat: gas exhaust @ approx. 500^{o}F
- Fuel flexible
- Low emissions <0.49lbs/MWh or 9ppm

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


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

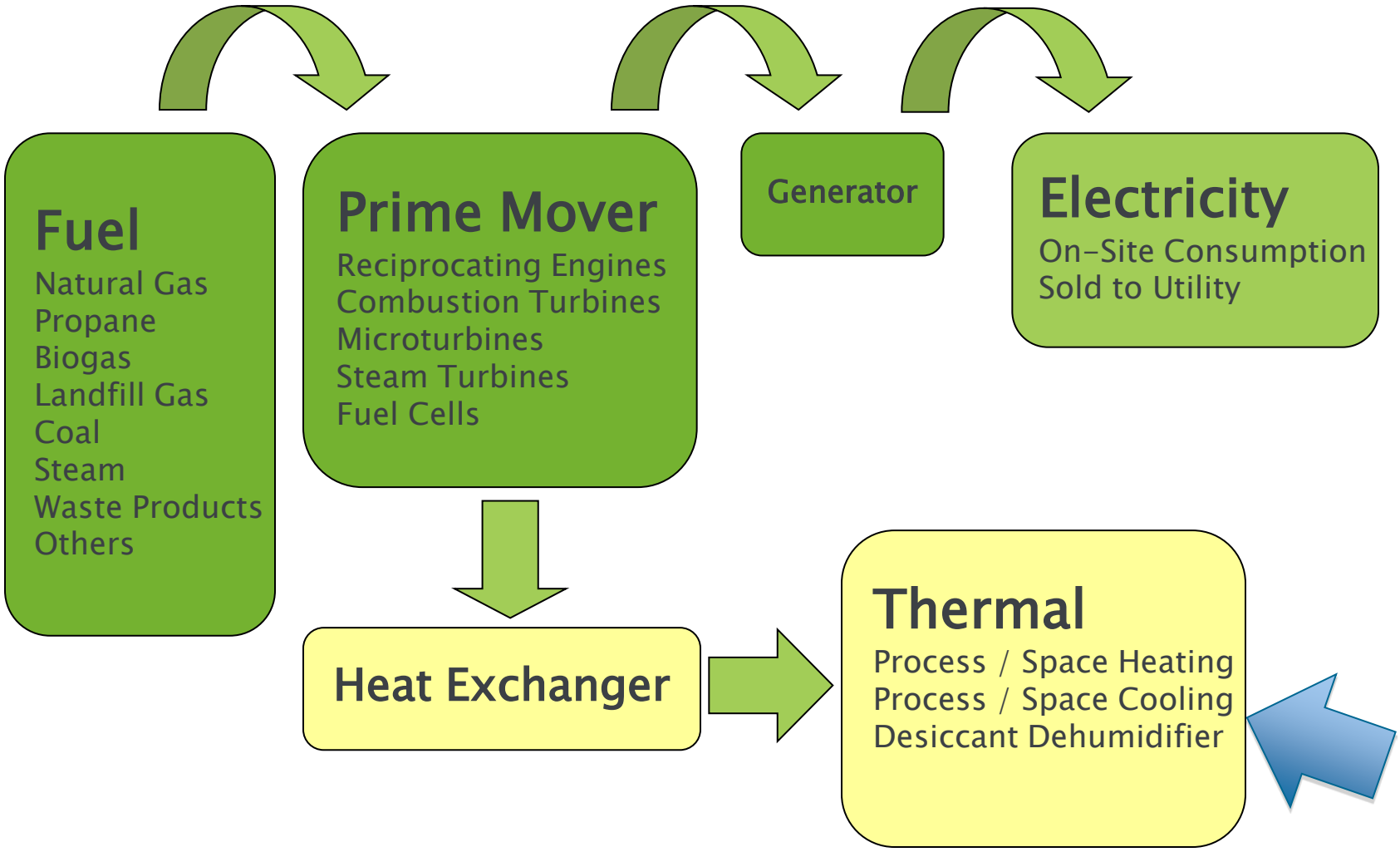
Two Types of Generators

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


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

Heat Capture: Converting Heat into Work

Heat Exchangers

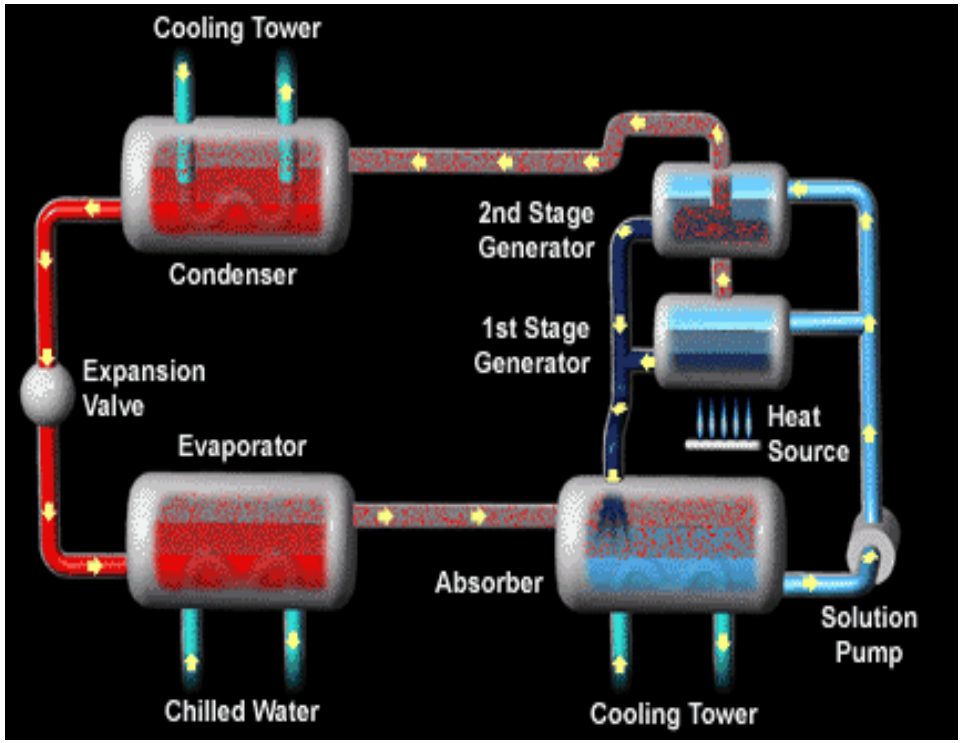
- Recover exhaust gas generated by:
  - Gas turbine
  - Industrial processes
- Transfers exhaust gas into useful heat (e.g., steam) for downstream applications
- Heat recovery steam generator (HRSG) the most common

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

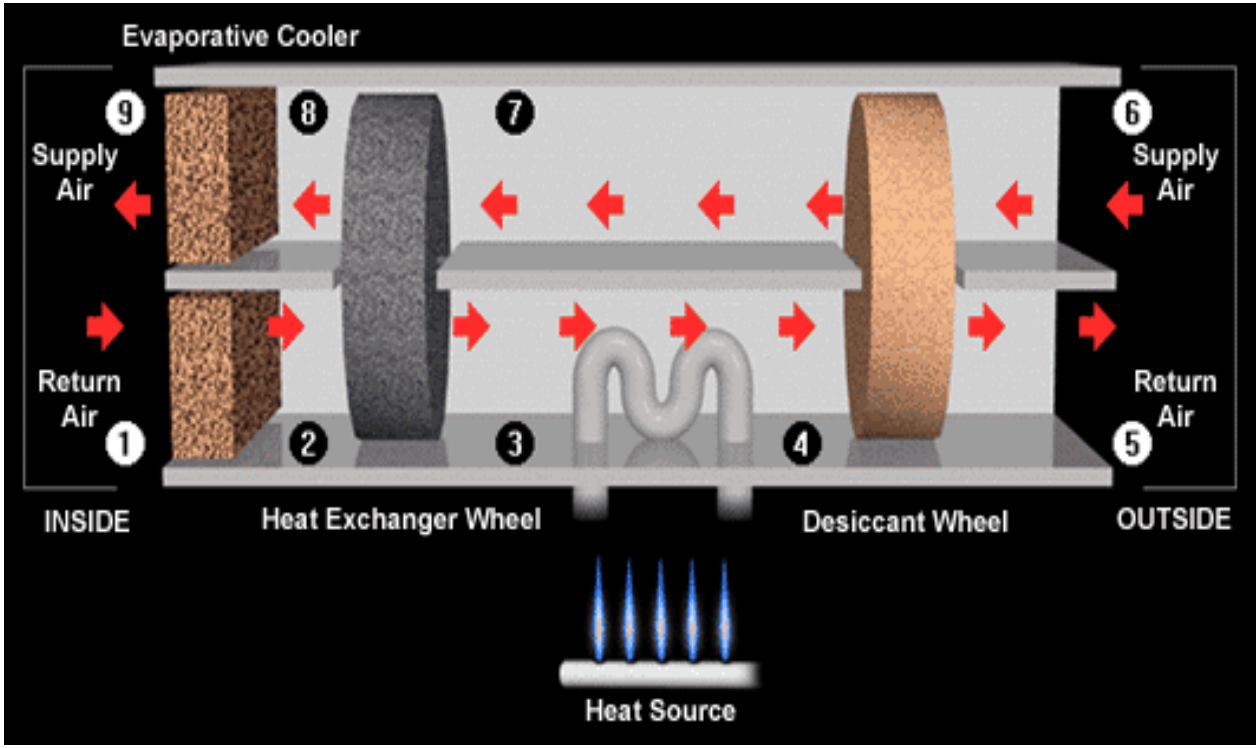
Use exhaust gas, hot water, or steam via thermal compressor to boil water vapor out of lithium bromide/ water solution and compress refrigerant to higher pressure; avoids CFCs/HCFCs

Range: 10-3,000 tons

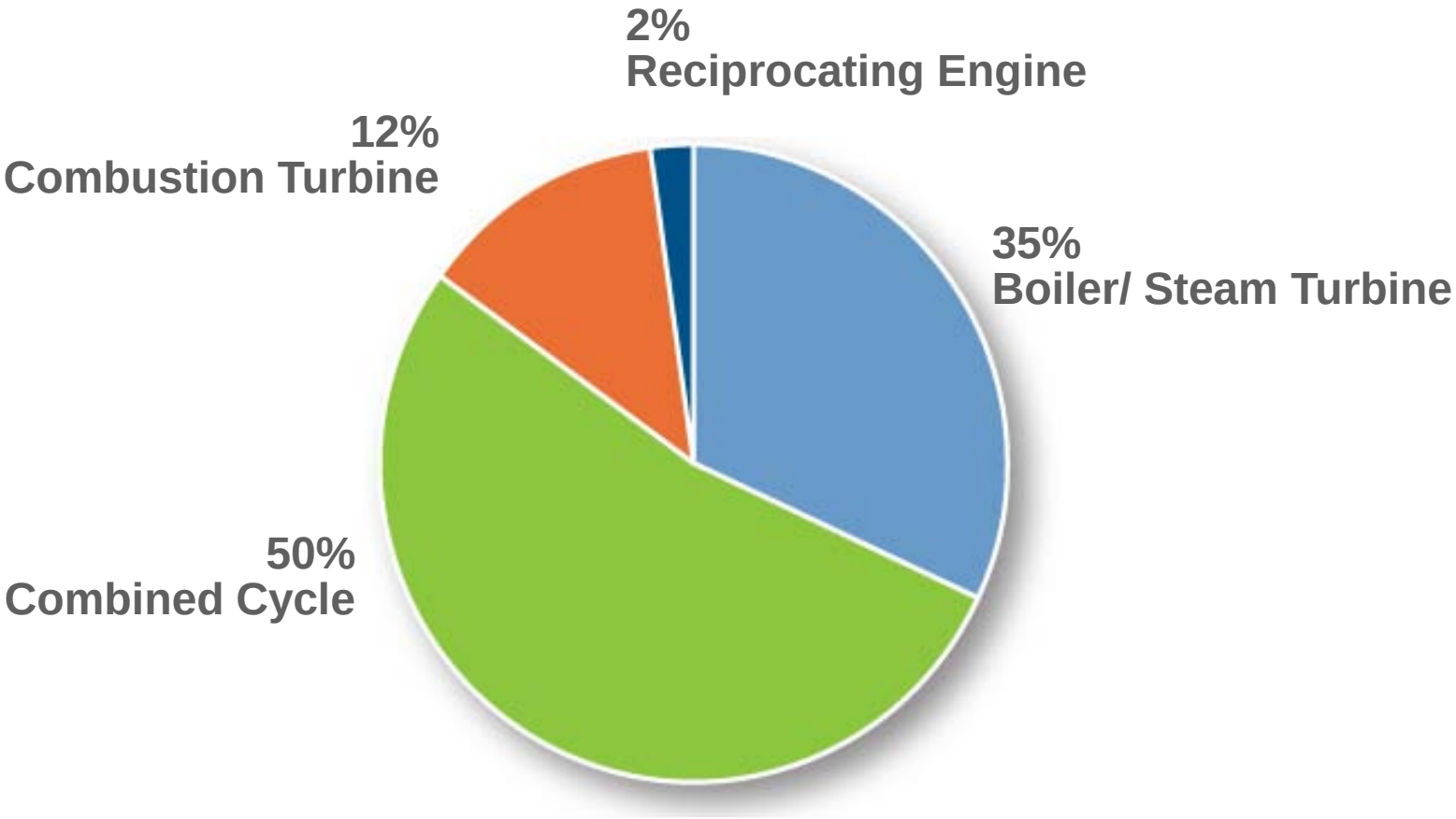
Heat Capture: Converting Heat into Work

Desiccant Dehumidifiers

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



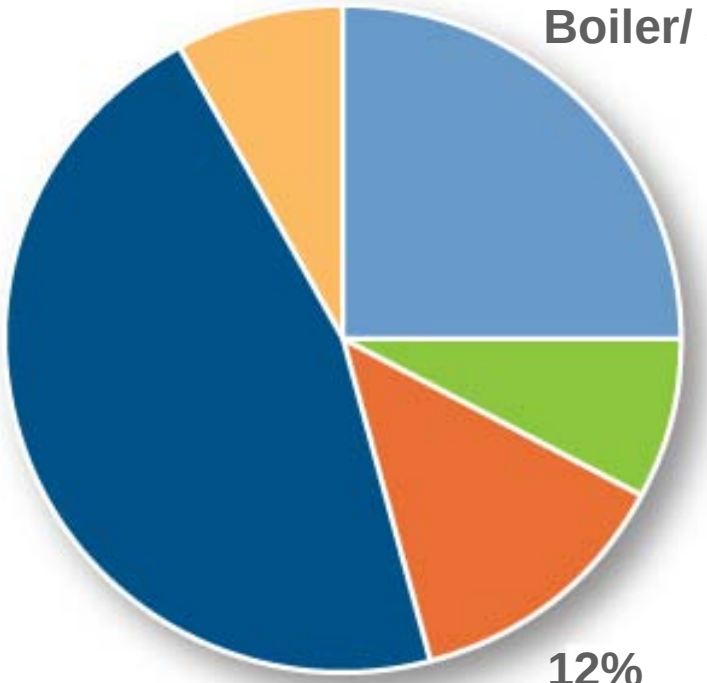
Existing CHP Capacity by Technology – 82 GW



Source: ICF/CHP Installation Database

CHP Technologies by Site

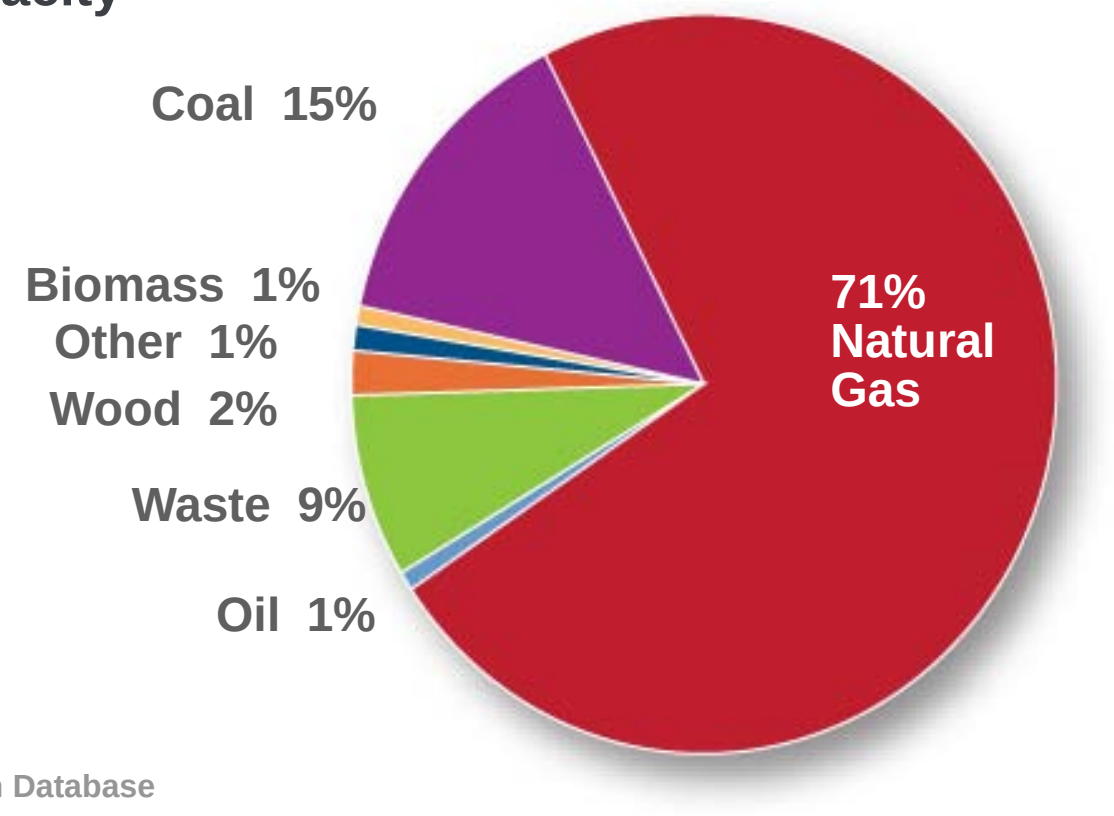
Existing CHP Sites by Technology



Source: ICF/CHP Installation Database

Natural Gas is the Dominant Fuel for Existing CHP

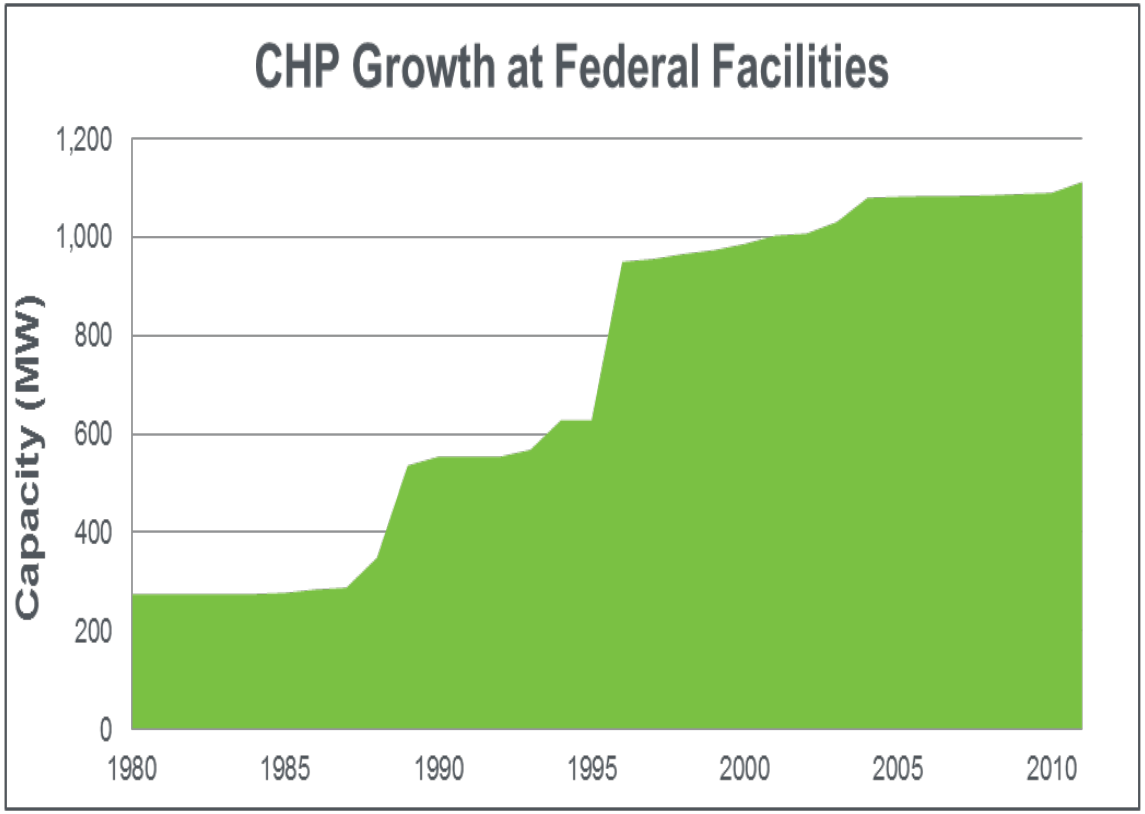
Existing CHP Capacity by Fuel – 82 GW



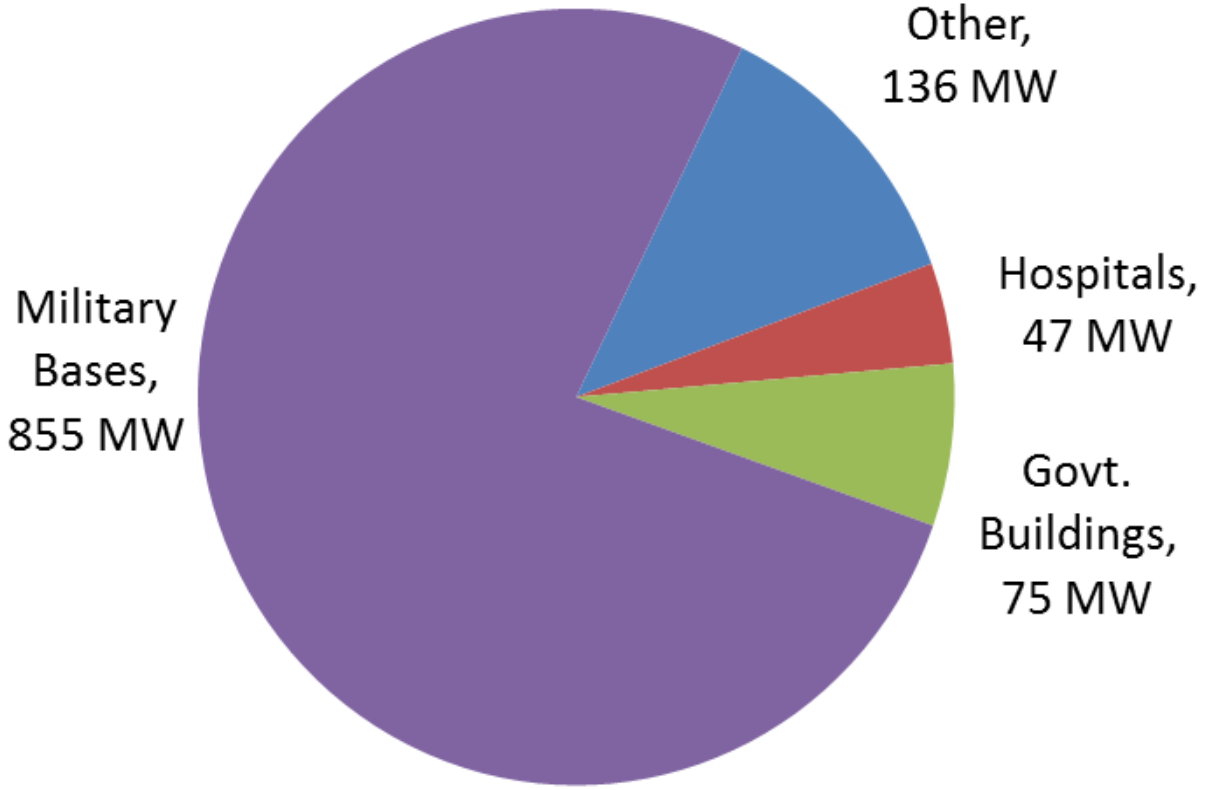
Source: ICF/CHP Installation Database

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)

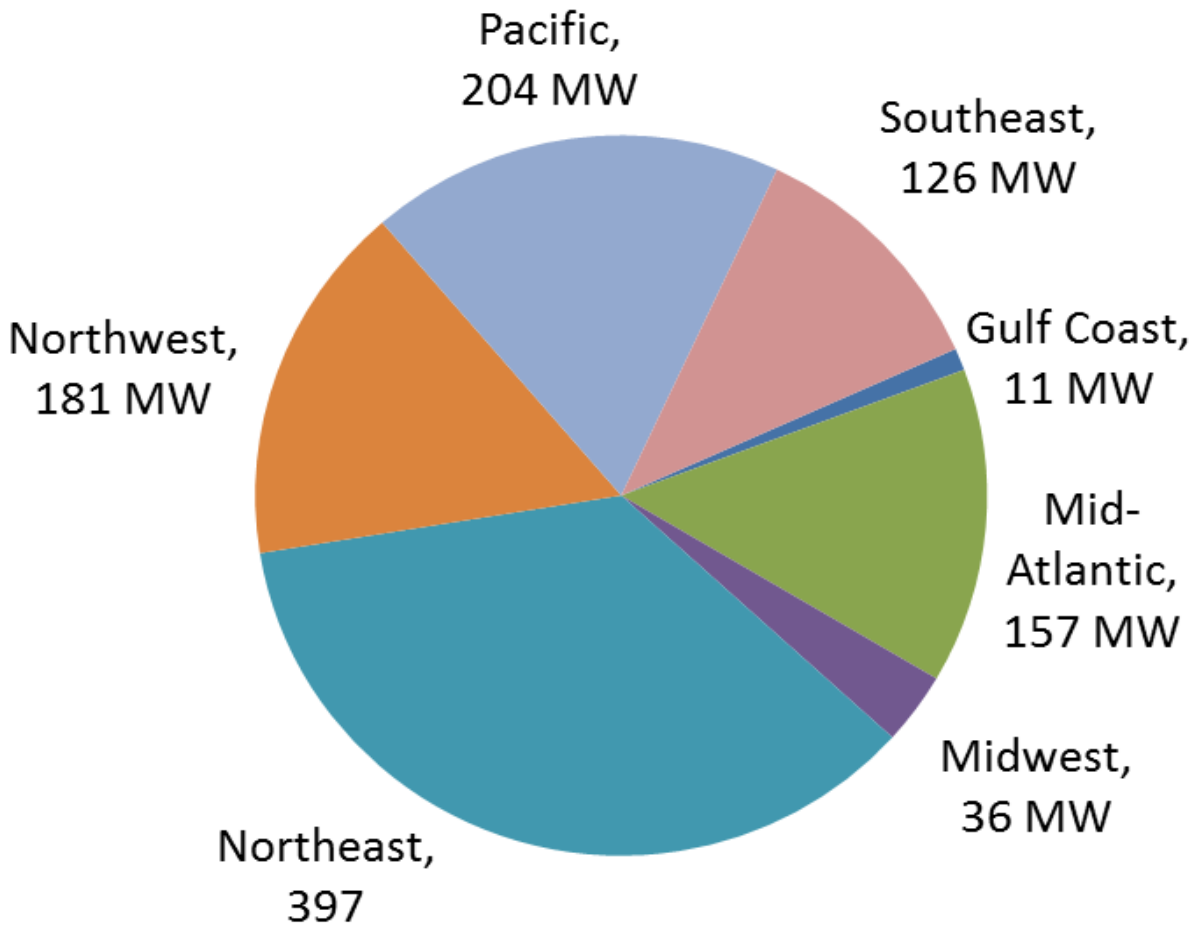


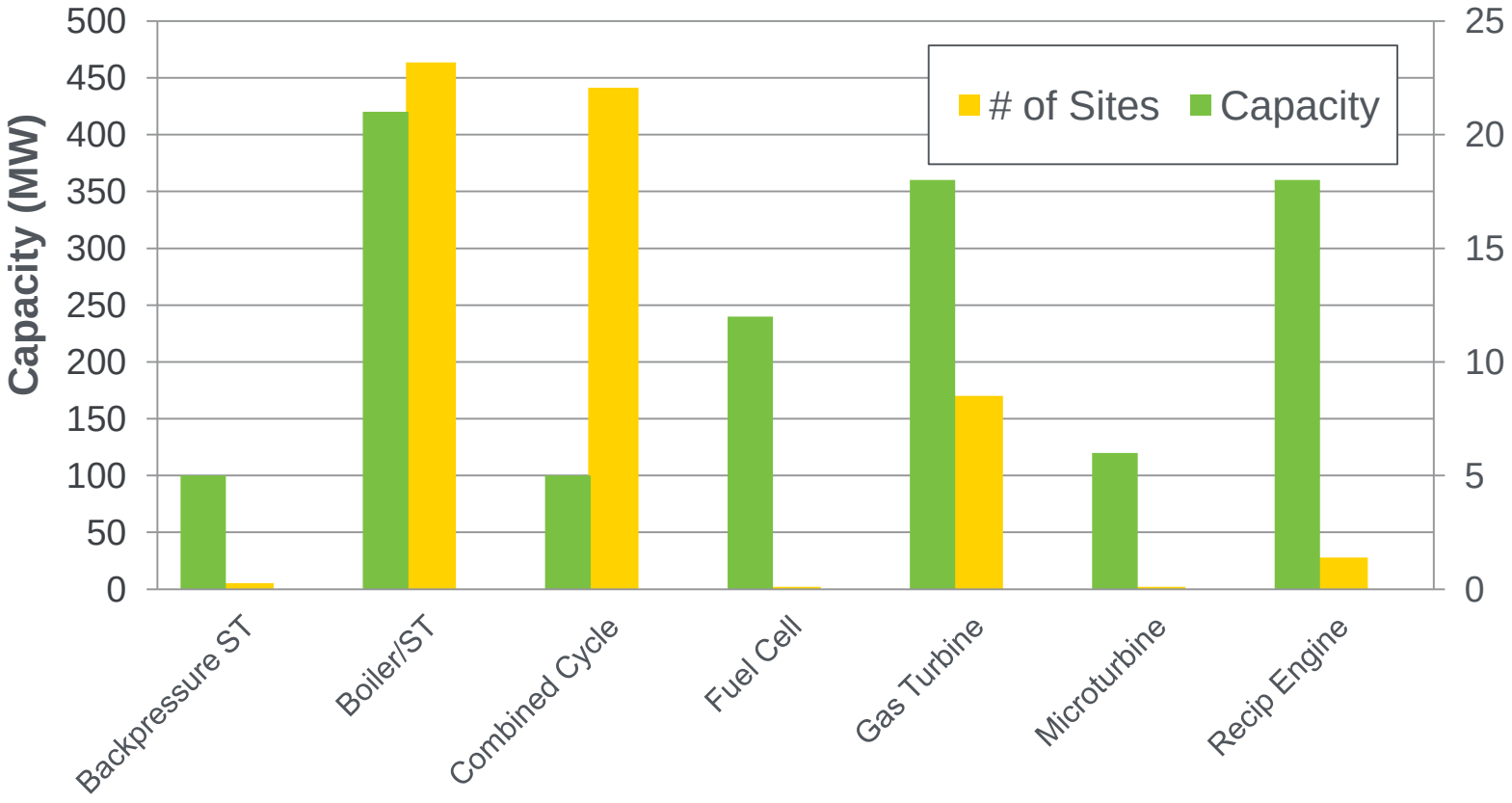
CHP in Federal Facilities by Application Type



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

Federal Facilities with CHP by Region

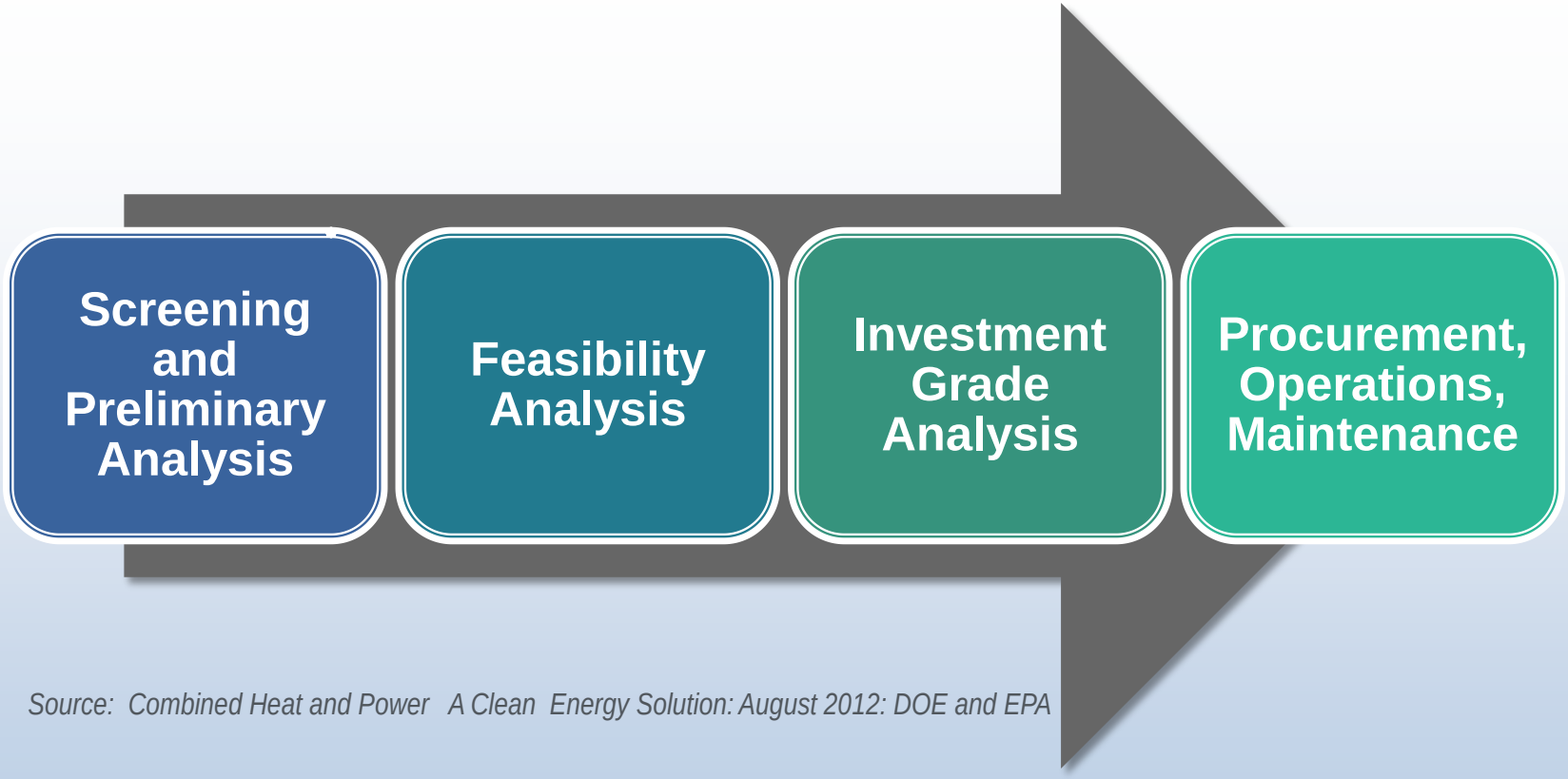




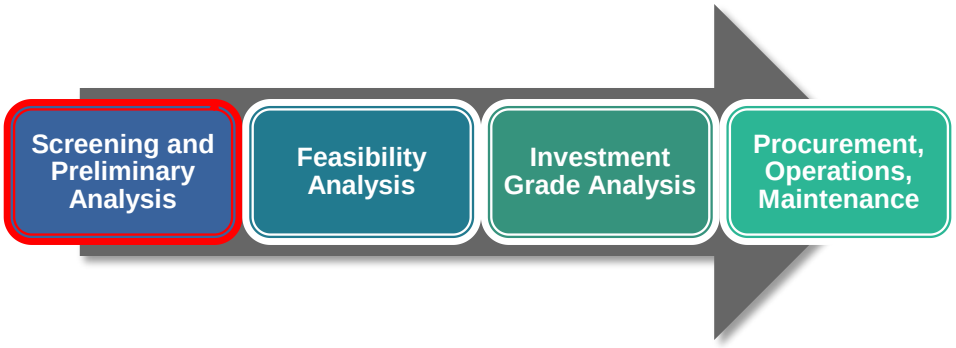
CHP in Federal Facility by Prime Mover Technology

CHP Project
Implementation

CHP Project Process



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



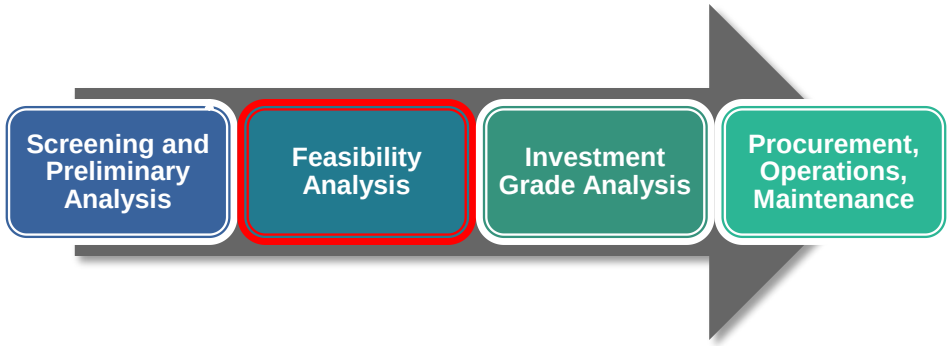
Screening Questions

- Do you pay more than $.06/kWh on average for electricity (including generation, transmission and distribution)?
- 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.)
- 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?
- Have you already implemented energy efficiency measures and still have high energy costs?
- Do you have access to on-site or nearby biomass resources? (i.e., landfill gas, farm manure, food processing waste, etc.)

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

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



Feasibility Analysis

A Feasibility Analysis typically involves

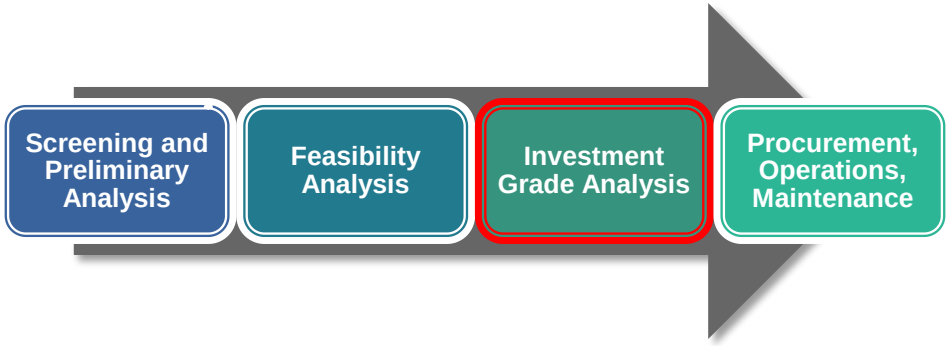
- Electrical load profiling
- Thermal load profiling
- New utility rate structure analysis
- Utility interconnection requirements
- Permitting Impacts
- Unit sizing
- Thermal use determination (what to do with the heat)
- Installation cost estimations
- Financing Options
- Analysis of ownership structure

Utility Partnership Considerations

Permitting, Tariffs, Rate Impacts

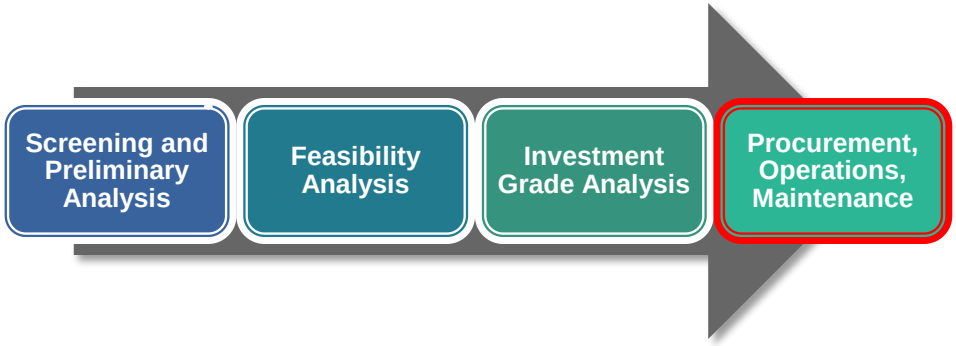
- Identify the state and local requirements for permitting a CHP plant early in the planning process.

- 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



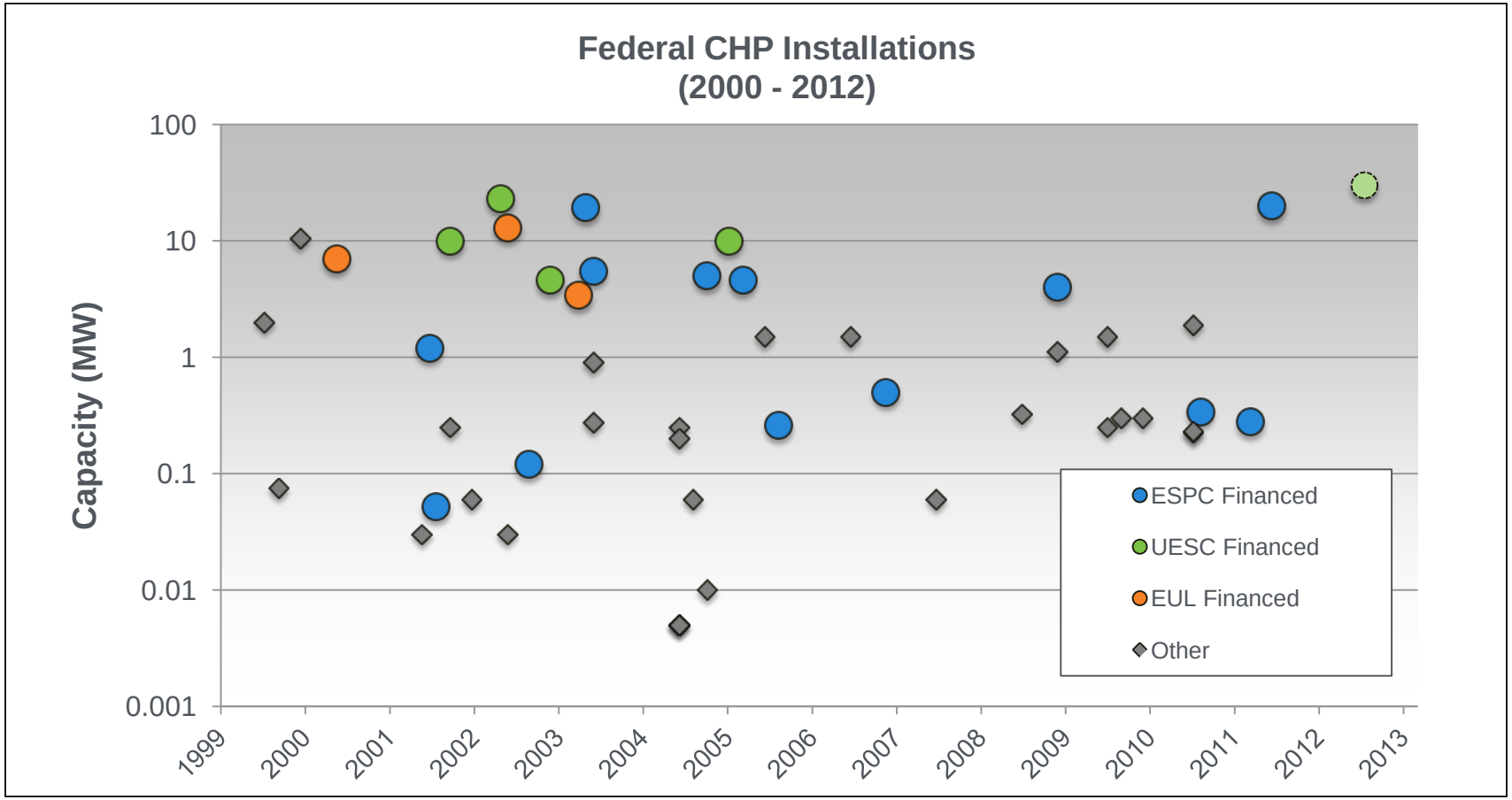
Procurement, O&M

- Project financing
- 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

Utility Energy Service Contracts

Financing of CHP at Federal Sites



Financing Vehicles utilized:

- Energy Savings Performance Contracts (ESPC)
- Utility Energy Savings Contracts (UESC)
- Enhanced Use Lease (EUL)

Federal CHP Implementation Under UESC

National Institute of Health (Bethesda, MD)
- 23MW Natural Gas Fired Turbine + Heat Recovery Steam Generator (HRSG) + Dual Fuel Aux. Duct Burner

General Services Administration/Smithsonian (Washington, D.C.)
- 10MW, Natural Gas Fired Turbines + HRSG + Absorption Chillers

Navy/NAVMEDCEN (San Diego, CA)
- 4.6MW Natural Gas Fired Turbine + HRSG

Navy/Naval Station Great Lakes (Great Lakes, IL)
- 11MW, Dual Fuel (Natural Gas/Fuel Oil) Turbines + HRSGs

Pending: GSA/DHS St. Elizabeth's Campus *(Washington, D.C.)*
- *20-25MW Natural Gas Fired Turbine (30% of site's electricity needs)*
- *Steam: HRSG (Building Heat/Hot Water + Absorption Chillers)*

CHP/UESC Case Study
National Institutes of Health

NIH UESC CHP Project Overview

Site Overview

- Bethesda, Maryland
- Medical Research and Hospital.
- 75 Buildings
  - Laboratories
  - Research hospital rooms
  - Teaching facilities
  - Offices
- 9 Million sq.ft. on 300 Acres
- 15,000 Employees

Project Goals

Over 1 M sq.ft. campus expansion

- Add new steam capacity required to meet master plan

Air Quality

- close proximity to neighborhoods

Efficiency Improvement

- Existing NIH Central Plant
  - 5 Dual Fired Boiler Units
    - 800,000 pph Steam
  - 60,000 Tons Chiller Capacity
    - Steam Driven Auxiliary Capable

NIH engaged with their local utility's energy service group to develop a project under a UESC

NIH CHP Project Solutions

23MW Natural Gas Fired Turbine
- Inlet Air Cooling System (improves turbine efficiency)

Heat Recovery Steam Generator (HRSG)
- 100,000 pph Steam @165 psig

Auxiliary Duct Burner
- Dual Fuel
- 80,000 pph Steam

Emissions Control
- AEV Combustion System (dry-NOx burner system)
- Continuous Emissions Monitoring System

Implemented through a Utility Energy Services Contract (UESC)
- Guaranteed performance
- Utility to Operate and Maintain CHP (10 Year term)
- 3rd Party Financed (15 Year financed term)
- Total Project Cost: $38M
- Energy Savings pay for project over the financed term

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

Questions

Bob Slattery

Oak Ridge National Laboratory

slatteryrs@ornl.gov