Track: The Power Connection: Electric Generation for Gas Utilities

Unit #6: Integration of Natural Gas & Electric Generation

Presentation Outline

- Distributed Generation & Cogeneration Facilities
- Case Studies
- Future Opportunities
- Source to Site Energy Efficiency

Distributed Generation & Cogeneration Facilities

Distributed Generation & Cogeneration

Distributed Generation – *"…technologies that generate electricity at or near where it will be used, such as solar panels and combined heat and power."* – EPA

- Includes many different technologies

Cogeneration (aka: Cogen, Combined Heat and Power, or CHP) – *"The concurrent production of electricity or mechanical power and useful thermal energy (heating and/or cooling) from a single source of energy."* – DOE

- An example of a distributed generation technology.

https://www.epa.gov/energy/distributed-generation-electricity-and-its-environmental-impacts
https://www.energy.gov/eere/iedo/combined-heat-and-power-basics

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Distributed Generation

Centralized Generation is the traditional grid architecture that utilizes a few large-scale generating facilities, sometimes in remote locations, to power a grid optimized for long-distance transmission.

Distributed Generation puts electricity generation at or near the location where it will be used. Term tends to define a plentiful and diverse mix of large- and small-scale producers *distributed* across the grid and, thus, closer to users rather than just a few utility-scale plants.

Benefits are reduced transmission infrastructure and losses, backup power capabilities, and the grid security decentralized resources have. Distributed generation can also support the creation of small businesses and public engagement with energy production and use.

Drawbacks can include a footprint in areas where space is a premium, use of local resources (water for steam, for instance), aesthetic concerns, and, if the distributed generation technology is combustion based, bringing pollution into a populated area.

https://www.epa.gov/energy/distributed-generation-electricity-and-its-environmental-impacts
https://www.energy.gov/eere/iedo/combined-heat-and-power-basics

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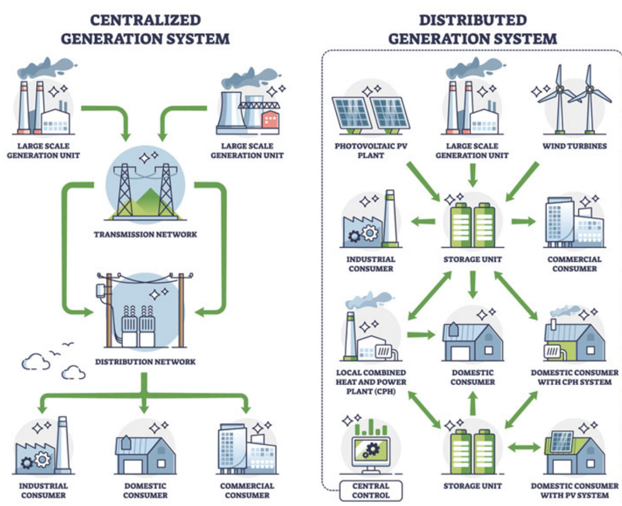
Distributed Generation



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Distributed Generation

Distributed Generation examples are:
- Solar generation
- Wind generation
- Cogeneration (CHP)
- Biomass or solid waste incineration
- Emergency backup generators

A solar installation on a warehouse roof can both serve the warehouse and nearby customers. Electricity doesn't need to travel far.

A university may operate its own cogeneration plant to help both heat and power its campus.

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https://www.epa.gov/energy/distributed-generation-electricity-and-its-environmental-impacts
https://www.energy.gov/eere/iedo/combined-heat-and-power-basics

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Cogeneration

Electricity generation from the burning of any fuel is limited by thermodynamics and will always produce waste heat.

Cogeneration captures this heat from combustion and puts it to use. As waste heat may not be hot enough to drive an electrical generator, it can be used directly for heat-dependent applications.

Cogeneration captures more energy from fuel, allowing the system to reach higher total efficiencies than single-generation solutions.

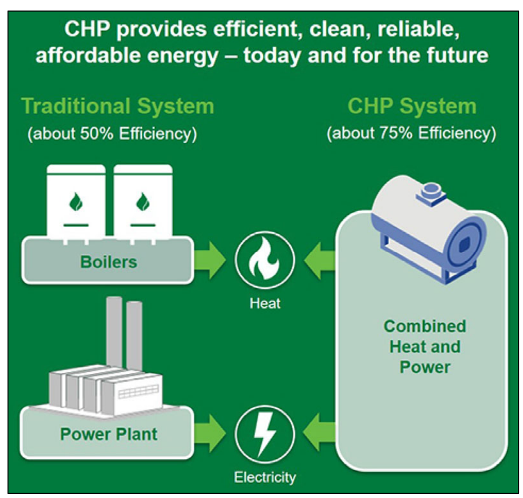

Image: https://www.energy.gov/eere/iedo/combined-heat-and-power-basics

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https://www.epa.gov/chp/chp-benefits
https://www.energy.gov/eere/iedo/combined-heat-and-power-basics
Image: https://www.energy.gov/eere/iedo/combined-heat-and-power-basics

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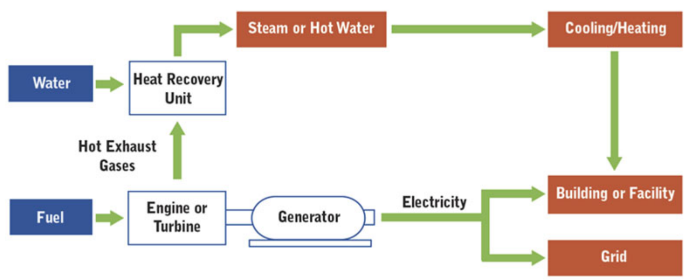
Cogeneration

CHP systems consist of an integrated package:

- Prime mover – engine, turbine or fuel cell
- Generator
- Heat recovery system
- Electrical interconnections

CHP systems provide power independence with around 75% - 85% overall system efficiency.



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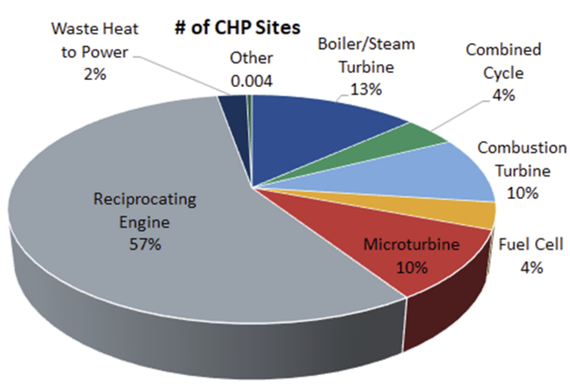
Prime Movers

Prime Movers



Prime movers include:

- Gas Turbines
- Internal Combustion Engines
- Steam Turbines
- Microturbines
- Fuel Cells

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Gas Turbines

Turbines are devices that can convert kinetic energy from a moving gas or fluid into mechanical energy.

Gas turbines ignite fuel with an oxidizer (air) at high pressure and velocity, and direct the hot gases from the burning fuel onto blades which create torque on a central shaft, causing it to spin.

This spinning shaft can be used to spin magnets or coils in a **generator**. The movement and constant switching of polarity of magnetic fields through coils of wire creates electricity.

Common efficiency at converting fuel to electricity ≈ 30% - 50%

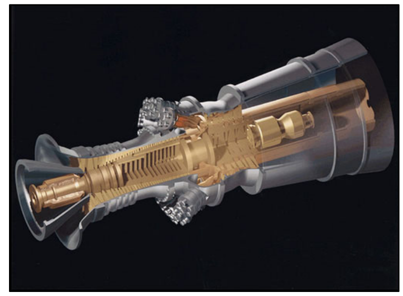


Image: By United States Department of Energy - http://www.netl.doe.gov/scng/projects/end-use/at/images/at31176 , Public Domain, https://commons.wikimedia.org/w/index.php?curid=1502086

Internal Combustion Engines

Internal combustion engines are **heat engines** that convert kinetic energy from the rapid expansion of burning fuel in a confined space into mechanical energy.

These engines ignite fuel with an oxidizer (air) in a **combustion chamber**, which causes the resulting high temperature and pressure gases to exert force on a component that creates torque on a central shaft, causing it to spin.

Internal combustion engines, like gas turbines, must be paired with a **generator** to produce electricity.

Common efficiency at converting fuel to electricity ≈ 30% - 50%

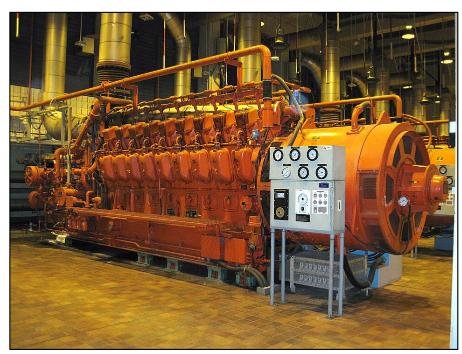


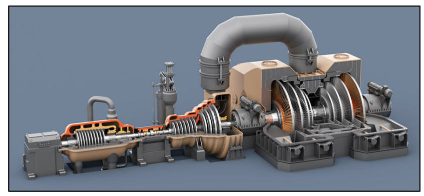
Image: By Jean-Daniel Drapeau-Mc Nicoll - De l'usine d'épuration des eaux usées de Montréal, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=11762515

Steam Turbines

Steam turbines are driven by high-pressure steam, generated by boiling water in a confined space. The pressurized steam pushes against blades which create torque on a central shaft, causing it to spin.

As before this spinning shaft can be used to spin magnets or coils in a **generator**, generating electricity.

Common efficiency at converting fuel to electricity ≈ 30% - 50%



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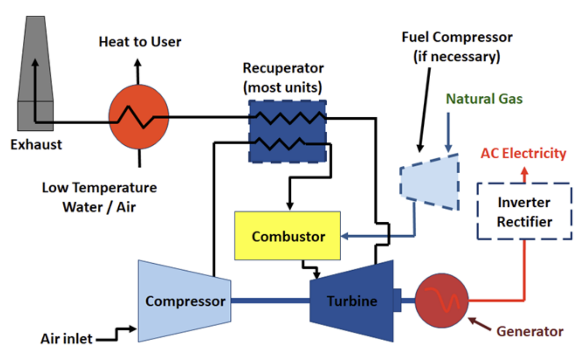
Microturbines

Microturbines are small-scale gas turbines that are more flexible in application due to their smaller size and ability to be scaled up through quantity, not size. Air is compressed and mixed with fuel which, when burned, expands and forces itself through the turbine, spinning the shaft.

As before this spinning shaft can be used to spin magnets or coils in a **generator**, generating electricity. Microturbines use smaller, lighter components and can thus have very fast start up times.

Common efficiency at converting fuel to electricity ≈ 15% - 30%



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Fuel Cells

Fuel cells directly extract electrons from hydrogen through electrochemical reactions, generating electricity.

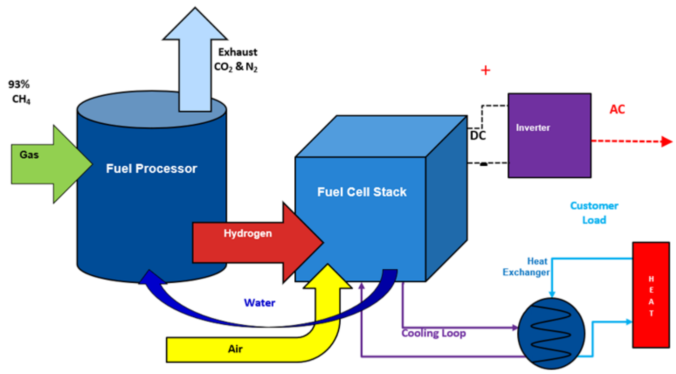
Benefits:

- Use stored hydrogen from electrolysis or from other hydrogen sources such as natural gas.

Shortfalls:

- High cost
- Lower efficiency than lithium-Ion batteries

Efficiency roundtrip: 34% - 51%



Energy Storage Comparison Analysis with Gas-Fueled Technologies, ICF

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Heat Recovery

Heat from CHP can come in the form of:

- Hot water from electrical generation equipment cooling.
- Heated air from electrical generation exhaust.

Different forms of heat recovery technologies exist to turn these heat sources to useful heat.

- Heat Exchangers
  - Plate & Frame
  - Shell & Tube
  - Heat Pipe
- Heat Recovery Steam Generator
- Engine Heat Recovery (exhaust, cooling jackets, lube systems)

Waste heat can also provide cooling through various methods:

- Steam Turbine Chillers
- Double Effect Absorbers
- Single Effect Absorbers
- Desiccants
- Adsorbers

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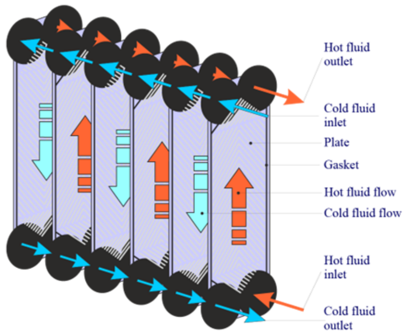
Heat Recovery Examples

Plate & Frame – Heat exchanger that uses a stack of sandwiched metal plates to allow heat exchange between two separate fluids without mixing. Hot fluid travels through narrow channels, losing heat to the metal plates which then warm cooler fluid in adjacent channels.



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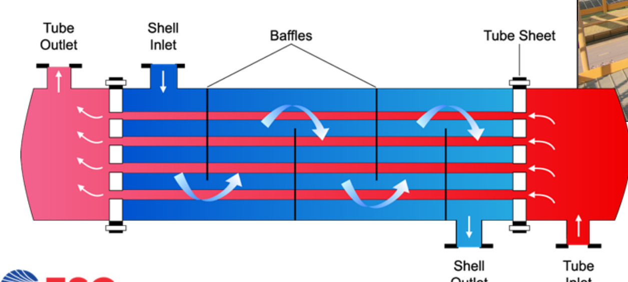
Heat Recovery Examples

Shell & Tube – Heat exchanger that uses a set of pipes in a tube to increase the surface area between the hot and cold fluids without mixing. Hot fluid travels through narrow tubes, losing heat to the tube walls and then warm cooler fluid in in the tube.



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Micro CHP (mCHP)

CHP can be scaled down for even small commercial use. Systems rated at lower than 50kW of generation capacity can be implemented, providing both electricity and heat to a small business.

Large CHP (commercial & industrial) tend to be **electricity-led**, meaning that the primary need for output is electricity, where heat is a by-product that can be put to use.

Micro CHP for small commercial operations tend to be **heat-led**. These businesses need heat and can benefit from the extra electricity mCHP systems can generate. Systems are sized based on the heating needs of the business.

Cogeneration

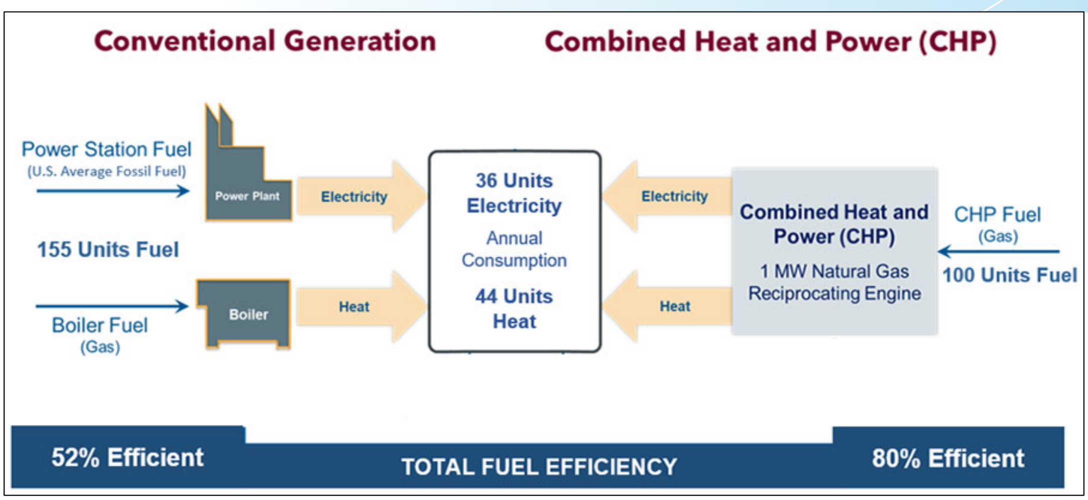

Image: https://www.epa.gov/chp/chps-role-decarbonization

Cogeneration

Waste heat from cogeneration can be used for things like:

- District heating
- Domestic or industrial hot water
- Industrial processes
- Cooling through absorption chillers
- Greenhouse heating
- Desalination
- Food processing
- Aquaculture

Most cogeneration facilities in the US use natural gas.

As heat is more difficult to transport than gas or electricity, the challenge is often identifying a mutually beneficial relationship within a local area, and for the possible life of the plant.

A cogeneration plant may not be able to transport heat to an industrial site several miles away, and altering site selection or construction plans to accommodate partnering with a local business that may not exist or stay for more than a few years is not beneficial.

https://www.eia.gov/todayinenergy/detail.php?id=8250

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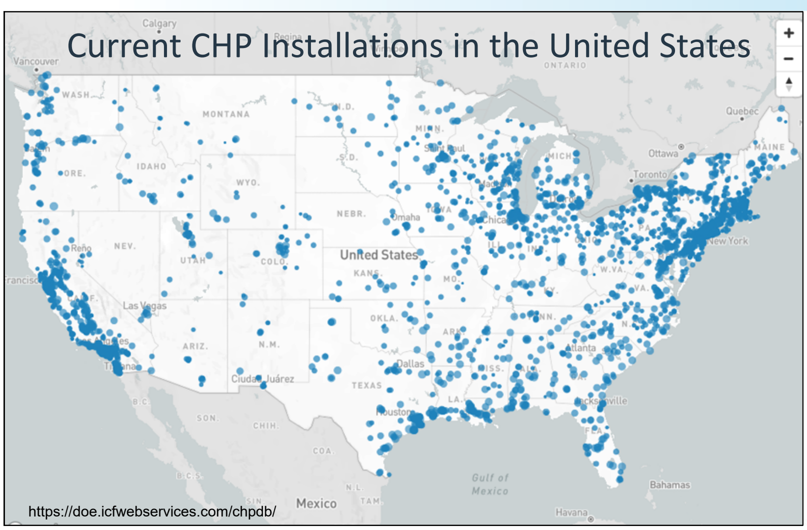
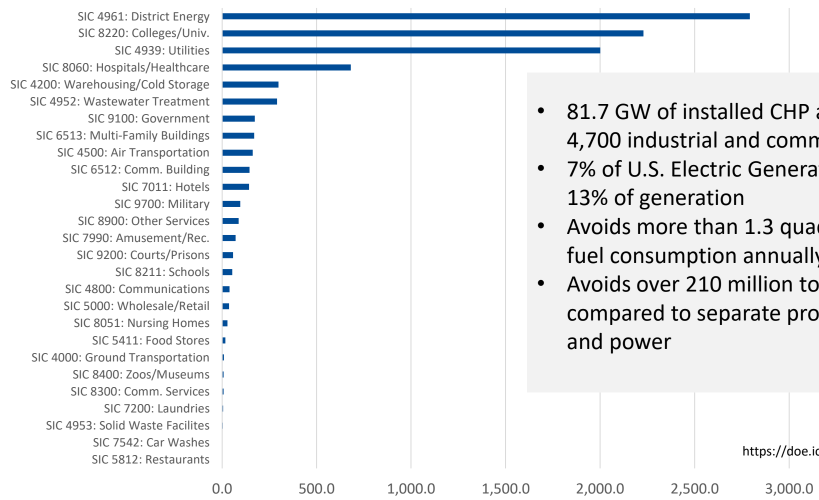
Combined Heat & Power (CHP)



Existing Commercial Gas Fired CHP Capacity by Business Type (9,609 MW)



- 81.7 GW of installed CHP at more than 4,700 industrial and commercial facilities
- 7% of U.S. Electric Generating Capacity; 13% of generation
- Avoids more than 1.3 quadrillion Btus of fuel consumption annually
- Avoids over 210 million tons of CO_2 compared to separate production of heat and power

https://doe.icfwebservices.com/downloads/chp

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Source: DOE CHP Installation Database (U.S. installations as of December 31, 2020)

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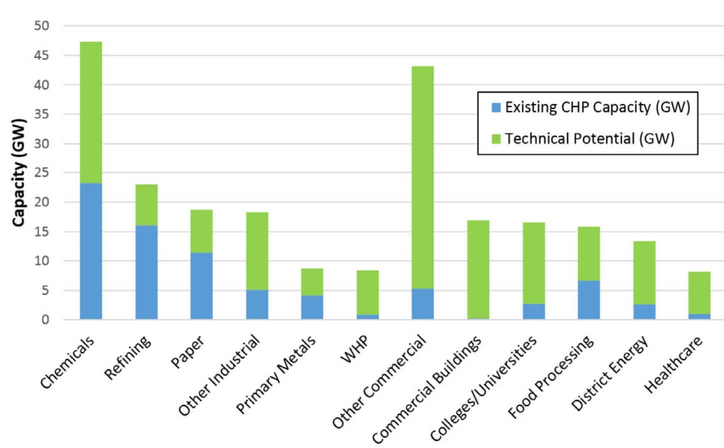
Technical Potential for CHP

More than 149 GW of CHP/WHP technical potential at over 291,000 sites in the U.S.



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Source: USDOE, "Combined Heat and Power (CHP) Technical Potential in the United States"

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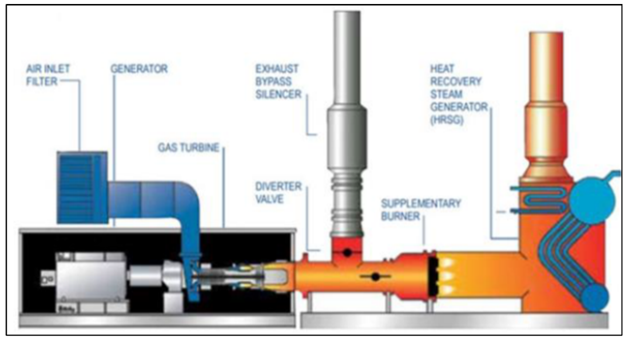
Natural Gas – Industrial CHP

Industrial CHP systems have long been used in industrial manufacturing plants for electricity generation and steam that is used in manufacturing processes.

Benefits:
- > 24 hours of duration
- Milliseconds response time

Shortfalls:
- Engineering and design is complex

Efficiency: 70% - 80%



Energy Storage Comparison Analysis with Gas-Fueled Technologies, ICF

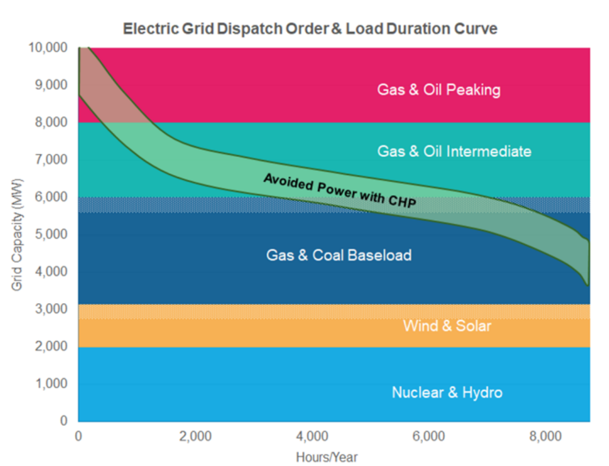
Natural Gas – Industrial CHP

Industrial CHP: Cost & Performance Specifications	
Discharge Duration	>24 hours
Capital Costs ($/kW, $/kWh)	$1,200 – 1,800
O&M Costs ($/kW-year)	$30-45/kW-year (FOM), ~$10/MWh (VOM)
Fuel Cost to Operate ($/kWh)	$0.015 – 0.020, including thermal credit
Energy Capacity (based on existing installations)	~5,000 - 80,000 MWh (in addition to onsite generation)
Power Capability (based on existing installations)	~1-20 MW (in addition to onsite power generation)
Expected Life	15 - 20 years
Roundtrip Efficiency	Recip. Engine: 70-80%; Gas Turbine: 70-75% (CHP efficiency, HHV)
Dispatch Response Time	Milliseconds to seconds (depends on operational status)
Technology Applications	Baseload onsite generation, demand response, spinning reserve, other grid services
Technology Drawbacks	Engineering and design process can be complex

Energy Storage Comparison Analysis with Gas-Fueled Technologies, ICF

CHP Dispatch

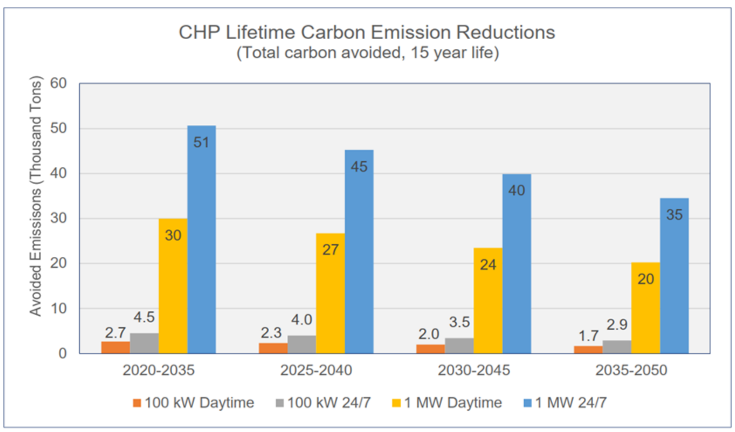
Figure ES-1. Avoided Power with CHP for an Example Utility



Combined Heat and Power Potential for Carbon Emission Reductions, ICF

CHP Emission Reductions

Figure ES-3. CHP Carbon Emission Reductions (Thousand Tons) Over System Life, Compared to Average U.S. Marginal Grid Emissions



Combined Heat and Power Potential for Carbon Emission Reductions, ICF

District Energy & Microgrids

*"A **district energy system** is an efficient way to heat and/or cool many buildings from a central plant. It uses a network of pipes to circulate steam, hot water, and/or chilled water to multiple buildings."* – DOE

*"A **microgrid** is a network of electricity sources and loads that is typically connected to and synchronous with the grid, but is also able to operate independently in 'island mode.'"* – DOE

Both of these systems bring energy generation to a local level. CHP is both robust and flexible, making it an important technology for both.

Source: Microgrids | Grid Modernization | NREL
https://www.energy.gov/eere/iedo/combined-heat-and-power-chp-and-district-energy

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District Energy

District energy is often used for campuses of dense buildings such as:

- Universities
- Hospitals
- Research facilities
- Business districts

They are also used in some densely packed cities, such as downtown areas, or communities. Some examples are:

- Minneapolis and St. Paul MN
- New York
- San Francisco

District energy can move energy equipment and associated emissions away from buildings in these areas, while remaining local to reduce infrastructure and energy loss. Economies of scale also can reduce energy and equipment costs for customers.

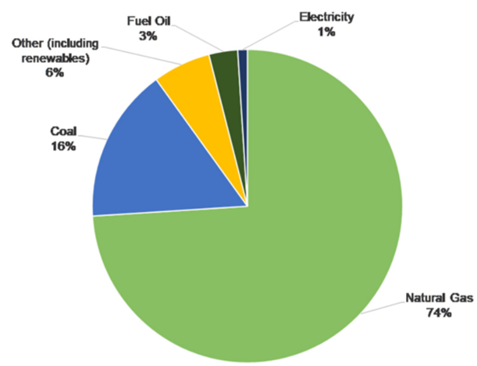

Figure 4. Fuel use in district energy systems (2012 data).

Source: https://www.energy.gov/sites/default/files/2021/03/f83/District_Energy_Fact_Sheet.pdf
https://www.energy.gov/eere/iedo/combined-heat-and-power-chp-and-district-energy

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Microgrids

*"A **microgrid** is a group of interconnected loads and distributed energy resources that acts as a single controllable entity with respect to the grid. It can connect and disconnect from the grid to operate in grid-connected or island mode.*

Advanced microgrids enable local power generation assets—including traditional generators, renewables, and storage—to keep the local grid running even when the larger grid experiences interruptions or, for remote areas, where there is no connection to the larger grid. In addition, advanced microgrids allow local assets to work together to save costs, extend duration of energy supplies, and produce revenue via market participation."

- NREL

Source: Microgrids | Grid Modernization | NREL

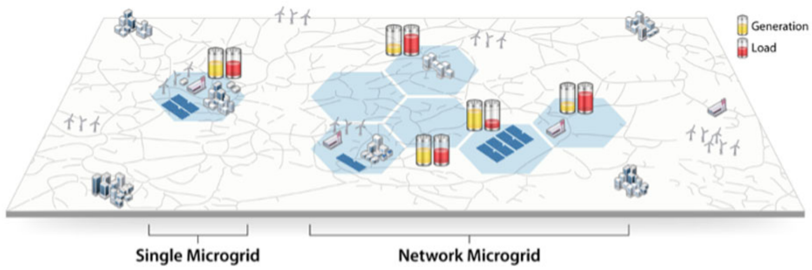

Image: https://www.energy.gov/oe/grid-systems

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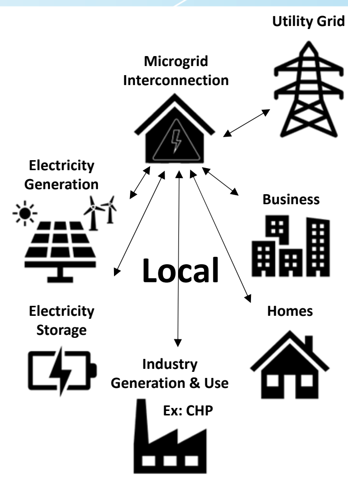
Microgrids

Microgrids support distributed energy infrastructure, supporting small scale solar, wind, CHP, energy storage, and other technologies as they integrate with the larger grid. Small scale electricity generation can support the creation of small businesses. This localization of resources can bring electricity economies to the local level, keeping money within communities.

With microgrids, energy is both produced and consumed in a small area, while still supported by the larger grid. Less long-distance transmission of electricity reduces the transmission infrastructure needed, reducing costs and energy losses.



Source: Microgrids | Grid Modernization | NREL
Microgrids 101 | Department of Local Government
Microgrids as a Building Block for Future Grids

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Case Studies

Cape Codder Resort & Spa

A 260-bed resort with both indoor and outdoor heated swimming pools.

"The resort installed two packaged units from Co-Energy America, one 250 kW system in 2007, and an 85 kW system in 2009. The 250 kW system provides domestic hot water to the resort while heating the indoor wave pool while the smaller 85 kW system also provides domestic hot water and heats the outdoor pool. The system is able to black start in the event of an outage and provides power to critical loads which include the hotel's kitchen, ballroom, and one wing of the resort when grid electricity is unavailable." – EPA

Quick Facts

LOCATION: Cape Cod, Massachusetts
MARKET SECTOR: Hotel
FACILITY SIZE: 260 Room Hotel & water park
FACILITY AVERAGE LOAD: 525kW
EQUIPMENT: Co-Energy America - Amerigen 8250 & 8085
FUEL: Natural Gas
USE OF THERMAL ENERGY: Domestic hot water, pool heating, dehumidification
CHP TOTAL EFFICIENCY: 87 %
ENVIRONMENTAL BENEFITS: 70% emissions reduction
TOTAL PROJECT COST: ~3k/kW
PAYBACK: 3 years
CHP IN OPERATION SINCE: 2007

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https://www.epa.gov/chp/chp-technologies#catalog
https://chptap.ornl.gov/profile/29/Cape_Codder-Project_Profile.pdf

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Multifamily Residential Building

A multifamily building utilizes a micro CHP system to both generate electricity for the building's common areas and provide domestic water heating.

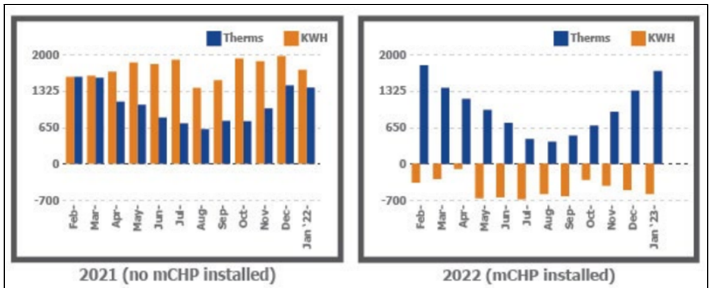

Figure 1: WE Energies Utility Bills, 2021 & 2022

Quick Facts

Location: South Milwaukee, Wisconsin

Market Sector: Multifamily Residential

Facility Size: 32 unit, two-story building

Prime Mover: Single cylinder, 8 HP, liquid cooled, Marathon reciprocating engine (1,200 to 3,400 rpm)

Engine Maintenance: 4,000 hr intervals

Fuel Type: Natural gas

Electric Output: 1.2 to 4.4 kW

Thermal Output: 13,000 to 42,000 Btu/hr (160°F hot water)

CHP Operation Began: January 2022

CHP System Efficiency: Over 90%

ESC https://chptap.ornl.gov/profile/473/Micro_CHP_in_Multifamily_Residential_Building-Project_Profile.pdf

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Southwestern Energy Data Center

An office campus and data center uses a natural gas CHP system to provide electricity to the data center and parking garage lights while heat is used to run an absorption chiller to cool the building.

"SWN decided to install CHP for two purposes. First, SWN's Spring, TX campus houses the data center for the company. Ensuring the data center remains online during natural or man-made disaster was key for the decision to invest in CHP. Second, SWN wanted to demonstrate the feasibility and opportunity of deploying natural gas powered CHP with chilling for commercial properties." – CHP Technical Assistance Partnership

Quick Facts

LOCATION: Spring, TX
MARKET SECTOR: Commercial Office/Data Center
FACILITY SIZE: 570,000 square feet
FACILITY AVERAGE LOAD: 982 kW
EQUIPMENT: GE Jenbacher J312 Reciprocating Engine; York 120 ton absorption chiller
FUEL: Natural Gas
USE OF THERMAL ENERGY: Building Cooling
CHP EFFICIENCY: 87%
CHP IN OPERATION SINCE: 2014

ESC https://www.epa.gov/chp/chp-technologies#catalog
https://chptap.ornl.gov/profile/214/swn-project-profile_final1.pdf

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Gatorade Facility

A drink manufacturing facility uses a natural gas CHP system to:

- Generate electricity for on-site consumption.
- Use the high heats exhausted to generate steam for the drink production processes.
- Further use the lower heats exhausted from the steam process to heat water for production processes.

Quick Facts

Location: Indianapolis, Indiana
Market Sector: Industrial, Beverage Manufacturing
CHP Generation Capacity: Total 3.6 MW
Prime Mover: Three Caterpillar 1.2 MW engine/generator sets
CHP Fuel Source: Natural gas
CHP Heat Recovery:
– 2,100 lbs/hr of 115psi steam
– 225 gpm of 190ºF hot water
Total CHP System Cost: $6M (including new utility building housing CHP system)
Projected Simple Payback: 6 years
Began Operation: January 1, 2019
Annual Emissions Saved: 10,770 MT of CO_2e (equivalent to 23,589,220 lbs.)

ESC https://chptap.ornl.gov/profile/368/IndianapolisGatorade-Project_Profile.pdf

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Saint Mary's Hospital

A hospital uses CHP for:

- Electricity generation through two turbines (gas combustion and steam)
- Space heating (with steam)
- Space cooling (steam driven chiller)
- Medical equipment sterilization (steam)

Quick Facts

LOCATION: Rochester, Minnesota
MARKET SECTOR: Healthcare
FACILITY SIZE:
3 Million Square Feet, 960 Licensed Beds
FACILITY PEAK LOADS:
Electric: 12.0 Megawatts
Heating: 130,000 lb/hr Steam
Cooling: 7,500 Tons
TOTAL CHP GENERATING CAPACITY: 7.75 Megawatts
HEAT RECOVERY RATE: 24,000 lb/hr of 250 psig Steam
HEAT RECOVERY UTILIZATION: Building heating or cooling, medical equipment sterilization, additional electricity generation
PRIME MOVERS:
(1) 3.0 MW Dresser-Rand Back Pressure Steam Turbine (installed 1971)
(1) 4.75 MW Solar Taurus 60 Gas Combustion Turbine (installed 1996)
FUEL TYPE: Natural Gas
TOTAL PROJECT COST: $5 Million*
EXPECTED PAYBACK: 5 Years*
ACTUAL PAYBACK: 3.5 Years*
BEGAN OPERATION: 1996*
**Data for 4.75 MW Combustion Turbine Installation Only*

ESC https://chptap.ornl.gov/profile/193/Saint_Marys-Project_Profile.pdf

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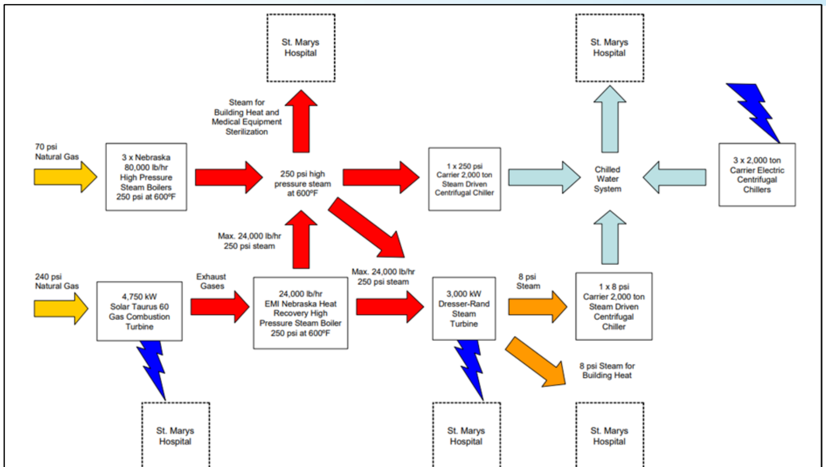
Saint Mary's Hospital



CHP Flow Diagram of Saint Marys Hospital

https://chptap.ornl.gov/profile/193/Saint_Marys-Project_Profile.pdf

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Durham Wastewater Treatment Facility

A wastewater treatment facility uses **biogas** from the wastewater to both generate electricity and provide heating to digesters.

"The plant launched a large system upgrade which enabled it to produce more biogas by incorporating a fats, oils, and grease recovery station along with its existing anaerobic digesters and installing two 848 kW reciprocating engines. These new engines enable the facility to not flare any excess biogas and remove fats, oils, and grease waste from local landfills." – EPA

Quick Facts

LOCATION: Tigard, Oregon
MARKET SECTOR: Wastewater Treatment
FACILITY SIZE: Average treatment of 26 million gallons per day (MGD) plus collected Fats, Oils, and Grease (FOG)
FACILITY PEAK LOAD: NA
EQUIPMENT: two 848 kW biogas-fueled Jenbacher reciprocating engines
FUEL: Treated biogas
USE OF THERMAL ENERGY: Space and process heating, including anaerobic digesters
CHP Output: 13 million kWh/year
ENVIRONMENTAL BENEFITS: Remove FOG from landfill waste stream
TOTAL PROJECT COST: $16.8 million
TOTAL ANNUAL ENERGY SAVINGS: $800,000
PAYBACK: 9.6 years with incentives and tipping fees included.

https://www.epa.gov/chp/chp-technologies#catalog
https://chptap.ornl.gov/profile/61/Durham_WWTF-Project_Profile.pdf

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Sheboygan Wastewater Treatment Facility

A similar 2006 project in Sheboygan, WI saw the install of ten 30kW microturbines and heat recovery systems. Biogas from the anaerobic digesters on site power the turbines, producing 2,300 MWh of electricity each year.

Captial cost was $300,000.

Energy savings of $78,000 per year in electrical costs and the equivalent of $60,000 in offset natural gas costs for heat at the time.

https://www.epa.gov/sites/default/files/2019-08/documents/microturbines_fact_sheet_p100il8p_0.pdf

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Future Opportunities

Future Opportunities

The natural gas and electric generation industries have been closely tied through the years and integration is likely to continue into the future. Natural gas has properties that lend it well to supporting electricity generation.

- It is a cost-effective fuel.
- Its extraction, processing, and distribution infrastructure is established and far reaching.
- It is storable for future use.
- It burns cleaner than many other fuels.
- It is flexible in how it is burned and used, both in scale and processes it supports.
- It can reach high efficiencies, especially when paired with combined cycle and CHP plants.
- It is responsive in its ability to ramp up and down electricity generation for the grid.

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Future Opportunities

Natural gas plays an important part in:

- Meeting rising electricity demand.
- Ensuring grid stability.
- Supporting intermittent renewable energy sources.
- Lowering grid emissions.
- Integrating with future technologies.

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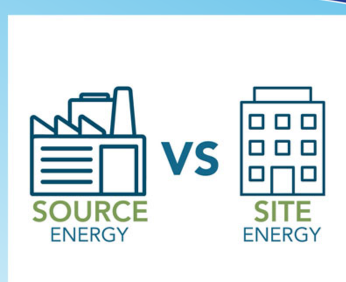
Future Opportunities

Electricity generation solutions on the horizon that incorporate natural gas might include:

- Supporting microgrids that can generate and distribute electricity on a local scale in a way that can increase the stability and reliability of electricity supply while reducing energy losses.
- Energy storage for backup power when supplies are intermittent.
- Hydrogen blending, where green hydrogen can be blended into natural gas supplies to reduce carbon emissions.
- Supporting hydrogen production through **blue & turquois hydrogen**.
- Natural gas fuel cells.

Source to Site Energy Efficiency



Source to Site Energy Efficiency

Site energy – The amount of heat and electricity consumed by a building.

Source energy – The amount of raw fuel needed to operate a building.

Source to site energy efficiency is the efficiency of an electric system inclusive of all steps from the energy source (such as fuel) to the consumption site.

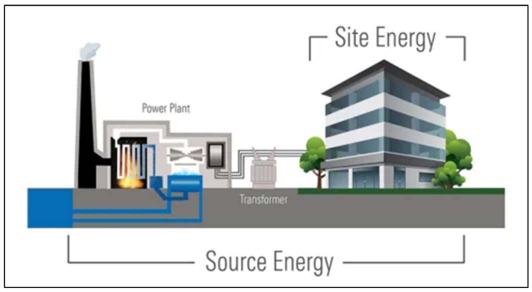


Image Source: https://www.energystar.gov/buildings/benchmark/understand-metrics/source-site-difference

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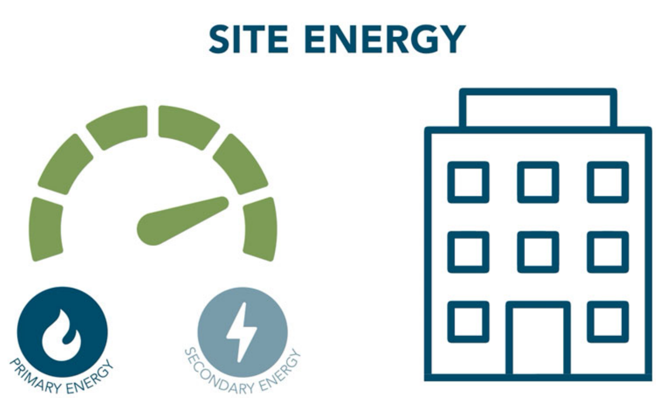
Site Energy

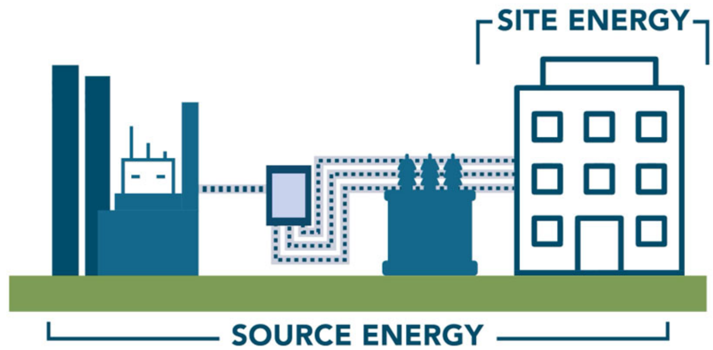
- The amount of energy metered at the point of use (e.g. consumed by a building)
- Refers to both primary energy (natural gas or fuel consumed on site) and secondary energy (heat or electricity created from raw fuel)



Source: EPA Energy Star

Source Energy

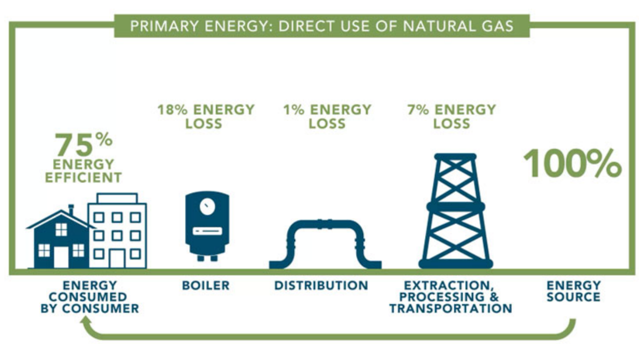
- The amount of primary energy consumed in supplying secondary energy to a building
- Has a larger scope (the amount of energy produced at a power source for a given end use)
- Less efficient than site energy
- The power generation, transmission, and delivery of source energy to the site results in losses.



Source: EPA Energy Star

Natural Gas as a Primary Energy Source

- Natural gas is the most widely used fuel for primary energy in the U.S.
- Energy consumed for extraction, processing, transportation and distribution reduces the efficiency of direct natural gas usage by approximately 8%[1]
- It's combusted and often connected to a furnace or boiler system to heat air, water or steam (with a typical efficiency of 82%)
- Direct use of natural gas is 75% energy efficient[2]



1 www.aga.org
2 https://www.icf.com/

Natural Gas as Secondary Energy Source

- Approximately 5% of the source energy used to produce electricity is lost in extraction, processing, and transportation of that source energy.
- Natural gas is combusted and connected to turbines or engines which generate electricity that is transmitted via power lines
- More than half the remaining energy is lost as heat to the atmosphere during electric generation
- Additional losses occur during electric distribution and conversion to heat for use in a building
- Delivered electricity generated by natural gas is 41% energy efficient[2]

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2 https://www.icf.com/

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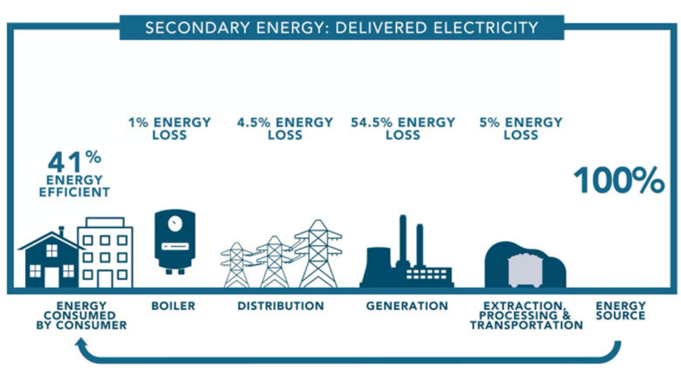
Primary versus Secondary Energy

- Energy required for secondary energy (via electricity production) is nearly double that of primary energy.
- Losses from electricity generation and delivery tend to result in higher source energy emissions compared to direct use of natural gas.



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1 www.aga.org
2 https://www.icf.com/

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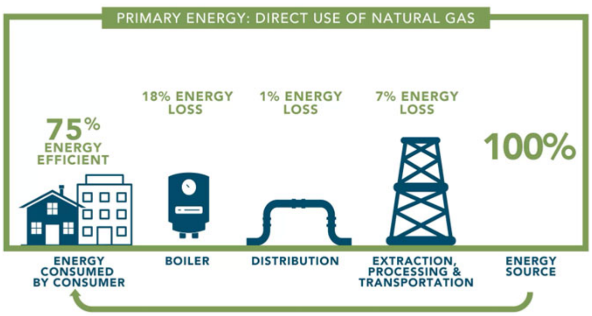
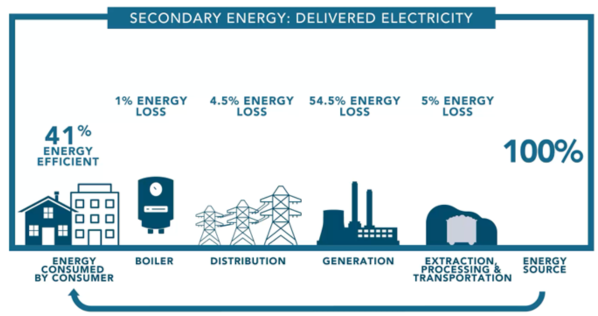
Primary versus Secondary Energy





1 www.aga.org
2 https://www.icf.com/

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Source to Site Energy Efficiency

Example:
An office building might require 1000 MMBTUs of energy for heating. This is the **site energy** produced by a boiler to meet heating needs.

Natural gas may be used in an 82% efficient boiler while electric boilers may be 99% efficient which simply means that 1,220 MMBTU of gas or 1,010 MMBTU of electric feeds each respective boiler.

There is about an 8% loss in gas transmission and distribution so the **source energy** use is 1,325 MMBTU to produce 1,000 MMBTUs of heat for the building using natural gas.

The electric heated building has losses of 54.5% for generation of electric and transmission and distribution losses of 9.5% so that a total of 2,447 MMBTUS of **source energy** provides the same 1,000 MMBTU of heat to the building using electric heating.

The source to site energy efficiency is the ratio of useful energy at the site to the energy contained in the fuel used to power the site. This includes efficiency losses at the power plant and in transmission. This ratio shows how effectively the fuel is used. Here, we find a source to site electric ratio of: **2.45 : 1**

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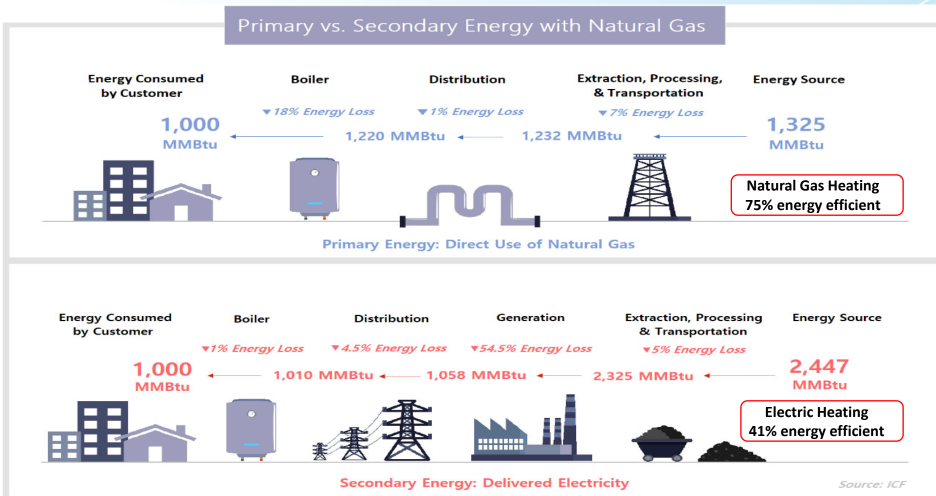
Source to Site Energy Efficiency Comparison



https://consortia.myescenter.com/GHP/ESC-GHP_Guide.pdf

CO2 Emissions for Direct use of Gas vs Electric Heating

Losses from electricity generation and delivery tend to result in higher source energy emissions compared to direct use of natural gas.

	Energy Used (MMBtu)	Energy Required (MMBtu)	On-Site CO_2 Emissions (lbs)	Off-Site CO_2 Emissions (lbs)	Total CO2 Emissions (lbs)
Gas Boiler Direct Use of Natural Gas	1,000	1,220	142,317	11,385	153,702
Electric Boiler eGRID Non-Baseload	1,000	1,010	0	458,016	458,016

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Thank You

Consider taking the on-line test while course material is fresh in your mind

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