Propane-Fueled Combined Heat and Power (CHP) Systems for Residential Applications

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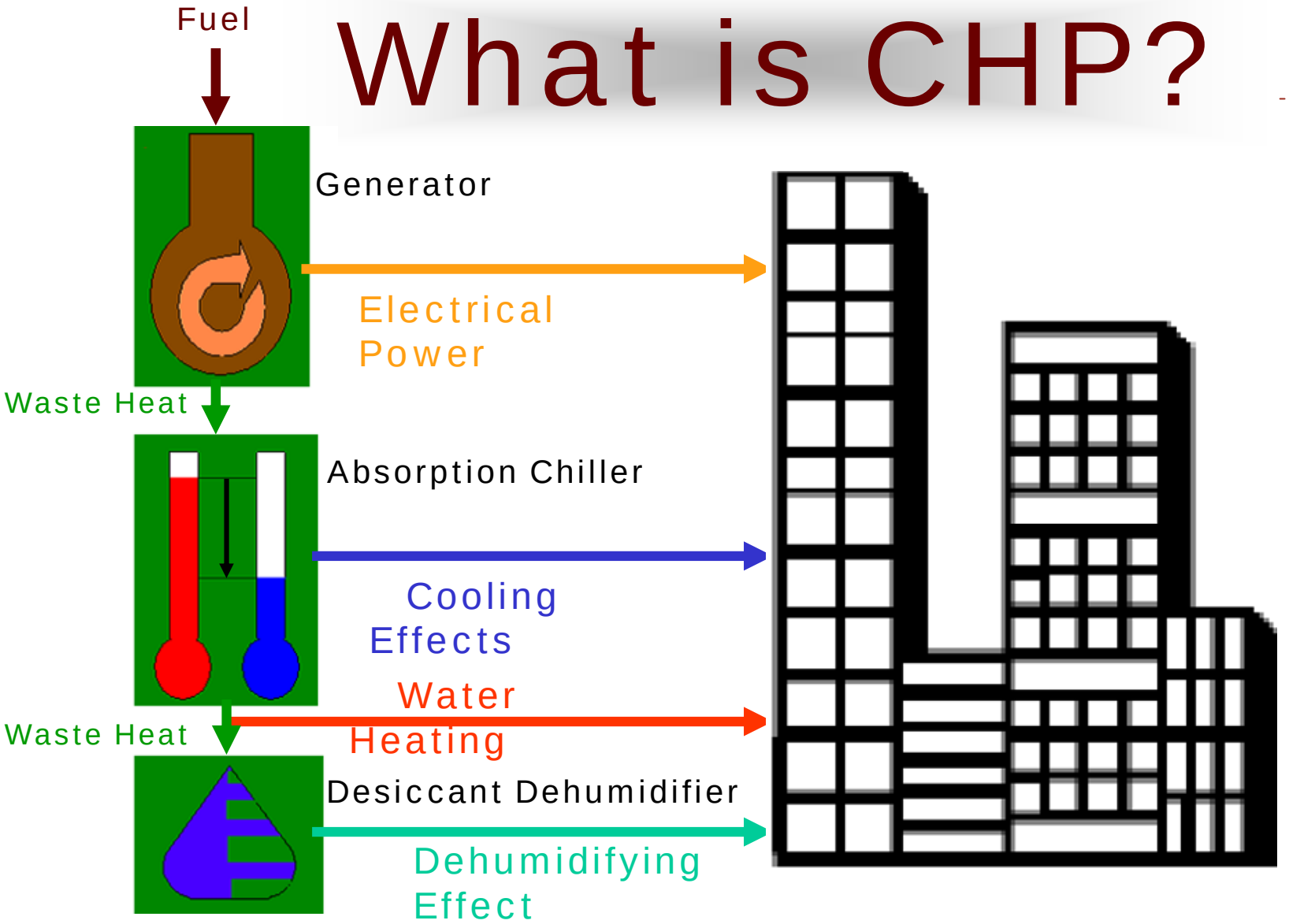
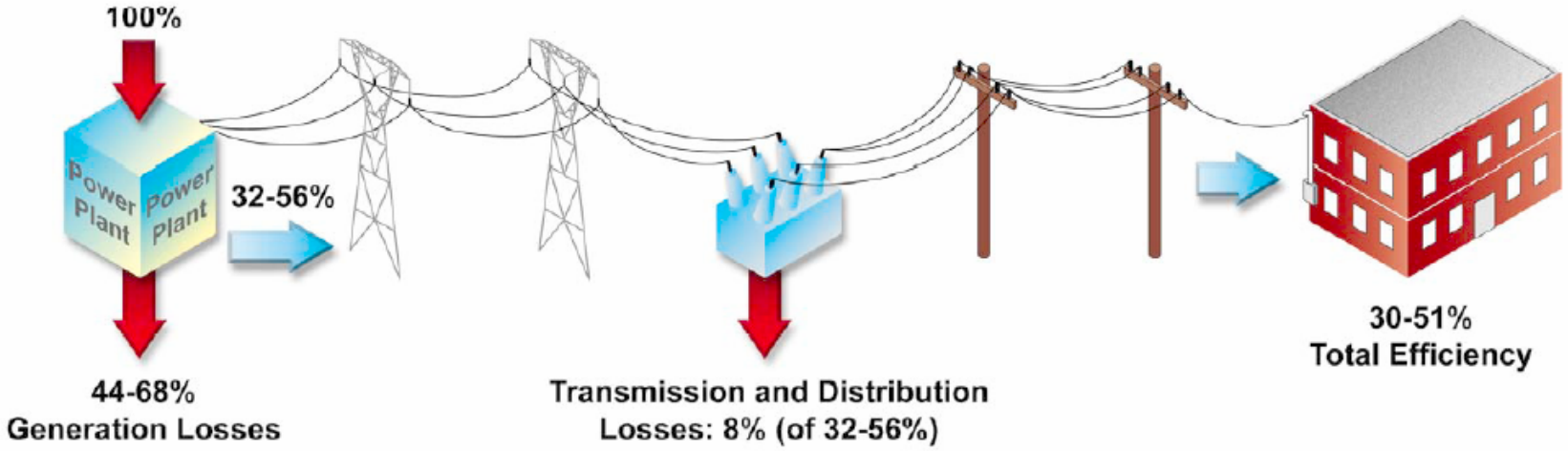
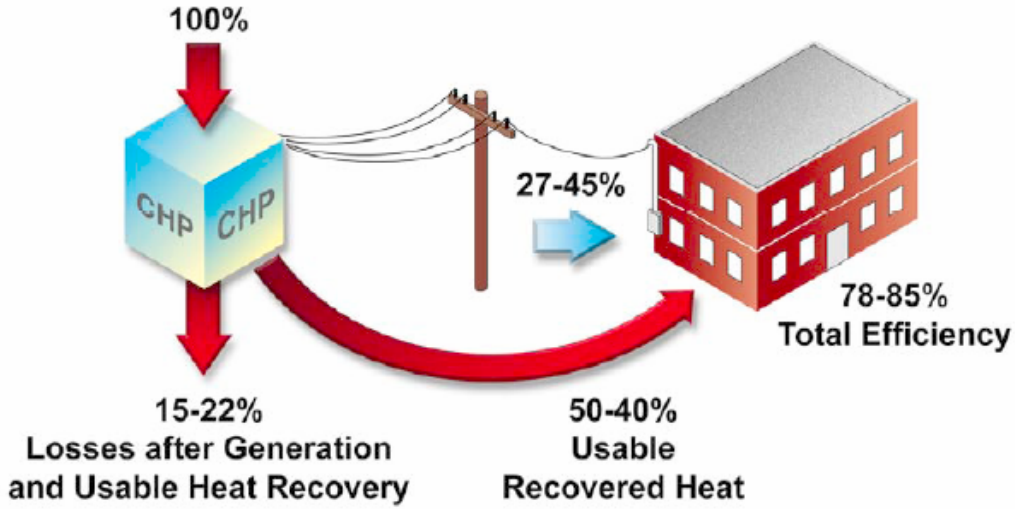
What is CHP?


Fuel
Generator
Electrical Power
Waste Heat
Absorption Chiller
Cooling Effects
Water Heating
Waste Heat
Desiccant Dehumidifier
Dehumidifying Effect

How CHP Saves Energy





Benefits of CHP

Energy Reliability

1. Improved power quality
2. Business continuity
3. Reduced grid congestion
4. End-of-the-wire supply
5. Short lead-time, off-the-shelf, modular technology

Energy Security

6. Reduced system vulnerability
7. Disaster Mitigation
8. Disaster Recovery

Energy Efficiency

9. Improved fuel efficiency (fuel economy)
10. Optimized use of scarce fuel resources
11. Eliminates line losses

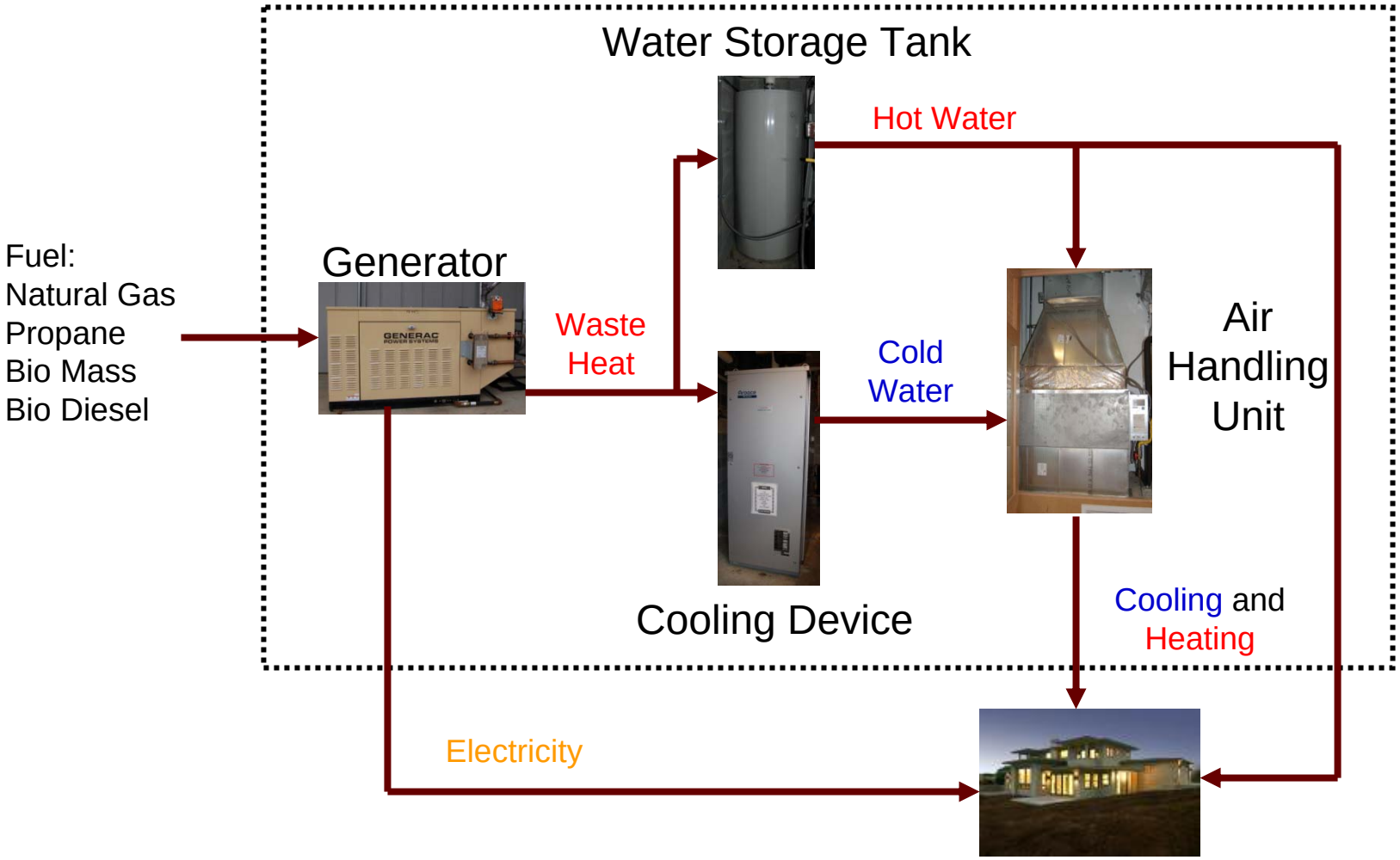
Economic Development

12. Lower cost for new electricity than new central generation and T&D
13. Improved energy cost predictability
14. No ratepayer investment required (generation or T&D)
15. Creates new high-tech manufacturing sector, domestic and export
16. Creates local jobs for installation, operation and maintenance
17. Supports competitive electricity market structure

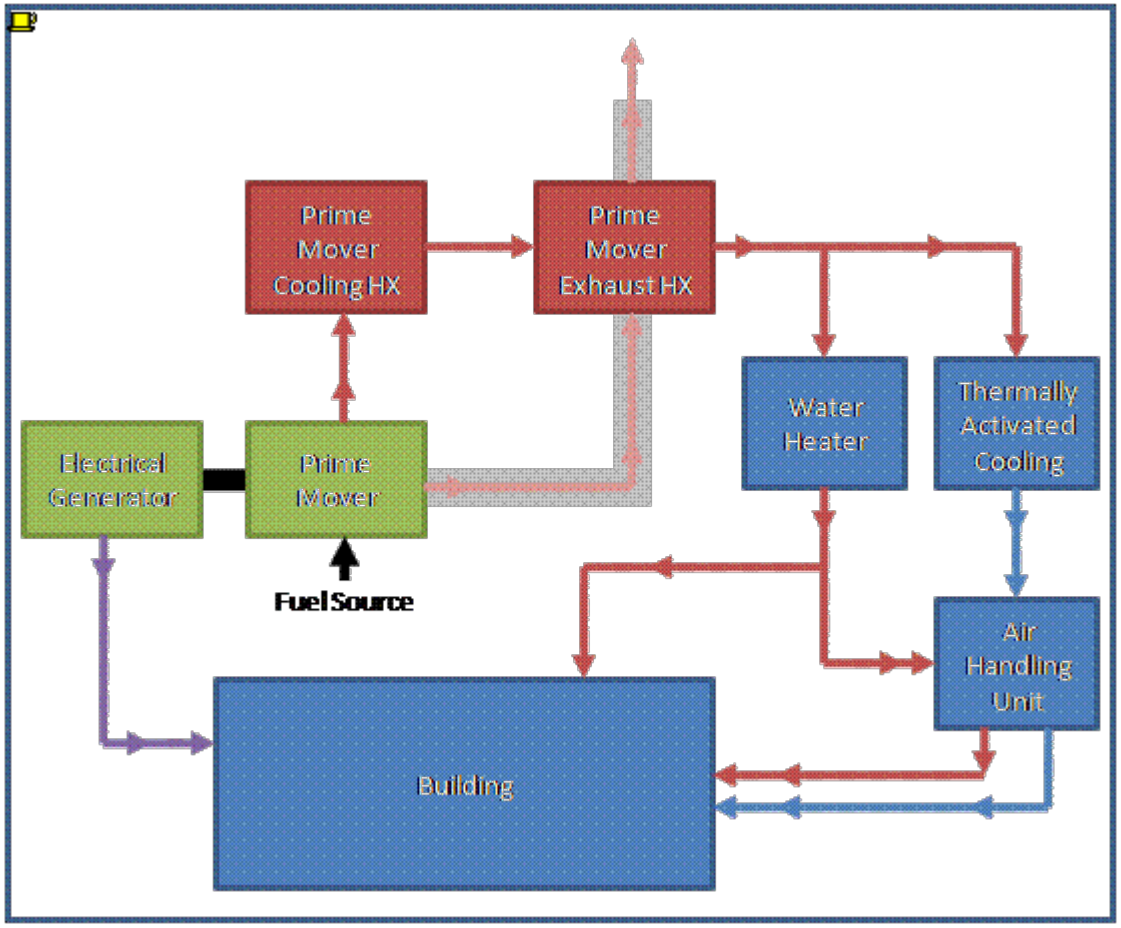
Environmental Stewardship

18. Reduced emissions per unit of useful output
19. Reduces land-use impacts and NIMBY objections
20. Reduces fresh water use

Micro-CHP Demonstration and Research Facility



Micro-CHP Demonstration Facility Energy Flow Diagram



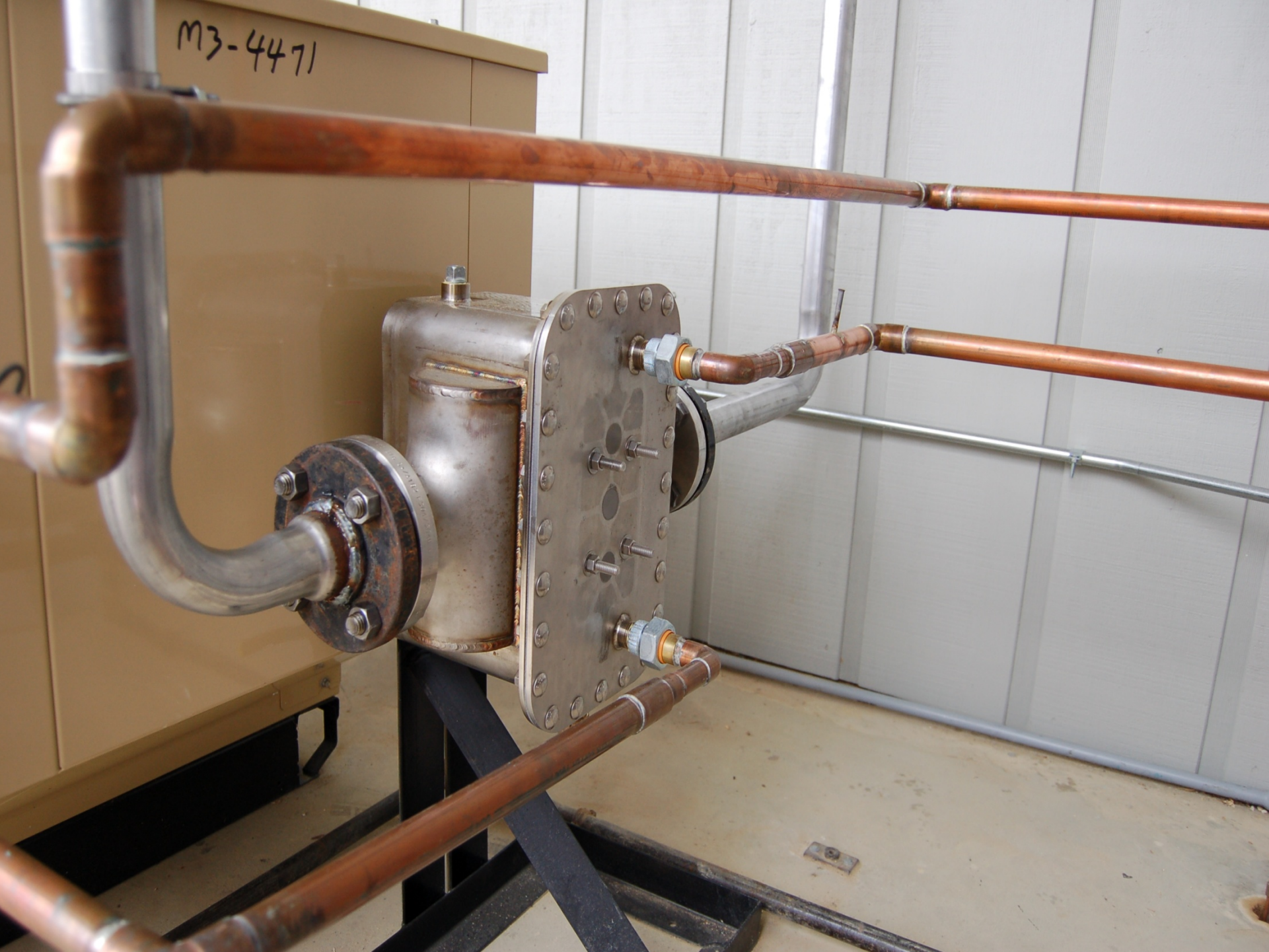
The Micro-CHP facility, located in the MSU Forest Products complex, is a combined effort of the College of Forest Products, the College of Architecture, and the Department of Mechanical Engineering

The photograph of the building is prior to renovation.

Outside Mechanical Room of the MicroCHP Building

View of the Back of the Micro-CHP Facility
(not showing)
5-Ton Package Return
Duct Work
Return for the 4-Pipe Air
Handler
Common Supply
Shop Existing AC Unit to
be Decommissioned
2-Ton High Efficiency
Condensing Unit
25-Ton Cooling
Tower
5-Ton Package
Unit
5-Ton 4-Pipe Outdoor Air
Handler

15 - KW Generator


M3-4471

BELIMO
LF 24 US
FlatPlate
MODEL FP5X12L-12 (1in MPT)
Low Pressure Drop
MAX. DESIGN PRES. PSI (BAR) 450 (31)
MAX. DESIGN TEMP. °F (°C) 350 (177)
SIDE A SIDE B
VOL. Ft³ (L) .013 (0.368) .015 (0.425)
MFG DATE 05.10.24
S/N: L012AC21505003
CRN: 0H0502.9C ADD1

Challenges of Micro-CHP

- One of the challenges of micro-CHP applications, where the loads are small, is the thermal and electrical load matching.
- By eliminating the absorption chiller, the thermal load of the building is limited to space heating and domestic water heating.
- Space heating, while usually large enough to reject all of the waste heat associated with electrical generation, is a seasonal thermal requirement. The heating load also occurs during a periods when most residential structures do not require large amounts of electricity.

- One solution may be to utilize a heat pump for space heating in the winter and use the waste heat to supplement the heat pump instead of electric strip heat.
- In this way, the electrical load could be balanced with the thermal load of the building during the winter. Many air-to-air heat pumps are not capable of producing air at the temperature required to maintain space comfort in colder climates.
- However, a heat pump coupled with a CHP system may be able to strike a perfect balance of electrical and thermal load and allow the use of heat pumps in climates that were previously thought to be too cold.

Challenges of Micro-CHP

- Another challenge of micro-CHP design and operation is the limitation with the available water-cooled-engines in the market.
- For residential applications usually less around 15 kW or less are needed. After searching for water-cooled-propane engines in this capacity range it was found that there are only a few companies that manufacture them.
- However, there is a wide range of air-cooled-propane engines in the 10 to 15 kW capacities. For micro-CHP a water-cooled-engine is needed to recover the heat and then use the hot water to heat the building during the winter season and to provide domestic hot water yearlong.

Challenges of Micro-CHP

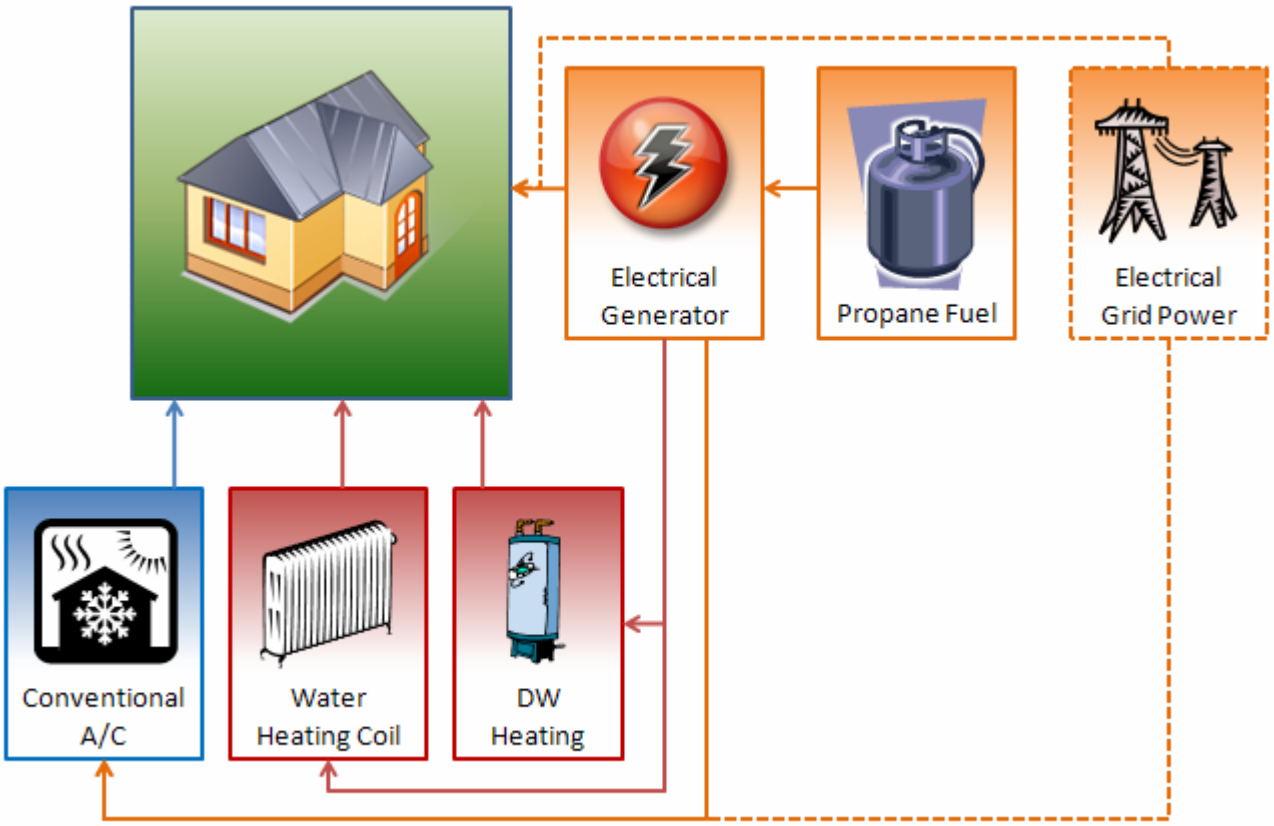
- Another issue with the prime movers is that most of them are not specified by the manufactures to be continuously running.
- They are specified as standby units.
- However, the current Micro-CHP is running a 15-kW Generac generator at this time fueled by natural gas. This generator has the ability to be fueled by natural gas or propane with use of a conversion.
- The engine in the generator is a liquid cooled, four-cylinder, four-stroke Mitsubishi internal combustion engine. The generator is approaching 6,000 hours continuous run time. The generator does however require a certain amount of down time for schedule maintenance. This down time is usually limited to no more than 1 hour per month.

Lessons Learned

- The current Micro-CHP facility utilizes a 15kW natural-gas-fired generator for electrical power generation. The waste heat from this engine is collected from both the jacket water cooling system and the exhaust system in the form of heated water.
- This water is used as the heat source in a 10-ton absorption chiller during the cooling season and as a source of space heating during the heating season.
- The system also incorporates a boiler to boost the water temperature when the generator is not loaded enough to produce the required amount of hot water. A cooling tower is required to reject the heat from the absorption chiller.
- The smallest commercially-available water-fired absorption chiller has a capacity of 10-tons. The peak cooling load in the building is estimated at 7 tons, although a building simulation shows that the cooling load rarely exceeds 5 tons. This means that the absorption chiller never operates at or near its design capacity. Since the total building electrical load rarely exceeds 10 kW, the generator never operates at more than two-thirds of its rated capacity.

- This results in less available waste heat for recovery, requiring the auxiliary boiler to fire to produce hot water for the absorption chiller.
- Tests performed on this system indicate that the electrical energy consumed by the pumps, cooling tower and fan coil units accounts for 78% (9.6kW) of the building's design energy consumption.
- For a system with an estimated peak output of 7 tons, this results in an air conditioning efficiency of 1.37 kW/ton. Currently available 16 EER air conditioning systems have efficiencies of 0.75 kW/ton.
- These results show that accomplishing an energy-efficient micro combined cooling, heating and power system (MCCHP) is not feasible with the absorption chiller equipment that is commercially available today.

Propane-Fueled CHP System

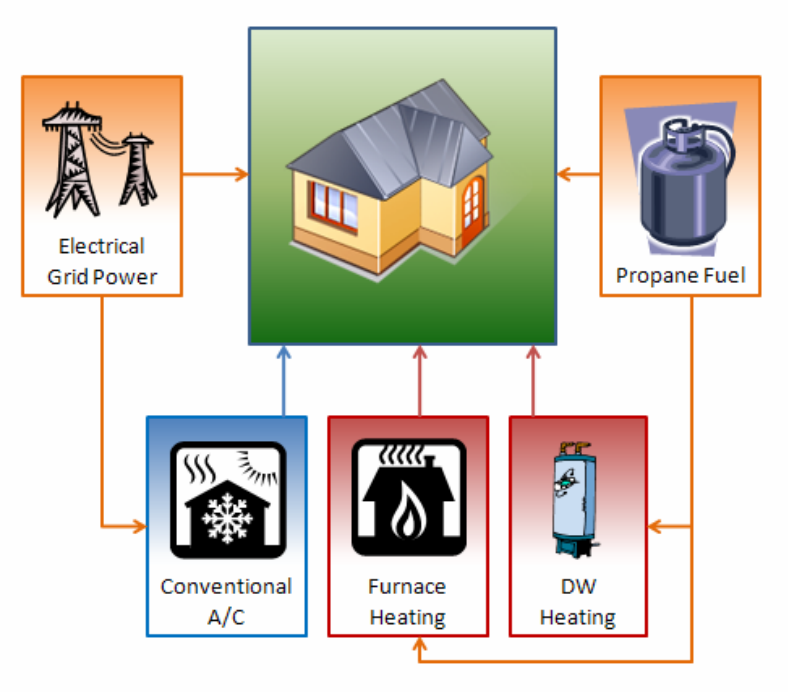


CHP system w/conventional cooling air conditioning system

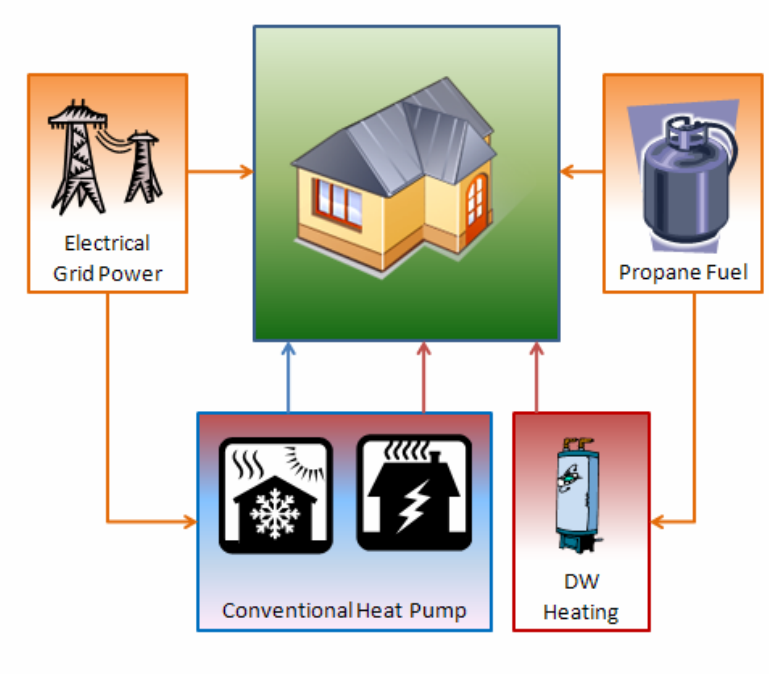
Use of Propane

- Propane is an excellent fuel source within the US economy.
- It is versatile, clean-burning, highly portable, and interchangeable with natural gas.
- Its heating value is 2.5 times that of natural gas and it is 270 times more compact as a liquid than as a gas, which allows transportation and storage using a variety of methods.
- Propane's ability to be stored and transported as a liquid is one of its most important advantages.
- Propane burns much cleaner than gasoline, home heating oil, and diesel fuel.
- All these properties make propane perfectly suited for distributed power generation.

Other Systems to Compare



Conventional Air Conditioning w/Propane Furnace and Domestic Water Heater



Conventional Heat Pump w/Propane Domestic Water Heater

Conclusions

- CHP is a promising technology for increased energy efficiency through the use of distributed electric and thermal energy delivery systems at or near end-user sites.
- Propane has different properties that make it perfectly suited for distributed power generation.
- The increased energy efficiency and the potential for using propane yields significantly reduced emissions of pollutants from CHP systems when compared to conventional systems.
- Final product will be a package system that can be commercialized, in which the users supply the fuel and the CHP package provide the electricity and cooling and heating for the building