Increasing power station efficiency with heat use

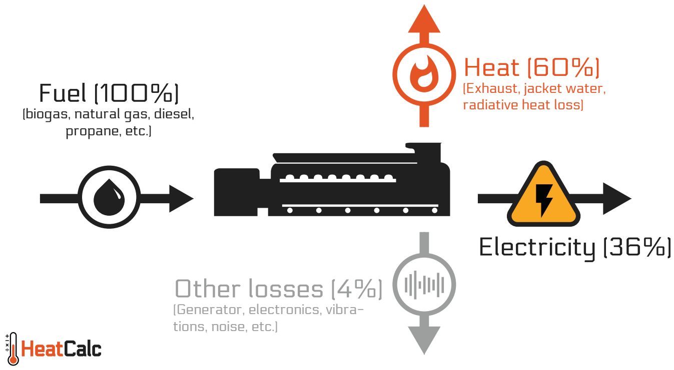
The benefits of the many forms of cogeneration, and how to enable a project

Globally, thermal power plants achieved a conversion efficiency of 36% in 2011. So for every 100 parts fuel that went into the generator, they provided 36 parts useful energy. Nearly all of the inefficiency (roughly 60%) is lost energy in the form of heat, which is a natural byproduct of electricity generation, but often goes unutilized despite its many uses and benefits.

By contrast, cogeneration or Combined Heat and Power (CHP) units, which utilize the electricity and the heat from the power plant, had an average efficiency of 58% in the same year. State-of-the-art cogeneration units today reach conversion efficiencies of as much as 90% (IEA). At 90% efficient, a power plant gets nearly 3 times the energy benefit from the same amount of fuel compared to a traditional power plan that uses only the electricity it produces and wastes the heat.

Typical fuel-fired engine schematic

Percentages indicate the energy balance



Uses for heat

The otherwise wasted heat from the power stations is often high temperature and high quality, which allows it to be used in a variety of ways, including:

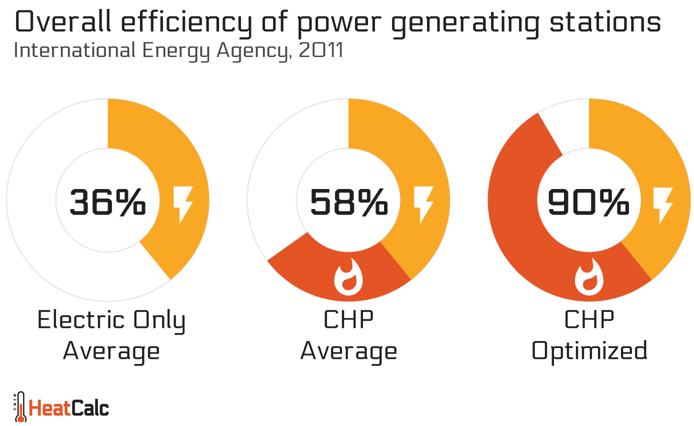
- Warming buildings, campuses, cities, hospitals, etc.
- Purifying and/or desalinating water
- Providing cooling (air conditioning or refrigeration) for buildings
- Generating additional electricity, such as with a combined cycle.

Benefits of heat recovery

Heat utilization from power stations also has significant environmental and financial benefits, including:

- Save money on energy bills through reduced fuel consumption (displacing burning fuel in a boiler) or and/or reduced electricity consumption (not having to run an air conditioner).
- Avoid the cost of capital equipment. In some cases, cogeneration systems can nullify the need for a boiler, air conditioner, etc. resulting in cost savings
- Increase energy security. By having an electric generator and provider of heat on-site, a facility

owner takes into their own control the power that is delivered to their site.
- Reduce greenhouse gases. Using the heat produces no incremental emissions and reduced fuel or electricity use translates into reduced greenhouse gases. In 2008, cogeneration accounted for 9 percent of total U.S. electricity generating capacity.



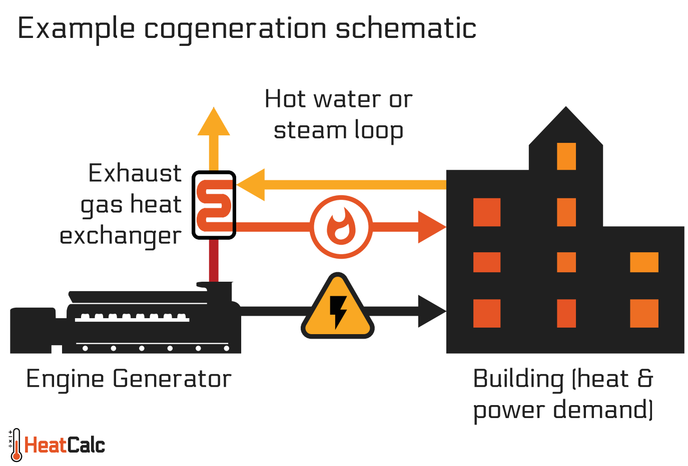
In 2008, cogeneration accounted for 9 percent of total U.S. electricity generating capacity. A study by the Oak Ridge National Laboratory calculated that increasing that share to 20 percent by 2030 would lower U.S. greenhouse gas emissions by 600 million metric tons of CO2 (equivalent to taking 109 million cars off the road) compared to "business as usual." (Center for Climate and Energy Solutions)

The use of Cogeneration in the US is on par with the world average; only 9% of global electricity generation uses cogeneration technologies.While some countries have achieved a high share of cogeneration in electricity production (for instance, Denmark has more than 60% and Finland almost 40%), most countries have not been that successful (IEA). Herein lies a huge opportunity for improvement as new capacity is added, and also with retrofitting existing generator stations with heat exchangers to convert them into cogeneration units.

Making a project happen

There are cogeneration and heat recovery professionals around the world that can help with new and retrofit projects. However, if you're looking to do a quick self-evaluation of your site, there are 3 primary criteria that enable a successful heat recovery project at a power station:

1. Heat is available and accessible
2. There is a use for the heat (or cooling, or electricity that can be generated by the heat).
3. The economics are attractive



1. Heat is available and accessible

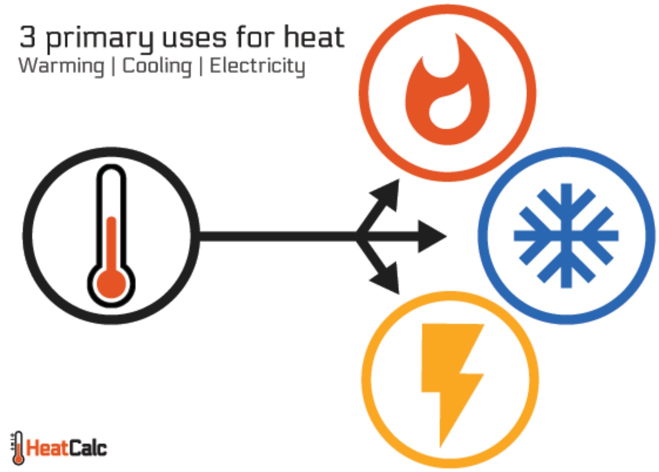
The first step in a project is understanding the quantity and quality of the heat source. The larger the quantity of heat available, and the higher the temperature, the more options for heat utilization. With engines, turbines, and fuel cells, typically the exhaust temperature and flow rate information can be found on equipment specification sheets. This information can be used to calculate the total quantity of heat available, using a tool like the one at heatcalc.com and many companies also offer waste heat audits.

It's important to make sure there is room for a heat exchanger to extract the heat from the exhaust and transfer it to pressurized water, steam, or for use in another device.

It's also important to understand the fuel being used by the generator and any associated air permits and/or limitations. Although installing heat recovery devices on existing generators will not change the chemical makeup of the exhaust, it will reduce the exhaust exit temperature, which reduces exhaust dispersion levels. Heat recovery professionals can size the heat exchanger to ensure that any backpressure requirements on the generator are not exceeded and that the temperature of the exhaust isn't reduced excessively. The lower limit is typically 150-180ºC (302-356ºF), depending on the fuel, dropping below that can cause corrosive buildup.

2. Finding a use for the heat

Based on the outputs from the heat analysis, you can select what you want to do with the heat source. In general, the most cost effective projects occur in the following order: 1) Using heat for warming; 2) Using heat for cooling / AC; and 3) Using heat to generate electricity. This is because it typically requires more equipment, complexity, and therefore cost for cooling and especially electricity generation than it does for heating.



So, look to the surrounding area for buildings that may need heat or air conditioning. Are there pools that want warm water, or industries that need steam?

Heat can be transferred over relatively large distances as steam without much loss of energy. This is why steam is commonly used at college campuses and district energy systems to deliver heat efficiently over long distances. Hot water piping is less expensive than steam (lower pressures), but it requires pumps, which use energy, to transport it over long distances. Energy being used by pumps reduces the overall efficiency of the site; therefore with hot water, it's important that the heat user is within a reasonable distance of the heat source.

In cases where there simply isn't any heat use nearby, the heat can be converted into additional electricity with a steam turbine, organic rankine cycle turbine, or other heat to power systems. By turning the heat into electricity, the overall electrical output and efficiency of the site can increase by 5-20% depending on the heat source and the technology used.

3. Attractive economics

Unfortunately, there is no simple rule of thumb to gauge heat recovery project economics as they rely on a variety of variables, however in many cases paybacks of <3 years can be achieved. Below is a list of variables to consider when retrofitting an existing power station along with indicators of favorable economics:

- Cost (CapEx and OpEx) of the heat recovery & delivery mechanisms [lower cost = better economics]
- Cost to produce the heating / air conditioning / purified water (e.g. fuel cost, OpEx, CapEx for a boiler) [higher displacement cost = better economics]
- Total hours when heat is available and can be used [more hours = better economics]
- Any incentives and/or demand charges that it offsets [more incentives = better economics]

There are many useful tools available for understanding how projects come together and the associated economics. Understandingchp.com has put together a useful calculator to estimate the economics for CHP projects when the heat used displaces a natural gas boiler.

> *"These [Cogeneration] technologies are ready for implementation today."*
> - Maria van der Hoeven. Executive Director, IEA (IEA)

Conclusion

Cogeneration isn't the silver bullet for the new energy economy, but it is a profitable means to have an immediate and sizable positive impact on the carbon intensity and efficiency of the power grid. While much emphasis is currently on new installations of cogeneration plants, it's important to also look at the existing enormous repository of engines, turbines, and fuel cells that currently do not use their heat and could be retrofitted to operate significantly more efficiently.

About the author

John Lerch has 9 years of experience in the power generation industry and is co-founder of HeatCalc, a platform that enables heat recovery projects throughout the world.
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