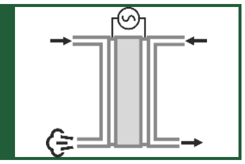
Fact Sheet:

Fuel Cells



Background

Fuel cell is a technique to produce electricity using two fluids (oxygen-rich and hydrogen-rich gases). Fuel cells are made of a cathode, an anode and an electrolyte (Figure 1). Different types of fuel cell technologies, called after their electrolyte composition, exist: Alkaline fuel Cell (AFC), Polymer electrolyte fuel cell, also called Proton Exchange Membrane fuel cell (PEM), Phosphoric Acid Fuel Cell (PAFC), Solid Oxide Fuel Cell (SOFC), and Molten Carbonate Fuel Cell (MCFC). Fuel cells convert the chemical energy from a fuel into electricity and heat [1].

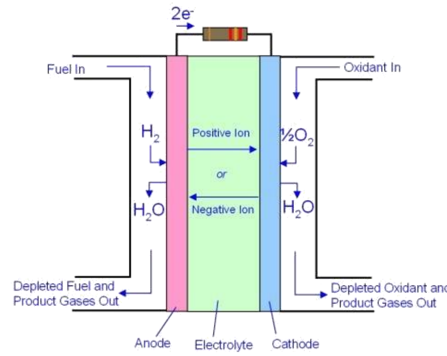


Figure 1: Schematic of a fuel cell [2].

Example of applications:

1 kW electricity and 1.8 kW heat system for residential CHP [3].

400 kW electricity and ~450 kW heat system for industrial supply or backup supply [4]

59 MW electricity power plant in South Korea [5].

Advantages

- No moving part
- Emit quasi no pollutant such as NOx, CO or SOx
- High efficiency up to 70%
- Suitable for cogeneration
- Complementary with a gas turbine cycle
- Versatility due to construction using modules allowing large range of power (from W to MW)
- Versatility of applications due to the variety of fuel cell types

Disadvantages

- Expensive
- New technology → reliability is yet unknown
- Emit CO2 when fuel other than hydrogen is used
- Fuel production can be problematic (pollution and/or low efficiency)

Properties

Temperature range:	60°C - 370°C
Power range:	1.8 kW_{heat} - 47 MW_{heat} (combined module)
Fuel range:	Hydrogen, natural gas, biogas, methanol, ethanol
Power density range (kw_{heat} par surface area):	1.1-2500 kw_{heat}/m^2 (median: 10 kw_{heat}/m^2)
Service life:	3'000 operating hours - 10 years
Price range:	n.a.

References

[1] L. Carrette, K. A. Friedrich, and U. Stimming, "Fuel Cells: Principles, Types, Fuels, and Applications ," ChemPhysChem, vol. 1, no. 4, pp. 162–193, Dec. 2000

[2] DiracDelta.co.uk, "Engineeing Site of the Day." [Online]. Available: http://www.eeweb.com/websites/diracdelta.co.uk.

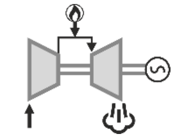
[3] www.hexis.com (accessed 23.09.2015)

[4] http://www.doosanfuelcell.com/en/markets/industrial.do (accessd 23.09.2015)

SCCER EFFICIENCY OF INDUSTRIAL PROCESSES

Fact Sheet:

Gas Turbine



Background

The basic operation of the gas turbine is as follows: atmospheric air comes from the intake, flows through the compressor. A fuel gas is then mixed with the high pressure air and the mixture is burned in the combustion chamber. High pressure and high temperature gases expand in the turbine producing a shaft work output. Gas turbines are often used to produce electricity by connecting the shaft to a generator. A combined cycle gas turbine reused the hot exhaust gas to create steam, electricity is then produced using a steam turbine. Exhaust gases can also be used for cogeneration (drying, producing hot water, etc.). Gas turbines are also used in aeroplanes where the high velocity of the exhaust gases is used to propel the aircraft.

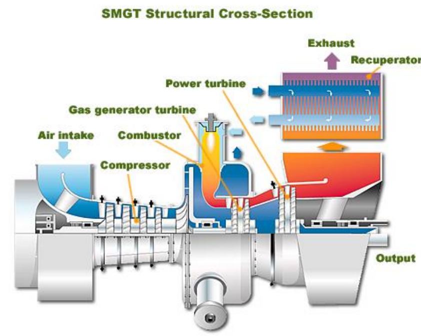


Figure 1: A schematic of a gas turbine. SMGT = Super marine gas turbine. [1].

Example of applications:

A 200 kW$_e$ cogeneration combined cycle gas microturbine in a food production plant in Naarn (Austria) [1].

A 24.5 MW$_e$ natural gas combined cycle GT produces steam for a pulp & paper industry in Girona (Spain) [2].

A 5'600 MW$_e$ power plant (21 GTs) using liquefied natural gas in Kawageo in Japan (Sweden) [4].

Advantages

- Produces electricity & heat
- Wide range of power
- Great reliability
- High electric efficiency (up to 60%) when used in combined cycle
- Can be combined

Disadvantages

- Produces non negligible emission of NOx and CO
- Slow starting time
- High cost
- Slow response to change in power demand

Properties

Temperature range:	370°C - 600°C
Power range:	30 kW$_{heat}$ – 1.2 GW$_{heat}$ (for 1 GT)
Fuel range:	Gas (natural gas, liquefied natural gas, biogas, etc.)
Power density range (kw$_{heat}$ par surface area):	87–344 kw$_{heat}$/m^2 (median: 183 kw$_{heat}$/m^2)
Service life:	n.a.
Price range:	n.a.

References

[1] http://content.stockpr.com/capstoneturbine/db/Case+Studies/794/pdf/CS_CAP412_Machland_lowres.pdf (accessed 24.09.2015)

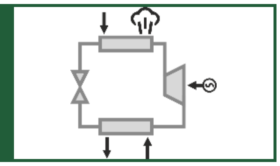
[2] https://turbomach.cat.com/cda/files/4407199/7/Toraspapel.pdf (accessed 24.09.2015)

[3] http://www.lngworldnews.com/wp-content/uploads/2012/01/LNG-Cargo-Due-at-Futtsu-Terminal-February-19.jpg (accessed 24.09.2015)

SCCER EFFICIENCY OF INDUSTRIAL PROCESSES

Fact Sheet:

Heat Pumps



Background

A heat pump (HP) is a device moving thermal energy from a heat source to a heat sink. A heat pump is able to harvest heat from a source colder than the destination or heat sink. This technology uses a fluid called refrigerant which goes through a cycle. This cycle has different pressure levels as shown in Figure 1. Thus the temperature of the refrigerant changes through compression and expansion, for a mechanical HP, to be able to absorb heat in the evaporator and to release heat in the condenser. The pressure and the composition of the refrigerant is adapted according to the temperatures of the heat source and the heat sink. Other HP types using heat instead of mechanical compression exist such as absorption HP. Another type, the organic Rankine cycle (ORC) driven HP uses high-temperature heat to drive the compressor.

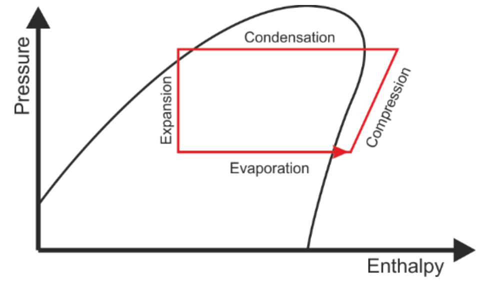


Figure 1: A schematic of a P-H diagram of a heat pump cycle.

Example of applications:

A 14 kW air-source HP for residential hot domestic water heating [1].

An 800 kW heating and 550 kW cooling system using 3 CO_2 HP in a slaughterhouse in Zürich (CH) [2].

A 180 MW system of 3 HPs using sea water as heat sink for district heating in Värtan Ropsten (Sweden) [3].

Advantages

- Produce more heat than electrical power required: coefficient of performance: COP > 1
- Emit no pollutant
- Able to reuse low-quality waste heat
- Very high efficiency for low temperature lift
- Can produce cooling at the same time

Disadvantages

- Maximal temperature is low
- Refrigerant leakage can cause environmental damage
- Is dependent on the carrier energy production in terms of emission
- Loss of efficiency for high temperature lift

Properties

Temperature range heat source:	-25°C to 50°C▣
Temperature range heat sink:	15°C to 90°C★
Power range:	1 kW_{heat} – 180 MW_{heat} (6 units combined)
Fuel range:	Electricity (mechanical HP), heat (ORC driven HP & absorption HP)
Power density range (kW_{heat} par surface area):	13–295 kW_{heat}/m^2 (median: 90 kW_{heat}/m^2)
Service life:	n.a.
Price range:	n.a.

▣ depends on heat sink temperature, ★ depends on heat source temperature

References

[1] http://kaldogvarm.no/produkter/luft-vann-varmepumpe (accessed 24.09.2015)
[2] http://www.durr-thermeco2.com/de/projekte/item/386-schlachtbetrieb-zuerich (accessed 24.09.2015)
[3] http://www.friotherm.com/webautor-data/41/vaertan_e008_uk.pdf (accessed 24.09.2015)

SCCER EFFICIENCY OF INDUSTRIAL PROCESSES

Fact Sheet:

Solar Thermal Collectors

Background

Solar thermal collectors absorb solar radiation and transform it directly to heat. Several types of collectors are available on the market. Distinction can be made between concentrating and non-concentrating systems. The most common non-concentrating collector types are flat plate and evacuated tube collectors and are usually used for domestic hot water and space heating.
Concentrating collectors, such as parabolic trough and Fresnel collectors, need a solar tracking mechanism and are therefore more complex on the system level. However, these systems reach higher temperatures and can hence be used to supply industrial process heat (commonly up to around 300 °C). Solar thermal collectors are usually combined with a heat storage in order to have heat available during the night or cloudy days.

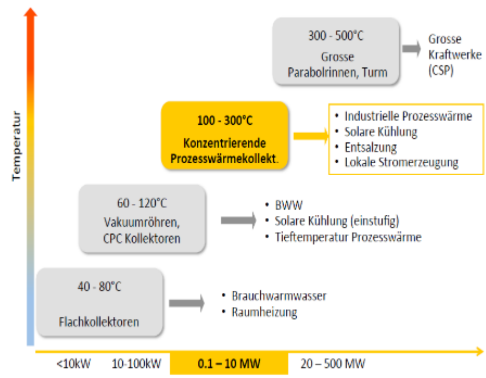


Figure 1: Temperature vs power [reference]

Flat collector

Vacuum tube collector

Collector filed in industry (Parabolic trhough collector)

Advantages

- Energy from renewable source
- Emission-free
- Various system design options for different applications and temperature ranges

Disadvantages

- Heat storage necessary
- Efficiency is weather and season dependant
- Long payback period

Properties

Temperature range [°C]:	40°C-300°C*
Power range [kW_{heat}]:[Δ]	list smaller and bigger peak value for industrial system used
Fuel range:	no need for fuel
Power density range (kw_{heat} par surface area):	NEED VALUE ?-0.6 kw_{heat}/m^2
Service life:	~ 25 years
Price range:	n.a.

References

[Δ]actually on the market

*Excluding high concentrating solar plants

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