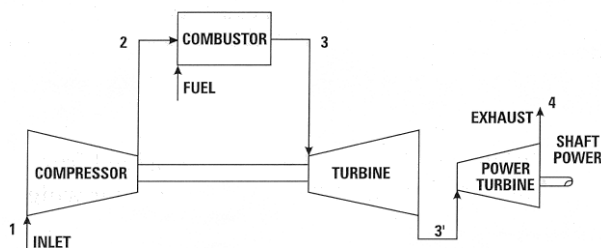


## Theory

Gas Turbines (GT's) generate power by means of the Brayton cycle as shown on the schematic below.



A working gas (typically ambient air) is compressed in the compressor, then fed with fuel and ignited. The high temperature, high pressure combustion products are then expanded through turbines to generate shaft power for the compressor and the electrical generator. This happens on a continuous basis.

The schematic above shows two shafts but single shaft machines are also common where the compressor and the various turbine stages rotate at the same RPM's. The electrical generator and the turbine shaft are typically coupled with a gearbox.

Waste heat is mostly available in the form of hot exhaust gases (~500°C) leaving the GT. There are also small amounts of low grade heat rejected by the GT enclosure and lube oil cooler.

Gas turbines have been used extensively for power generation initially to provide peaking power but more recently as the main component in the Combined Cycle Gas Turbine power stations.

There are two types of gas turbines: those derived from aeronautical engines and those originally designed for industrial and

power generation applications.

## Industrial machines

These are typically of a heavy weight and robust construction and are designed for a long life with less frequent maintenance overhauls. They are sometimes referred to as frame-type machines.

## Aeronautics derived machines

Referred to as aeroderivatives, these are characterised by low weight and high efficiency (lower exhaust temperature) and high complexity. For this reason, they will typically have higher maintenance costs. Capital costs can be lower as the machine may benefit from mass production in the aeronautical sector.

## GT Sizes available

Conventional gas turbines are available from 500 kWe to over 100 MWe. They are produced in discrete sizes with relatively few machines available in sizes suitable for CHP for buildings.

Microturbines (about the size of a refrigerator) in the range of 25 – 500 kWe fill the gap for smaller building applications. The mass of an 80 kWe micro-turbine CHP package is about 2 tonnes.

In general, HV (11 kV) generators will be used above 2 MWe.

## Waste heat recovery

Hot exhaust gases from the GT will be fed into a heat recovery steam generator (HRSG) or hot water for use in the building or process. The main advantage of a gas-turbine CHP system over an IC engine alternative is that all of the waste heat is

available at a high temperature. For this reason, gas turbines have been predominantly used for industrial process CHP applications. For building applications, gas turbine CHP would be most suited to large sites where high temperature hot water or steam is currently used as the distribution medium or where steam is needed for process use. Where absorption chillers are being considered the higher temperatures available would reduce the capital cost of absorption chillers and potentially improve their CoP.

It is also relatively easy to dump surplus heat by means of a bypass stack which will release the exhaust gases.

A further advantage is that additional heat can be produced at a high thermal efficiency (100% NCV or more) by means of supplementary firing. The waste heat boiler can also be auxiliary fired (fresh air firing) so that heat can be produced without the gas turbine operating. These options provide flexibility in operation and potentially a lower capacity for peak and standby boilers.

### Efficiencies

The main disadvantage of gas turbines when compared to reciprocating engines is the lower efficiency, particularly for smaller sizes. Depending on size, the efficiency of GT's ranges from about 20% (NCV) to 40% or higher. The net efficiency also depends on the power required for fuel compression so the available natural gas supply pressure is an important factor to consider at an early stage.

Overall CHP efficiency depends partly on the temperature at which the exhaust gas leaves the heat recovery boiler which in turn is determined by the temperature of the heating medium. Typical upper limit for CHP efficiency is around 75% (GCV).

At part-load, the electrical efficiency of the GT reduces markedly so this should be avoided by sizing the CHP appropriately, using multiple units or incorporating thermal

storage.

The power output from a gas turbine is significantly affected by ambient temperature – the output decreases as ambient temperatures rise.

Several measures are available to augment the power or efficiency of gas turbines: inlet air heating or cooling, inlet fogging, steam injection, water injection, or fuel pre-heating. Manufacturers should be consulted before any of these are considered.

### Environmental impacts

NOx production is relatively low due to the external combustion which can be carefully controlled. Low NOx combustion technologies (dry low NOx - DLE) have been developed as a response to air quality concerns from aircraft and major power generation plant. Typical NOx emissions are 0.2g/kWhe.

Noise and vibration can be controlled by means of silencers and acoustic enclosures without undue difficulty as a rotating machine does not give rise to high vibration levels and the high speed of rotation results in higher frequency noise which can be attenuated more easily.

### Maintenance aspects

Gas turbines will have a higher availability than reciprocating engines and a more complex maintenance regime. The replacement of those elements subject to very high temperatures will be required around every 30,000 hours of continuous operation (overhaul). The maintenance schedule is normally defined by the equivalent running hours with each start-up accounting for a number of hours operation. A long-term maintenance contract with the supplier is normally necessary and advisable.

### Practical considerations

Although the size of the turbine itself is very compact, a large volume of combustion air

is required and this has to be filtered to a high quality. The most bulky part of the plant is frequently the air intake filters and silencers.

Gas turbines are not as heavy as a similar size reciprocating engine set; the weight of a 1.2 MWe gas turbine package is 8 tonnes. The weight of a heat recovery boiler may be significant however.

### **Benefits of GT's over reciprocating engines**

For building applications, a GT will usually compete with a reciprocating engine characterised by higher electrical efficiency.

Benefits of GT's include:

- Higher waste heat temperatures
- Higher availability
- Fuel flexibility: GT are able to burn "dirtier" gases than reciprocating engines
- Less vibration and noise.
- Less moving parts and therefore cheaper maintenance
- Compactness
- Possibility of supplementary firing.

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This datasheet was produced by the CHP Group of the Chartered Institution of Building Services Engineers (CIBSE) to inform building professionals about all forms of CHP. To join or contact the CHP Group go to [www.cibse.org/chp](http://www.cibse.org/chp) or contact CIBSE, 222 Balham High Road, London, SW12 9BS (020 8675 5211).

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