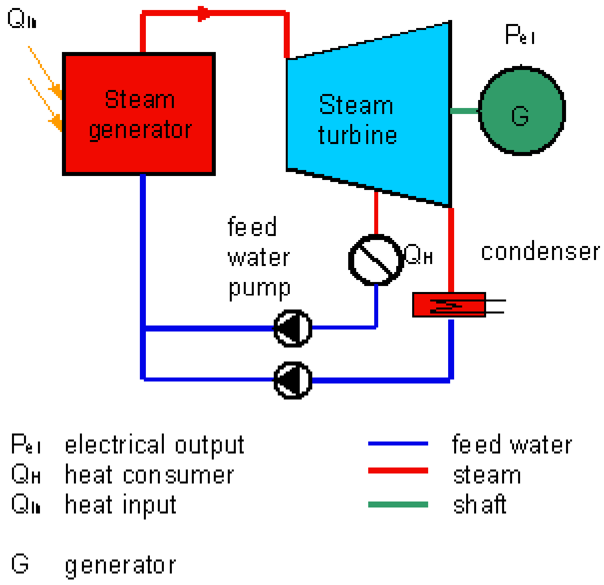
CHP with gas turbine cycle

>> Basic principle

- Conversion of mechanical energy (turbine) into electrical energy with the help of the generator.
- Utilization of gases escaping from the turbine for heat supply.

Figure 8: Basic principle of CHP with gas turbine cycle



The basis for this type of CHP is the gas turbine cycle which is explained in more detail in the following.

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>> Gas turbine cycle

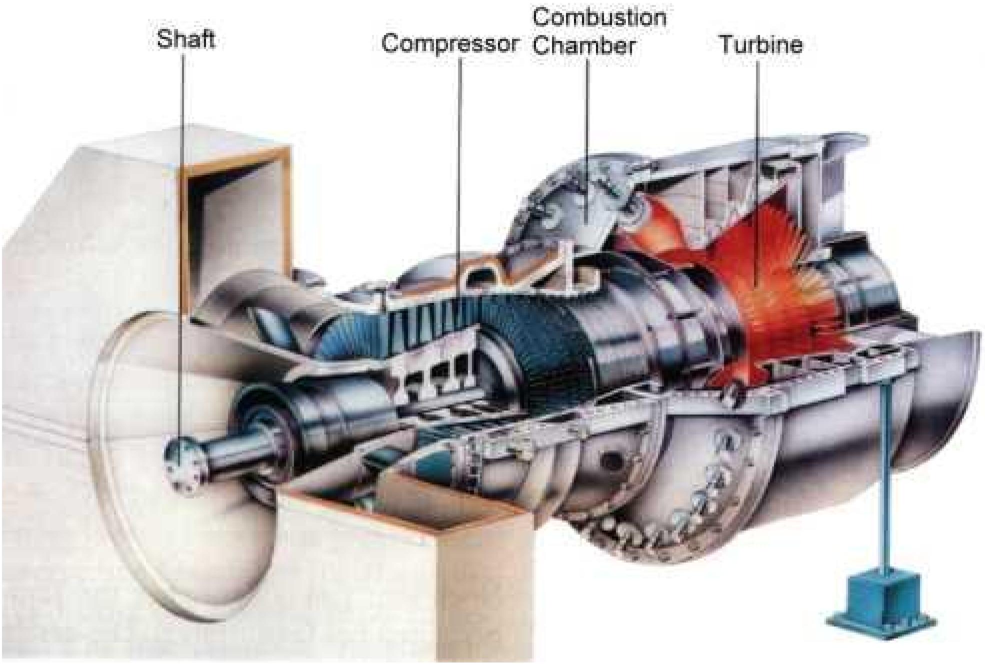
The main elements of the gas turbine cycle are: the compressor, the combustion chamber and the turbine.

Surrounding air is sucked in and compressed in a compressor. Subsequently it is fed into the combustion chamber where a combustion reaction takes place when fuel (gas, oil…) is added. The exhaust gas resulting from the combustion is expanded in the turbine. The turbine drives the compressor as well as the generator responsible for power generation. The exhaust gas leaves the turbine with a temperature of about 400-600°C and in the simple gas turbine cycle escapes into open air without any further utilization.

For further utilization of this heat a heat exchanger transferring heat energy to another medium (mostly water) is required. For this process there are various set-ups described in more detail in the following.

The following figure shows a gas turbine from Siemens (Siemens V64.3) for higher output.

Figure 9: Section through a gas turbine of higher output



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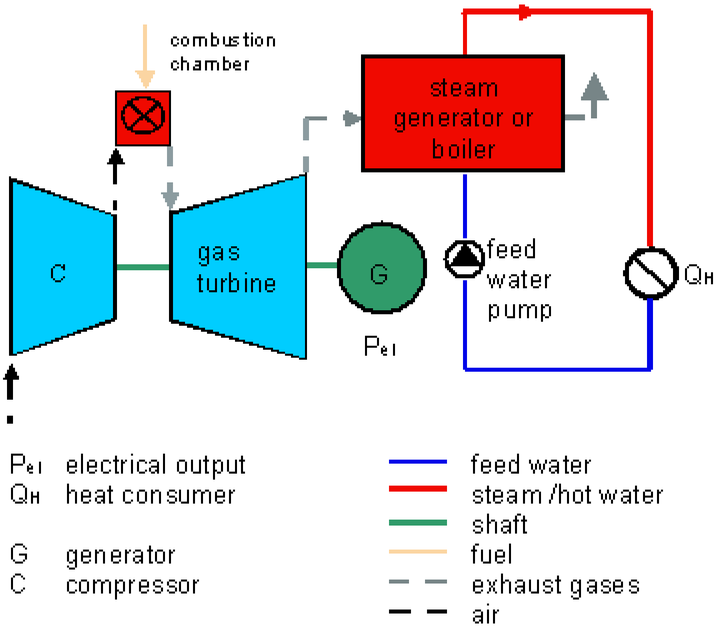
>> Gas turbine cycle with heat recovery

Functionality

In this process the heat content of the turbine exhaust gases is entirely used for supplying heat. This heat is then available for heating purposes, drying processes or other processes requiring heat (e.g. absorption refrigerating machines).

Figure 10: Gas turbine cycle with heat recovery



Application

- for generation of electrical output and heat from ~ 30 kWel
- when a relatively constant amount of heat is required

Possible fuels

- gas
- petroleum
- gasification of coal
- ...

In table 5 some data from a plant within a certain range of performance is outlined.

Table 5: Data of a gas turbine plant with heat recovery

Plant size ~20 MWel	Unit	Value
Specific investment costs	[EUR/kWel]	~ 1.200
Specific maintenance costs	[EUR/kWhel]	~ 0,007
Electrical efficiency [etha]el	[%]	25 - 35
Overall efficiency	[%]	70 - 92
Emissions (NOx)	[mg/Nm³]	~ 25

Best operational mode

Power or heat operated.

Figure 11: Gas turbine type FP-16-G with an electrical output of about 1,6 MW (Source: FP Turbomachinery)

Operating state

Gas turbines of medium and higher output (~20 MWel and more): Peak temperature: ~1200 °C

Control

Control of the gas turbine is mostly achieved through the amount of fuel injected into the combustion chamber of the turbine. To cover increased heat requirements there is an auxiliary firing equipment in the waste heat boiler.

Stage of development/ outlook

CHP plants with gas turbines are well-established and therefore used in big quantities all over the world.

Trends are definitely going towards higher temperatures and pressures resulting in increased output and efficiency.

Some important parameters regarding stage of development and outlook are summed up in the following table.

Table 6: Stage of development/ outlook

Stage of development/ outlook	status
Present stage of development	ready for the market 1)
Short term cost reduction potential	medium 2)
Short term development potential	low 2)
1) Stages of development: concept stage, laboratory stage, pilot stage, demonstration stage, market maturity 2) 1 year...high, 2 years...medium, 3 years...low	

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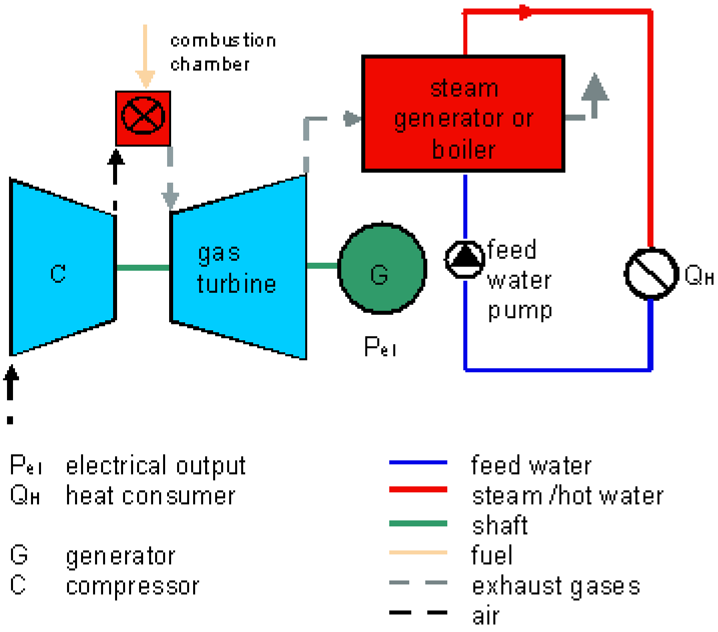
>> Cheng-Cycle (Steam Injected Gas Turbine, STIG)

Functionality

The so-called Cheng-Cycle (STIG-Cycle) offers another variant of the gas turbine cycle with utilization of waste heat. The generated steam is partly fed into the combustion chamber and the turbine. Thus output and electrical efficiency are significantly increased. It also allows an adjustment to the heat requirements of the plant so there can be more or less steam fed into the gas turbine according to the requirements.

Figure 12: Cheng-Cycle



Application

- variable power and heat requirements
- for higher output (~20 MWel and more)

Possible fuels

- gas
- petroleum
- gasification of coal

Advantages

- released heat can be varied
- increase in gas turbine output and electrical efficiency

Disadvantages

- Processing of steam fed into the gas turbine is expensive

In table 7 some data from a plant within a certain range of performance is outlined.

Table 7: Data of a Cheng-Cycle

Plant size ~20 MWel	Unit	Value
Specific investment costs	[EUR/kWel]	~ 1.300
Specific maintenance costs	[EUR/kWhel]	~ 0,007 - 0.011
Electrical efficiency [etha]el	[%]	40
Overall efficiency	[%]	70 - 85
Emissions (NOx)	[mg/Nm³]	~ 25

Best operational mode

Power or heat operated

Operating state

- Gas turbines of medium and higher output (~20 MWel and more)
- Peak temperature: ~1100 °C

Control

Control of the electrical output is achieved through fuel supply into the combustion chamber of the gas turbine and through variation of the amount of steam injected into the turbine.

Control of the released heat is achieved through variation of the amount of steam injected into the turbine.

Stage of development/ outlook

CHP plants with Cheng-Cycle are well-established and therefore used in big quantities all over the world.

Trends are definitely going towards higher temperatures and pressures resulting in increased electrical output and efficiency.

Some important parameters regarding stage of development and outlook are summed up in the following table.

Table 8: Stage of development / outlook

Stage of development / outlook	status
Present stage of development	ready for the market 1)
Short term cost reduction potential	medium 2)
Short term development potential	medium 2)
1) Stages of development: concept stage, laboratory stage, pilot stage, demonstration stage, market maturity 2) 1 year...high, 2 years...medium, 3 years...low	

Microturbine

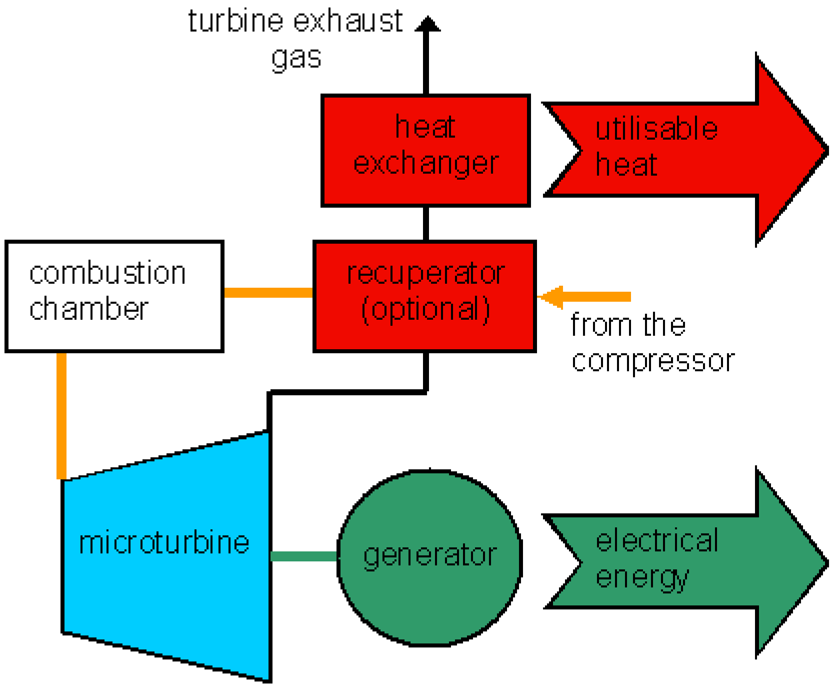
Eine interessante Möglichkeit zur Realisierung kleinerer Leistungen (ca. 30 - 300 kW und weniger) bieten die sogenannten Mikroturbinen.

Functionality

In contrast to a gas turbine cycle with heat recovery, block construction is possible because of the compactness of the plant. Therefore this microturbine plant can also be seen as a block heat and power plant. Yet electrical efficiency of the plant is relatively low (~15-25%) because of its small size.

In order to achieve good electrical efficiency despite low peak temperatures usually a heat exchanger (recuperator) is used for preheating combustion air with the help of hot turbine exhaust gas. Another heat exchanger is used for obtaining process heat. If the first heat exchanger can be switched off the released process heat can be increased at the expense of electrical efficiency if required. This enables a very good adjustment to variable heat requirements.

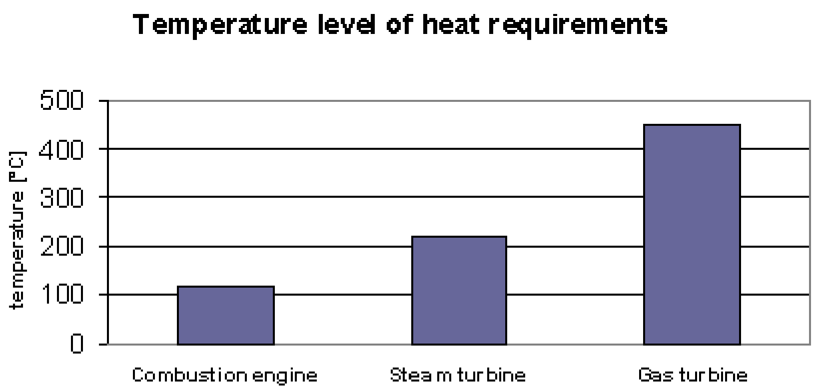
Figure 13: Diagram of a microturbine



Besides block heat and power plants equipped with gas or diesel engines, recently also microturbines are gaining importance as another variant of a block CHP plant. If, however, high waste heat temperatures are required the microturbine represents the better solution.

Figure 14 shows the temperature level at which heat is available for different concepts. A high temperature level is usually put down to worse electrical efficiency. Therefore bigger heat quantity, that has to be taken in account in the design, is obtained in the gas turbine if electrical efficiency of the gas turbine and the internal combustion engine are equal.

Figure 14: Temperaturniveau der bereitgestellten Wärme



Application of microturbines

- steam generation in small boiler plants
- high temperature water networks over 100°C
- drying plants
- hospitals
- laundries
- local heat networks
- ....

Possible fuels for microturbines

- natural gas
- fuel oil
- liquid gas
- sewage gas
- firedamp
- petroleum associated gas
- ...

Advantages

- compact design
- low maintenance costs at maintenance intervals of at least 8000 hours of operation
- easy installation
  Because of compact design and low plant weight it is possible to keep a small plant area.
- adjustment of heat and power requirements is possible
- quiet because there are no low frequency noise emissions

Disadvantages

- full market maturity of the technology is not yet achieved

In table 9 some data from a plant within a certain range of performance is outlined.

Table 9: Data of a microturbine

Plant size ~20 MWel	Unit	Value
Specific investment costs	[EUR/kWel]	~ 650 - 1.100
Specific maintenance costs	[EUR/kWhel]	~ 0,005 - 0.007
Electrical efficiency [etha]el	[%]	15 - 25
Overall efficiency	[%]	70 - 90
Emissions (NOx)	[mg/Nm^3]	20

Best operational mode

Power or heat operated.

Figure 15: Microturbine type FP-CS-30 with a heat output of about 69 kW (Source: FP Turbomachinery)

Operating state

For microturbines of low output (~55 kWel):

- Exhaust gas temperature: ~600 °C
- Pressure ratio: 3 - 5
- Rotational speed: 105.000 rpm

Control

Control of the gas turbine is usually achieved through fuel supply.

Maintenance

Part	Action	Maintenance interval
Air filter and fuel filter	replace	8.000 hrs.
Turbine exhaust gas thermocouple	replace	16.000 hrs.
Ignition	replace	16.000 hrs.
Fuel injection	replace	16.000 hrs.
		(Source: Capstone)

Stage of development

The breakthrough of the microturbine has not yet been achieved in Austria. However in the USA they are often used and have therefore already reached high technological maturity.

Because of their easy handling and high overall efficiency they will soon win recognition in Austria too and will offer an alternative possibility to block heat and power plants with internal combustion engines.

Some important parameters regarding stage of development and outlook are summed up in the following table.

Table 10: Stage of development / outlook

Stage of development / outlook	status
Present stage of development	Demonstration stage to market maturity 1)

Short term cost reduction potential	high 2)
Short term development potential	medium 2)
1) Stages of development: concept stage, laboratory stage, pilot stage, demonstration stage, market maturity 2) 1 year...high, 2 years...medium, 3 years...low	

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>> General information on the gas turbine cycle

Ecological aspects

When using natural gas in gas turbines very low emission values can be obtained. The NOx content amounts to 25 ppm, the CO content can be further reduced with the help of a downstream catalyst.

Weak points

Thermodynamics:
High efficiency of gas turbines can be achieved through high turbine inlet temperatures of up to 1300 °C. This process requires expensive material and complex technologies for blade cooling. Therefore gas turbines of highest efficiency are very maintenance intensive.