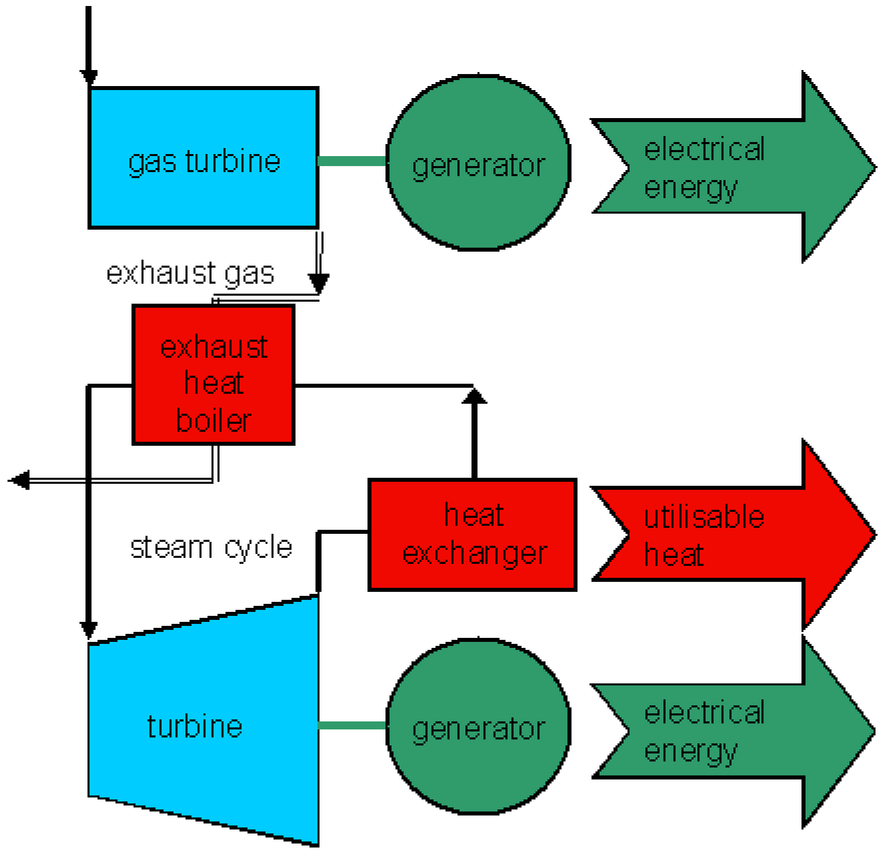
CHP with combined steam-and-gas cycle

>> Basic principle

- Mechanical energy (gas turbine and steam turbine) is converted into electrical energy with the help of a generator.
- Hot gases escaping from the gas turbine are used for generating steam for the steam turbine.
- Heat energy of the steam escaping from the turbine is used for providing heat.

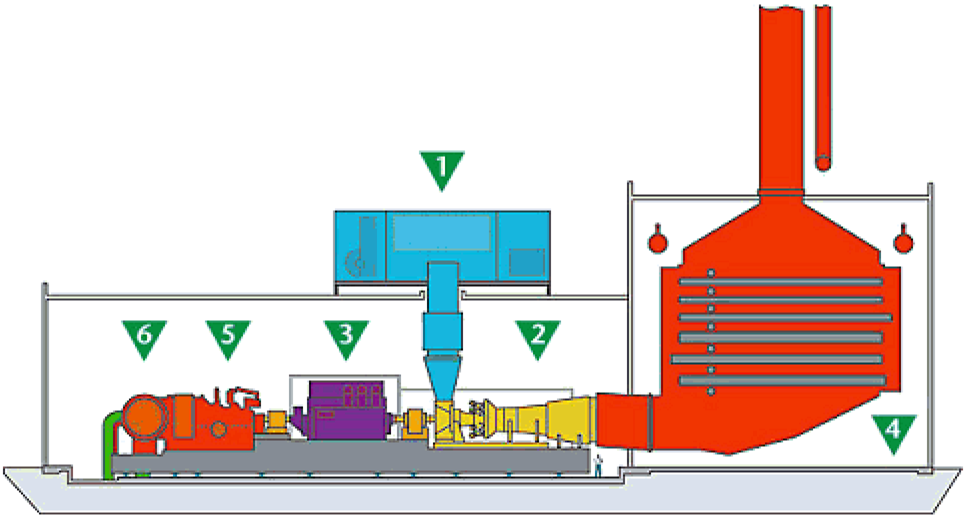
Figure 16: Principle of CHP with combined steam and gas cycle



The following figure (Source: GEW Köln AG) shows a simplified section through a combined steam and gas plant with its most important components:

1. Air filter at the compressor inlet
2. Gas turbine
3. Generator
4. Waste heat boiler
5. Steam turbine
6. Condenser

Figure 17: Section through a combined steam and gas plant



The steam turbine cycle can again be carried out in backpressure operation or in extraction condenser operation.

These two types are explained in more detail in the following.

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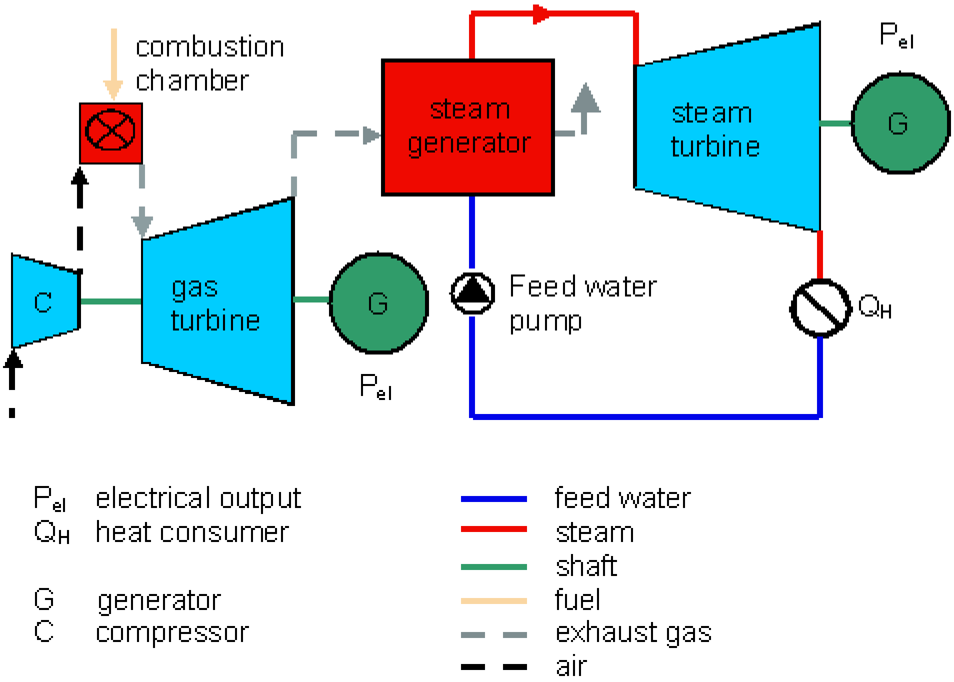
>> Combined steam and gas turbine cycle with back pressure turbine

Functionality

The combined steam and gas cycle is a combination of the steam turbine cycle and the gas turbine cycle. Exhaust gases from the gas turbine are used for generating high pressure steam which is later expanded in a steam turbine. Electrical output is reached by the gas turbine as well as the steam turbine. The steam escaping from the steam turbine can further be used for providing heat.

Figure 18: Combined steam and gas cycle with back pressure turbine



Application

- for power and heat requirements of higher output (> 10 MW electrical)
- if a constant process heat is required (e.g. paper mill)
- if high electrical efficiency is required

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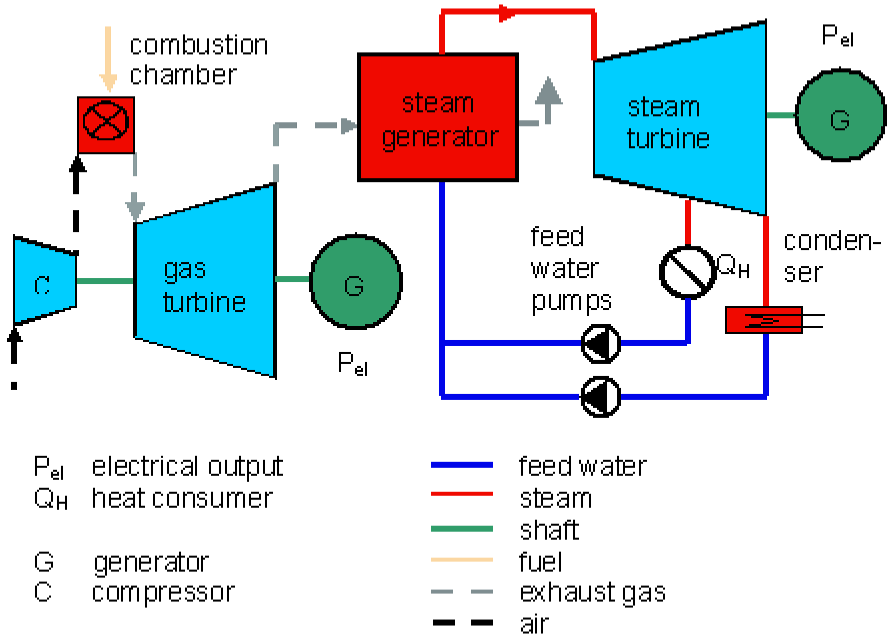
>> Combined steam and gas cycle with extraction condensing turbine

Functionality

The functionality is based on the same principle as the combined steam and gas cycle with back pressure turbine, but with the difference that here extraction steam for heat generation is not taken from the end of the turbine but from the middle part. This has the advantage that heat as well as power generation can be better adjusted to the different requirements.

Figure 19: Combined steam and gas cycle with extraction condensing turbine



Application

- for heat and power requirements of higher output (> 10 MWel)
- different requirements concerning heat and power requirements
- if high electrical efficiency is required

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>> General information on the combined steam and gas cycle

Possible fuels

- gas
- petroleum
- fuels obtained through gasification of biomass or coal

Advantages

- high electrical efficiency
- sophisticated technology

Disadvantages

- expensive operation
- only suitable for higher output (electrical)

In table 11 some data from a plant within a certain range of performance is outlined.

Table 11: Data of a combined steam and gas cycle

Plant size ~40 MWel	Unit	Value
Specific investment costs	[EUR/kWel]	800
Specific maintenance costs	[EUR/kWhel]	~ 0,007 - 0,011
Electrical efficiency [etha]el	[%]	up to 50 (55)

Overall efficiency	[%]	up to 85 (90)
Emissions (NOx)	[mg/Nm³]	~ 25

Best operational mode

Power or heat operated

Operating state

Decentralized CHP plants of medium output:

- **gas turbine:**
  - peak temperature: ~1150 °C
  - pressure: ~ 12 bar
- **steam turbine cycle (often also run as a double-pressure cycle):**
  - steam pressure: ~50 bar
  - live steam temperature: ~ 400 °C

Control

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

Control of the steam turbine is on the one hand reached through the steam condition in the heat recovery steam generator which depends on the output of the gas turbine.

On the other hand the steam turbine can be controlled as follows:

- Through a throttle valve in front of the turbine controlling steam pressure and output
- Through nozzle group control in the individual turbine, which allows individual nozzles in front of the first blade wheel to be switched in or off. Thus the mass flow rate as well as the output of the turbine can be regulated.

Maintenance

Gas turbine cycle:
· Inspection of the fuel piping, the turbine casing, etc. once a week

Steam cycle:
Inspection of the steam piping once a week
Regular inspection of the steam conditions
Every 5 years a more extensive one-week revision should be conducted

Ecological aspects

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

Steam cycle:
During the vaporization process of water the salts contained in the water remain in the boiler. In order to avoid high salinity (scale build-up!) water is continuously desalinated (1-5 % of the circulated feed water).

In addition it is necessary to discharge the mud resulting from material abrasion and the remaining salts in the water (manually or automatically).

When discharging sewages into a stream or into the sewerage system, the corresponding legal regulations have to be complied with.

Weak points

Thermodynamics:
The greatest losses occur in the heat recovery steam generator because of the great temperature differences between the cooling curve of the exhaust gas and the heating curve of the steam including vaporization. Therefore often double pressure as well as triple pressure cycles are used in order to achieve a better adjustment of the steam curve to the exhaust gas curve.

Costs:
The operation of combined steam and gas plants is very expensive. Yet they show remarkably high electrical efficiency. In CHP they are usually used if a high amount of power is required.

Stage of development/outlook

CHP plants with combined steam and gas cycles use a well-established technology and therefore used in big quantities all over the world.

Trends are going towards gas turbines with high exhaust temperatures in order to have the possibility to connect a downstream steam cycle with high efficiency.

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

Table 12: Entwicklungsstand / Aussichten

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	