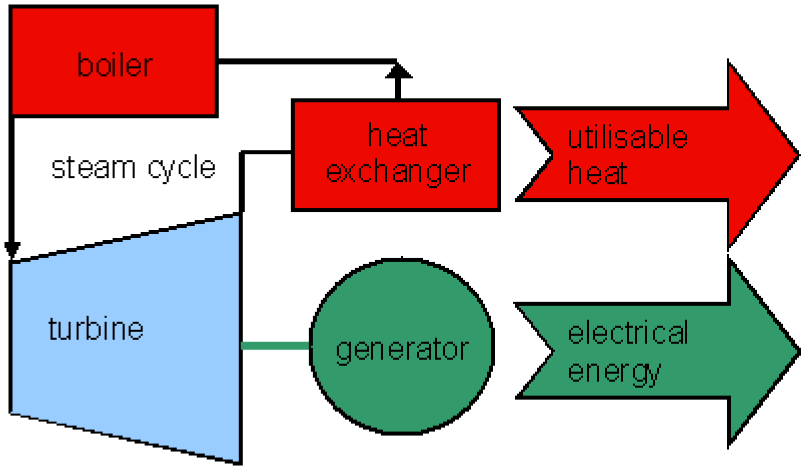
CHP with steam turbine cycle

>> Basic principle

- Conversion of mechanical energy (turbine) into electrical energy with the help of a generator.
- Utilization of the heat energy of the steam discharging from the turbine to provide heat.

Figure 2: Principle of CHP with steam turbine cycle



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

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>> Steam turbine cycle

The main elements of a steam turbine cycle are: the boiler with super-heater, the turbine, the condenser and the feed water pump.

The water is vaporized in the boiler and later brought to the desired temperature in the super-heater. This live steam then is flowing through the turbine which drives the generator to generate power. In the condenser the steam discharging from the turbine condenses and is brought to process pressure with the help of the feed water pump. Afterwards the steam is fed into a boiler whereby the cycle is closed.

As a cooling medium in the condenser usually river water or surrounding air will be used, and the released condensation heat remains unused.

To use this waste heat there are a series of different configurations allowing the usage of any incidental heat. It is crucial though that for using waste heat a higher pressure and temperature level is required.

The following figure shows a section through a steam turbine for high output which consists of a high pressure-, a medium pressure- and a low pressure section . In this kind of machines about 70 % of live steam from the low pressure sections is passed on to the condenser, the remaining 30 % are used for preheating feed water and afterwards are fed to the steam cycle.

Figure 4 shows the rotor of a steam turbine with an output of 8 MWel.

In figure 5 a plant with a condensation steam turbine is depicted. The plant has an electrical output of 10MW.

Figure 3: Section through a steam turbine

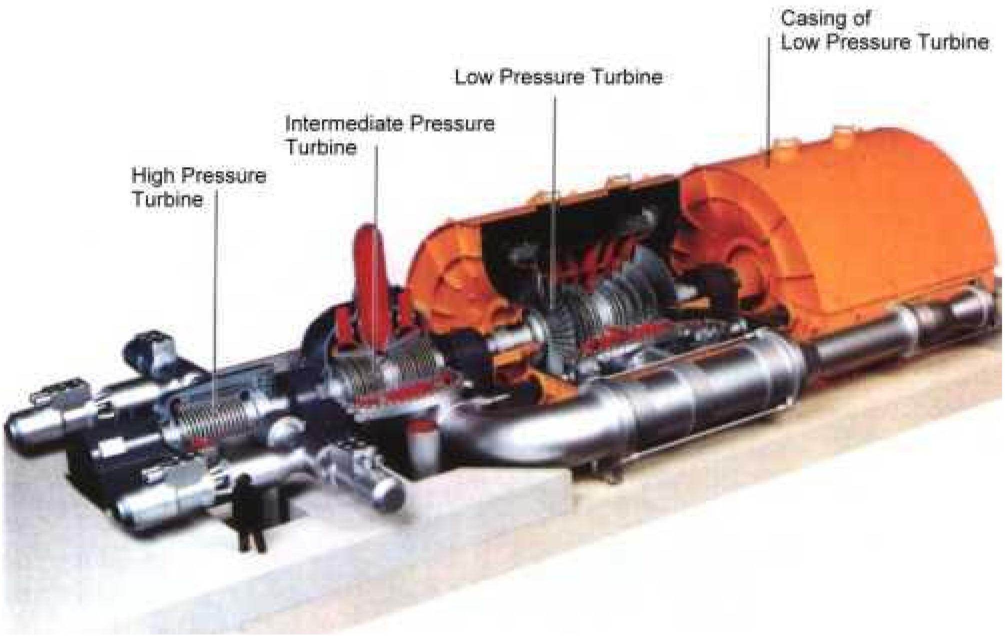

Figure 4: Rotor of a steam turbine with 8 MWel (Source: Peter Brotherhood Ltd)

Figure 5: A condensation steam turbine with 10 MWel (Source: Peter Brotherhood Ltd)

There are two main types of CHP plants based on steam cycle:

- Steam cycle with a back pressure turbine
- Steam cycle with an extraction condensing turbine

For lower heat output steam is extracted by tapping the steam turbine and therefore the technical design is simpler compared to an extraction condensing turbine. Yet pressure and temperature during the tapping process can only be kept when run in full load.

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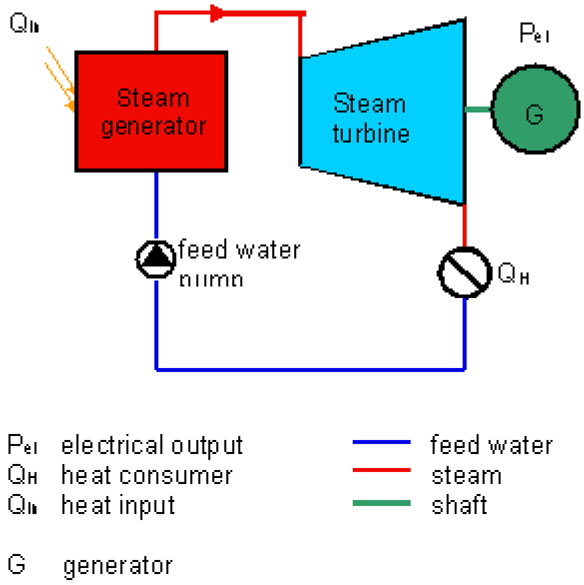
>> CHP with steam cycle and back pressure turbine

Functionality

In a turbine (back pressure turbine) the hot steam produced in the boiler is expanded down to back pressure which results from the desired temperature of the process heat. Thus it is performing mechanical work for the generator. The generator transforms mechanical energy into electrical energy. Heat exchangers outside the turbine can be used to pass the remaining heat quantity of the steam to another medium (e.g. water) with the help of condensation. This heat quantity can now be utilized in different ways. Later the condensed steam is fed to the steam generator again with the help of water preparation through a feed water pump. Thus the cycle starts again. Valves on the turbine are used for control.

This design is mostly used when a more or less constant amount of heat is required.

Figure 6: Steam cycle with back pressure turbine



Application

- Industry and power supply enterprises (electricity, district heating), (outputs of ~0,5-30 MWel and more)
- When a constant amount of heat is required (because of little possibilities of control)
- Very often there are various steam turbines arranged on a line in order to allow using one or more turbines according to the requirements.

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>> CHP with steam cycle and extraction condensing turbine

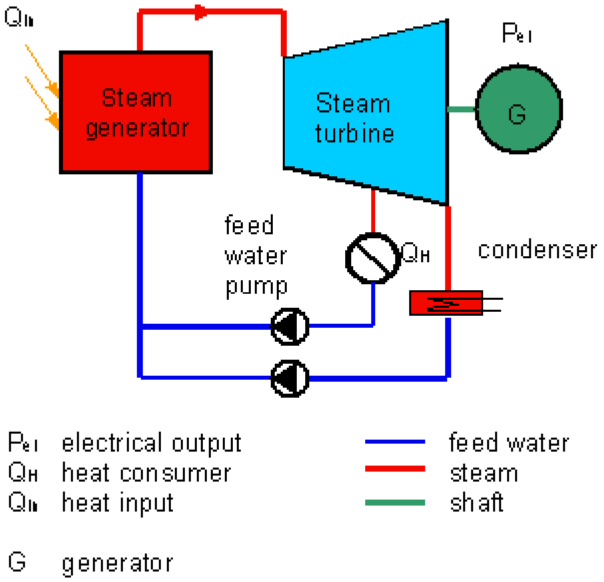
Functionality

The functionality is similar to that of a cycle with back pressure turbine with the difference that here the extraction steam for heat generation is not taken from the rear part but from the middle part of the turbine. This has the advantage that heat and power generation can be adjusted to the different requirements.

With the help of valves the extraction pressure can be adjusted right at the extraction point so that the required steam conditions for heat generation can also be kept when run at part load. This is the advantage over the topping steam turbine where the conditions vary according to the load point.

To meet the demands of high heat requirements all steam for heat generation can be taken from the extraction point. For low heat requirements this type of turbine can be used like a conventional condensing turbine. Various other operational modes are possible due to valve control.

Figure 7: Steam cycle with extraction condensing turbine



Application

- medium to higher output (~0,5-10 MWel and more)
- variable heat and power requirements

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>> General information on CHP with steam turbine cycle

Possible fuels

- coal
- petroleum
- biomass, garbage
- basically every fuel is possible that can be burnt in a boiler

Advantages

- basically every fuel can be used
- well-established technology
- size of plants is not limited

Disadvantages

- low electrical plant efficiency
- bad part load performance
- expensive operation

In table 3 some data from a plant within a certain range of performance is outlined.

Table 3: Data of a back pressure steam plant

Plant size ~ 1 MWel	Unit	Value
Specific investment costs (with back pressure turbine)	[EUR/kWel]	~ 1.500
Specific maintenance costs	[EUR/kWhel]	~ 0,007
Electrical efficiency [etha]el	[%]	10 - 20

Overall efficiency	[%]	70 - 85
Emissions (NOx) - coal fired	[mg/Nm³]	~ 450 - 600

Best operational mode

Power or heat operated. Very often various steam turbines are arranged on one line so that one or more machines can be used according to power demands. Therefore it is possible to run the turbines close to the optimal operating point.

Steam conditions

Decentralized CHP plants of low to medium output (output ~1 - 10 MW)

- Steam pressure: 30 - 70 bar
- Live steam temperature: ~ 400 - 500 °C

Control

Control of the steam turbine can be reached through the following two possibilities:

- Through a throttle valve in front of the turbine which controls steam pressure of the flow leading from the steam line to the individual turbines as well as their output.
- Through nozzle group control in the individual turbine, which allows individual nozzles before the first blade wheel (control wheel) to be switched in or off. Thus the mass flow rate of the other stages as well as the output can be regulated.

Maintenance

- Inspection of the turbines and the steam pipelines for irregularities once a week
- Every 5 years a more extensive one-week revision should be conducted
- Regular inspection of steam conditions

Ecological aspects

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

a. **Thermodynamics:**
High electrical efficiency can only be achieved through high live steam pressure and temperature (170 bar, 600°C) at given condensation conditions. Since this requires expensive high temperature material, CHP plants of low and medium output are designed for lower live steam conditions.

b. **Operation:**
The operation of a steam plant is relatively expensive because according to the Austrian laws for steam boiler operation there always has to be a steam guard present.

c. **Biomass utilization:**
Live steam temperature in biomass plants is limited because of the increased danger of corrosion due to alkali metals, sulphur and chlorine contained in the fuel.
Variations in the water content of biomass can lead to changes in temperature and mass flow of the steam. In order to prevent this, it has to be taken into account in the control system.

Stage of development/outlook

Industrial steam turbines are well-established and therefore used in big quantities all over the world.

Trends are definitely going towards higher temperatures resulting in increased output . Therefore the development of high temperature proof material is of great importance.

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

Table 4: 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	