Thermal power stations

Educational text

Thermal plants and heating plants are energy generating plants for the electric power and heat production. It is also possible to come across to the term heating station, which is unlike the previous energy generating plants, intended only for heat distribution. According to the principal of electric power production nuclear power plants can also be included within thermal plants. However, in common user practice these energy generating plants are called by their own name.

On a global scale thermal plants take the main share of the electric power production. The main energy source of these energy generating plants are fossil fuels originated from dead plants and animals in the ancient times without the access to oxygen. We can count among them anthracite (the best quality hard coal), hard and brown coal, lignite (the youngest and least quality kind of brown coal), turf, crude oil and natural gas. These energy sources are considered to be non-renewable because after the depletion of reserves in a given deposit there is no way to renew the energy material which is extracted from the spot in a short time.

From renewable sources, which are used for this kind of generating stations, these are products of animal and plant origin. In the Czech Republic there is as the main source of energy mined brown coal, in the Most and Sokolov region. The hard coal extraction is only deep under the ground and is concentrated only within the Kladno and Ostrava-Karvina regions. The crude oil and natural gas reserves are insignificant in the CZ and they are extracted only in the South Moravian region and all the consumption is, therefore, covered by import. The main distributor for the CZ is Russia and a part of the natural gas consumption is covered by import from Norway.

Next natural materials, which can be used for burning and subsequent electric power production, are of plant and animal origin and they are used in bio power plants. There are also different kinds of waste, communal waste included, which are burnt in incineration plants. Energy sources of plant and animal origin are counted among renewable sources of energy. Waste is counted among scrap materials of energy because it was produced by a certain technological process and was not used in this process anymore. Among the main sources of thermal plants in the

CZ there are counted brown coal and natural gas. The produced electric power in power plants is conducted into the electric grid of the Czech Republic through generator block transformer where it is transformed for the required voltage level which fits into the voltage level of transmitting and distribution system.

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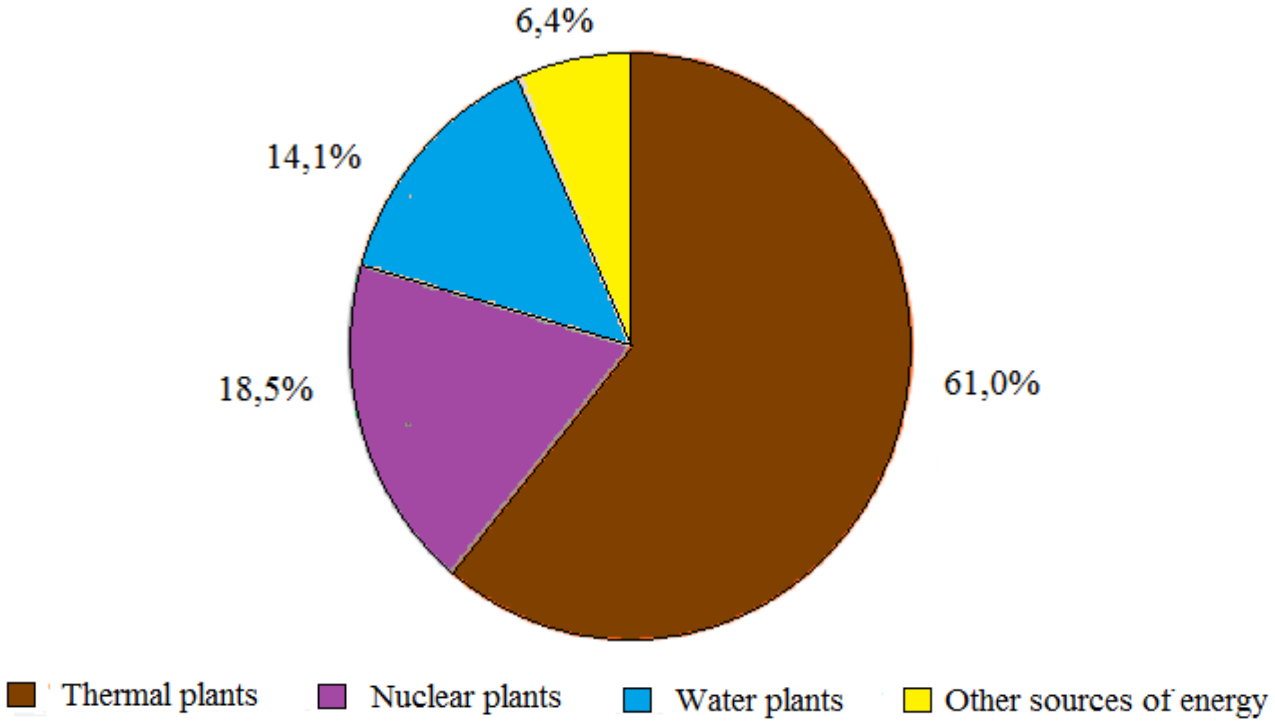
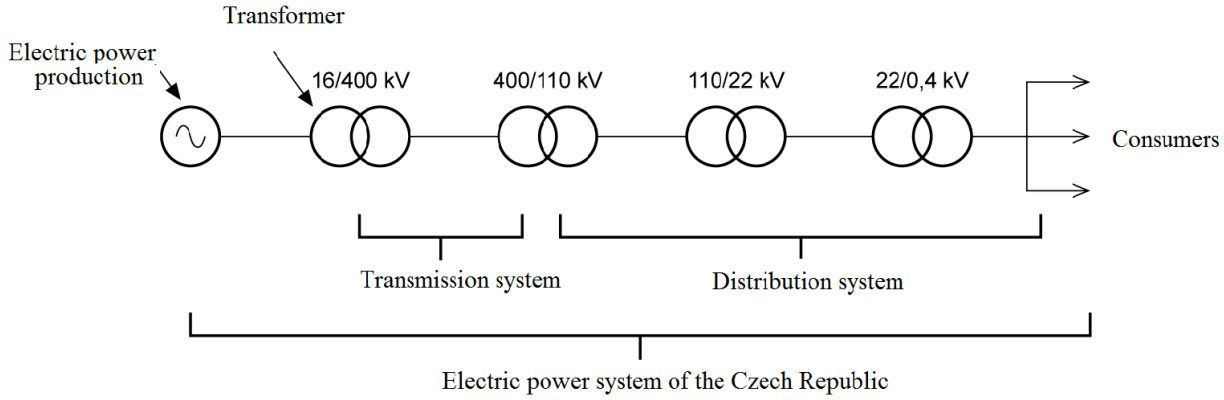
World electric power consumption share in OECD countries (2014)

(*Organisation for Economic Co-operation and Development)*



Simplified scheme of electric power system of the Czech Republic



How it works ???

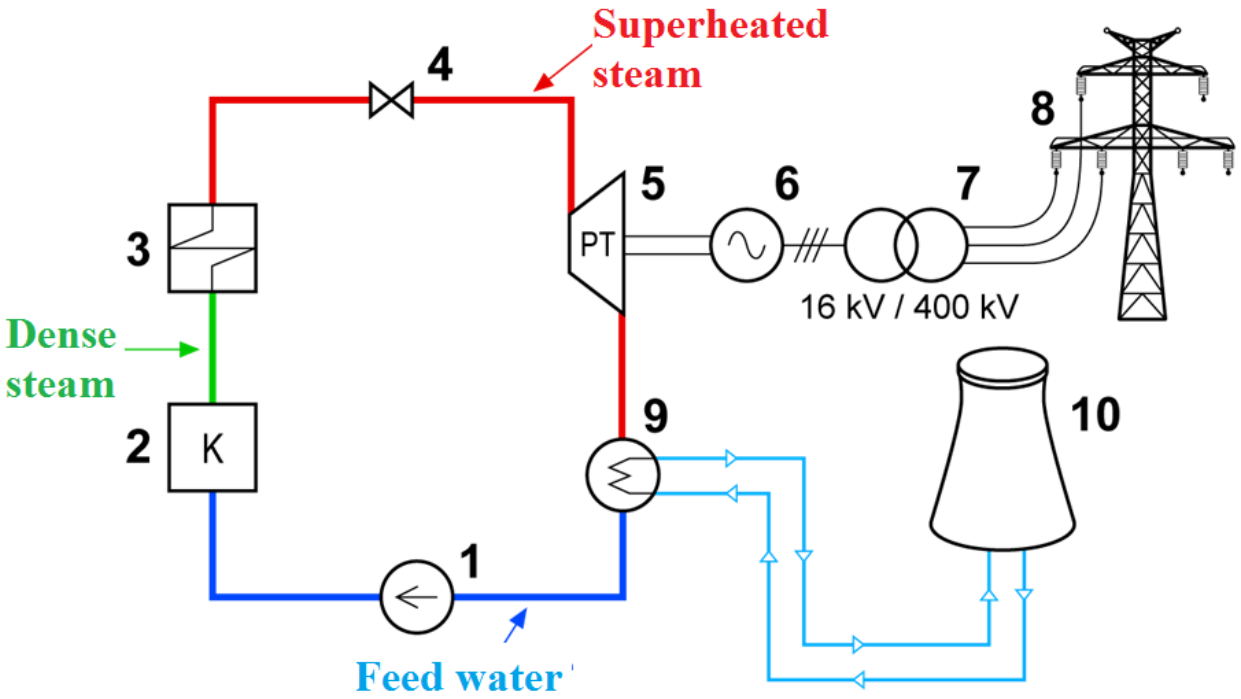
All types of thermal plants use as the main work medium steam. Among the most widely used thermal plant types in the CZ are counted condensation plants with full steam condensation and combined cycle (gas and steam). Each type of thermal energy generating plant can be depicted via termal circuits.

Working principal of a condensation power plant

First of all there is water pumped by a supply pump into a boiler. In the boiler there is produced heat by burning fuel and the heat warms up water which comes into the boiler. After transmittion of sufficient heat the water starts boiling and changing into dense steam. Due to presence of small water drops in steam the steam is being overheated in a steam superheater and there is produced superheated steam. This steam is subsequently led through a reduction valve on a turbine. In the turbine there is the steam pressure transformed into mechanical force of cogged wheels which are mechanically connected with the generator rotor. After transferring the energy, the steam leaves

from the turbine into a condenser where it is condensed back into water and that is led back into the boiler by the water pump. The electric power produced in the generator is then transformed and added into the power grid.

Heat diagram of a condensation power plant



1- Pump, 2 – boiler, 3 – steam superheater, 4 – reduction valve, 5 – turbine, 6 – generator (electric rotating machine), 7 – transformer (electric static machine), 8 – transmission system, 9 – condenser (heat exchanger), 10 – cooling tower

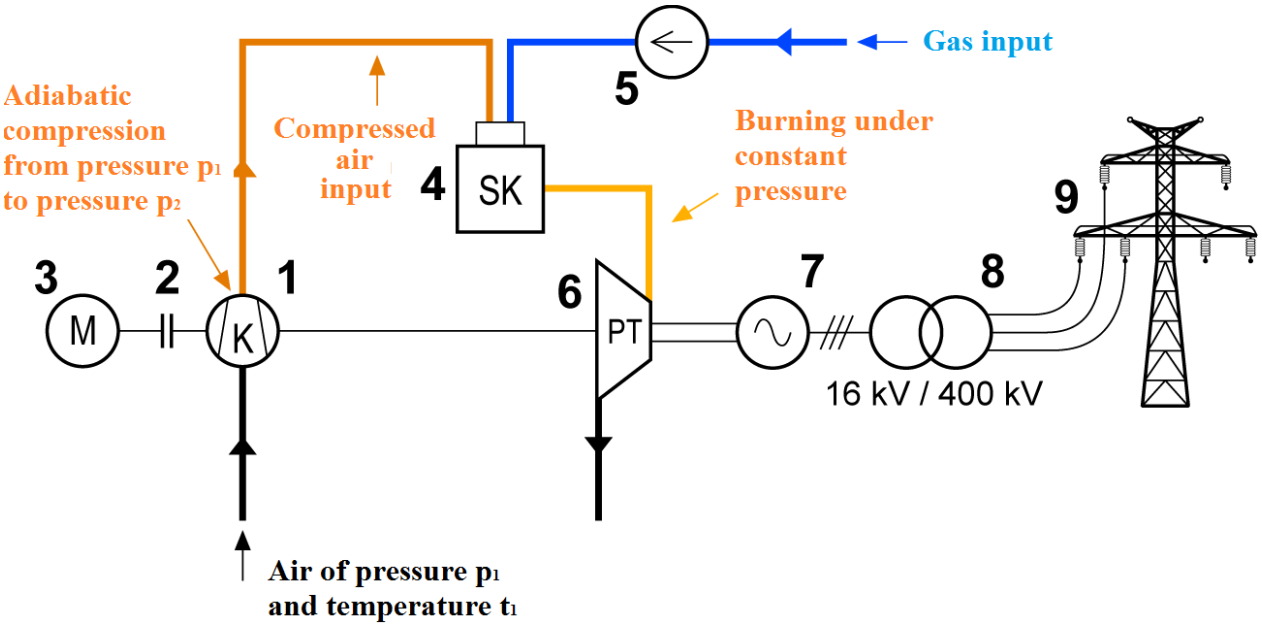
Working principal of a combined (gas and steam) cycle power plant

The combined cycle power plants are currently based on two ways of gas transformation into mechanical and subsequently electric power. First one uses a gas turbine which has a combustion turbine engine similar to an airplane turbine engine in which burning down the gas, and its expansion, immediately spins the rotating turbine wheels which are connected to the rotor of turboalternator. The exhaust fumes have the temaperature as high as 500 °C. Therefore, they are

used for additional water warming which is intended for heating or further electric power production.

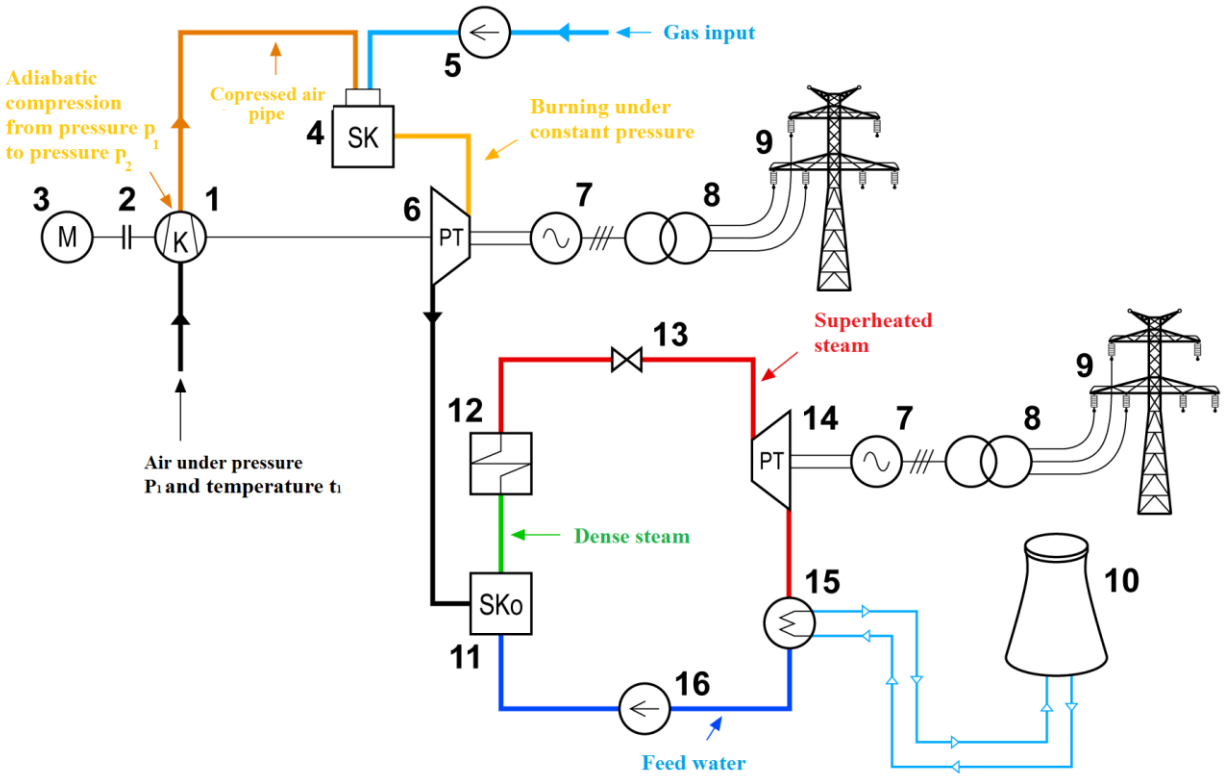
The second gas transformation uses the steam boiler fired by gaseous fuels which has a similar construction to the boiler of condensation power plants. The design and components are the same as with solid fuel power plants. This gas-steam power plant gradually changes the heat energy from burning gases, in a similar way as condensation power plants, into the steam pressure which is then in the turbine changed into mechanical and, in the generator, electric power.

Heat diagram of a combustion turbine



1 – compressor, 2 – gearbox, 3 – starting engine, 4 – combustion chamber, 5 – gas pump, 6 – turbine part, 7 – generator, 8 – transformer, 9 - transmission system

Heat diagram of combined power plant



1 – compressor, 2 – gearbox, 3 – engine, 4 – combustion chamber, 5 and 16 – pumps, 6 – combustion turbine, 7 – generator, 8 – transformer, 9 – transmission system, 10 – cooling tower, 11 – combustion boiler, 12 – steam superheater, 13 – reduction valve, 14 – steam turbine, 15 – condenser

Components of a thermal power plant ???

Steam boiler and boiler furnice

The boilers used in heating plants and power stations are energy devices which are used for heating circulating water and its subsequent change into steam. For that reason they are called steam boilers. Those that are used for warming up water are called hot-water and warm-water ones. Basically, they are devices where is coming about transformation from chemical energy of fuel into thermal energy of combustion products and subsequent heat transmission on the working medium (water, steam). Steam boiler is composed of two elementary systems of energy devices, that are:

- **combustion device with its accessories**
- **pressure heat exchanger**

Combustion device with its accessories	**Pressure heat exchanger**
Components for fuel preparations	*Water heater – EKO (economizer)*
Fireplace with grate	*Steam superheater*
Burner	*Steam reheater (Mid-reheater)*
Air heater (LUVO)	*Evaporator (boiling system with boiler drum)*
Baghouse for ashes and fumes	
Cleaning	

From the above table it is apparent that the boiler pressure component concists of three or four heat exchangers. First, the water is pumped through the water heater into the boiler drum. From the boiler drum it flows into the evaporator pipes where the water is warmed up and after that it flows back into the boiler drum. There is separated the dense steam from water. Then, the dense steam is led into the steam superheater where owing to overheating appears superheated steam which flows on the steam turbine. After that, it is possible to use the steam reheater where the water is heated up again. This steam is then used in the low-pressure turbine part.

Water boiler (economizer – EKO)

It is situated in the area with the lowest temperature of flue gases. There comes about water heating from the temperature of feed water to the temperature about *10 °C – 20 °C* lower than there is the boling point. From there the water is led into the boiler drum.

Evaporator and steam drum

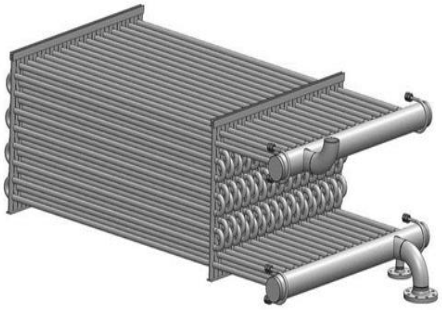
Evaporator is a boiler radiant part. It is situated in the area of a fireplace. In the evaporator there comes about boiling and water evaporation, i.e. water is transformed into dense steam. One of the evaporator components usually is a boiler drum where water is separated from steam and is desalinated, i.e. deprived of salt. The water flows from there into the steam superheater.

Steam superheater

The superheater coils are ordered into the area with the highest temperature, namely into the fireplace or the first boiler suck. In the steam superheater the dense steam, from the boiler drum, changes into superheated steam of required qualities.

Air heater (LUVO)

It heats up the air which flows from the combustion chamber. It results in increasing in efficiency of the combustion device because there is used the energy of flue gases. It is the last heat exchanger.



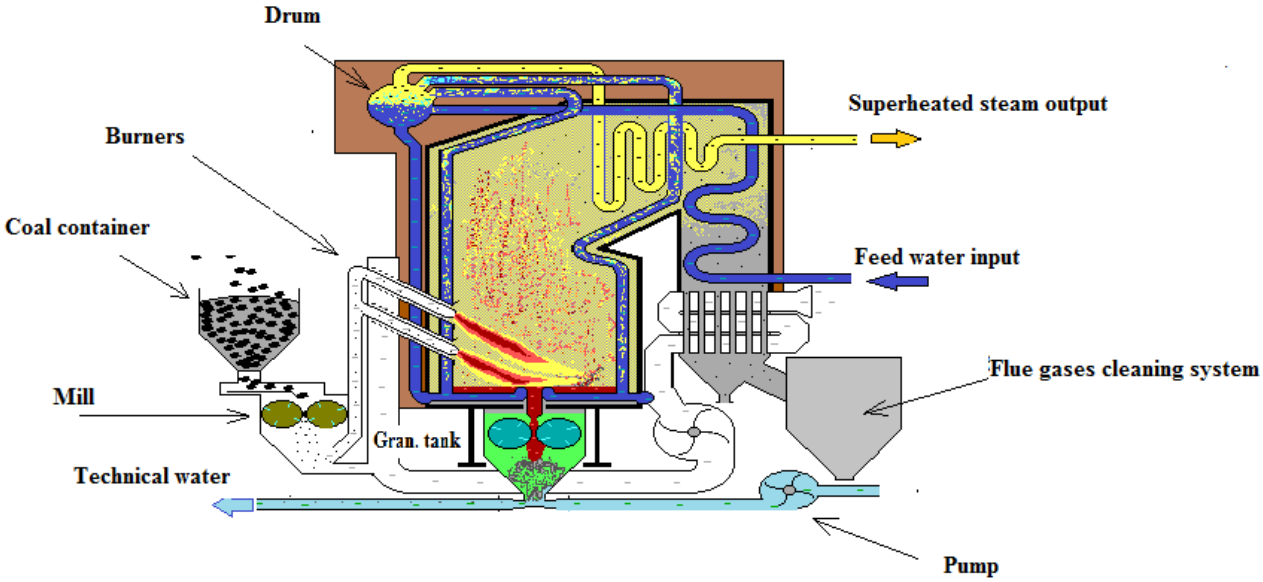
WATER HEATER

BOILER DRUM

STEAM SUPERHEATER

AIR HEATER

Diagram of boiler functioning



Thermal plant turbine

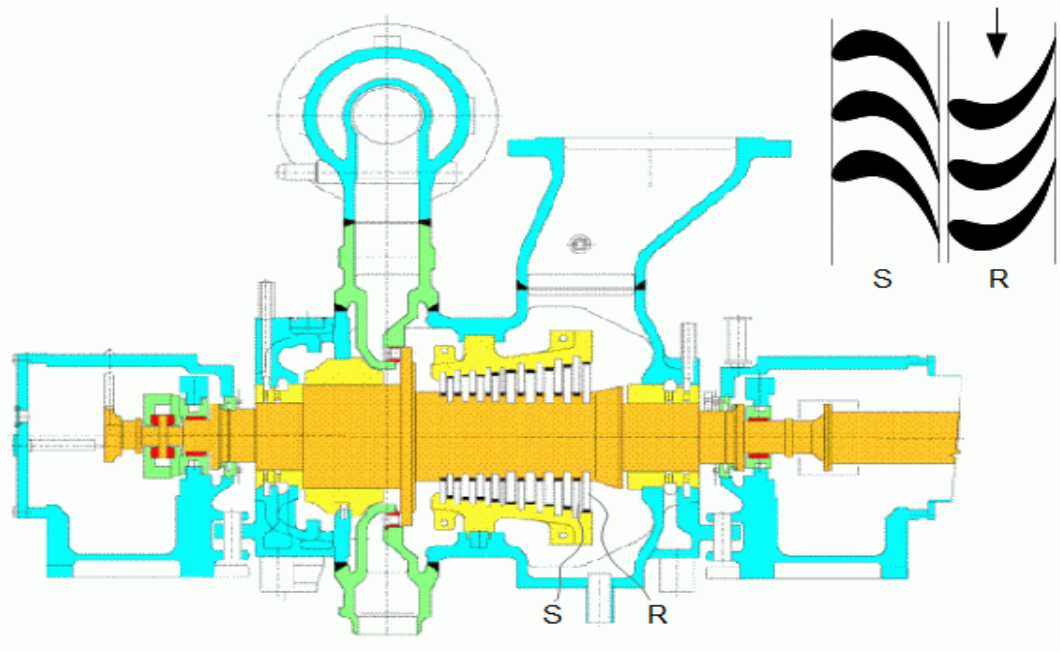
A shared feature of thermal plant turbines is an expansion of working media from higher to lower pressure which results in lowering the temperature. Thermal plant turbines which are most widely used can be divided:

- Steam turbines
- Gas turbines

Steam turbine

In condensation power plants there is always used a steam turbine. Its working media is steam. The basic turbine parts are a stator and a rotor. There are constructed sequential transmission steam turbines for higher performance. In every sequence there is integrated a stator and rotor set of blades. The static blades are fixed to a turbine box and rotating blades are fixed to a rotor. One set of static and rotating blades is together called a degree of blade machine. Turbines of high perfomance are divided into several smaller turbines and these are placed one by one or next to each other and mutually interconnected by a joint (not always). These turbines are called multibody system turbines.

Cross section of a steam turbine



S - a static set of blades; R – a rotating set of blades

Condenser

In condensation plants it is used for steam cooling and its condensation back into water. Basically, it is a heat exchanger in which the steam is going through a system of pipes and takes the heat from cooling water which flows by. The lower the pressure in the condenser, the lower is the temperature of condensed steam and the better is utilization of the heat gained from coal. There is kept an underpressure behind the turbine by a pump – vaccuum with atmospheric pressure of 4 hundredths. Under this atmospheric pressure the steam condenses at about 35 °C. From the condenser the condensed water is led back into the boiler. In the condenser there is a big energy loss what results in a rather low effeciency of power plants which is about 40 %. For increasing the effeciency of production the steam that comes out of the turbine is used for feed water heating before it enters the boiler. With thermal plants the residual heat of steam after going through the turbine is used for heating the water which is intended for supplying costumers with heat and hot water.

Cooling tower

It is inteded for circulatory cooling of water in a cooling curcuit. The water which has taken the heat from the condensed steam in a condenser is led to the cooling tower where it goes again

through the system of pipes. The pipes are showered with water from a river. One part of the water evaporates and the rest returns into the river.

Generator

Similarly as with nuclear plants, it uses a synchronous alternator – a turboalternator which is propelled by a steam turbine. Generators are high-speed machines, as a rule, of 3000 revs/min. The stator of a turboalternator has the shape of a hollow cylinder and it is welded from sheets and reinforced with ribs. The rotor is always smooth because of its high-speed revs. It is made of one piece of special chrome-nickel steel with added molybdenum. Into the cylinder there are cutted two grooves for rotor binding which is charged with direct current. The grooves of rotor are not all over the circumference but in two axial symmetrical parts so after insertion of binding into the grooves there is two-pole rotor. The two ends of binding are connected with two rings and there is conducted to them the direct current through two carbon brushes. After fitting the binding into the grooves they are closed with some bronze and dural wedges. The rotors are ended with hammerheads which are in touch and form the connecting rings of a shock absorber.

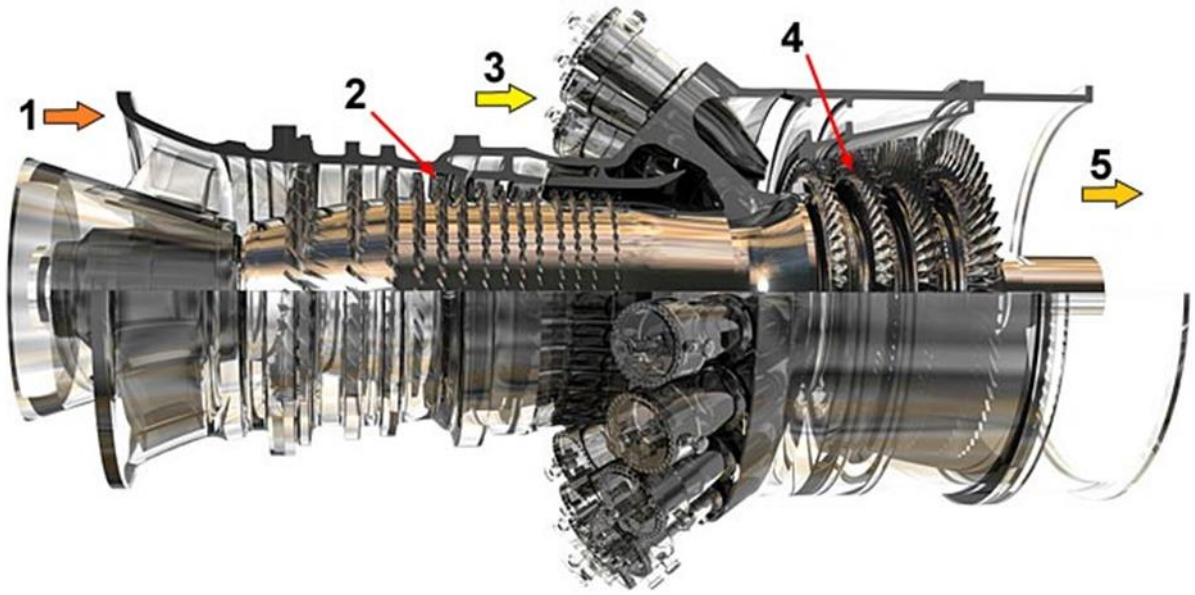
Generator block transformer

It is an electric non rotating machine based on the principal of electromagnetic induction. For thermal plants there are made two winding transformers when on the primary side the voltage corresponds to the voltage level that comes from the generator and on the secondary side the voltage corresponds to the voltage level of trasmitting and distribution system. They are made with oil and for their heaviness placed on some rails for a potential need of manipulation.

A triplet of single-phase generator block transformer

Gas turbine

With gas turbines the working medium is gas or flue gases. Most of all there are used the gas turbines with a combustion chamber. For this reason we can also find the name combustion turbine. One component of a combustion turbine is a tourbocharger (compressor). Into the turbocharger there is sucked in the air which is pressed there. This air is lead together with some fuel into the combustion chamber where they burn. When burning there are produced hot flue gases – gas which propels the turbine part of combustion turbine. The performance of turbine part is also used for propelling of the turbocharger. A device with a combustion turbine is simple because the fuel is burned right inside the turbine.



1 – sucking in the air, 2 – turbocharger, 3 – combustion chambers, 4 – turbine blades, 5 - output

Advantages of thermal plants??

- ✓ A permanent source of electric power
- ✓ As for gas-steam power plants there is a possibility to use them as a top-class electric power source, e.i. to reach the full performance takes about a few minutes.
- ✓ As for coal-fired power stations it is possible to use the national sources of energy
- ✓ As for incineration plants there is carried out the process of ecological waste disposal either produced by people or industry.

Disadvantages of thermal plants ???

- ✓ It is an unlimited source of energy
- ✓ There is carried out a negative impact on the character of landscape and overal negative effect on the environment during the extraction of fosile energy sources.
- ✓ As for coal-fired power stations there is carried out the production of air pollutants into the air inspite of modern technologies. Nowadays, the operation of thermal power plants itself, to a certain extent, effects the emission limits issued for the members of the EU.
- ✓ In case of power failure of some important energy units it has a substential impact on the whole electric grid of the Czech Republic.

Relationship between thermal power stations and the environment

Positive qualities:

- The majority owner of thermal power plants is ČEZ Group which cooperates closely with ornithologists and enables them to place on their buildings, for example on the cooling towers, some nesting boxes for birds of prey. This fact, for example, has enabled to increase the number of peregrine falcon.

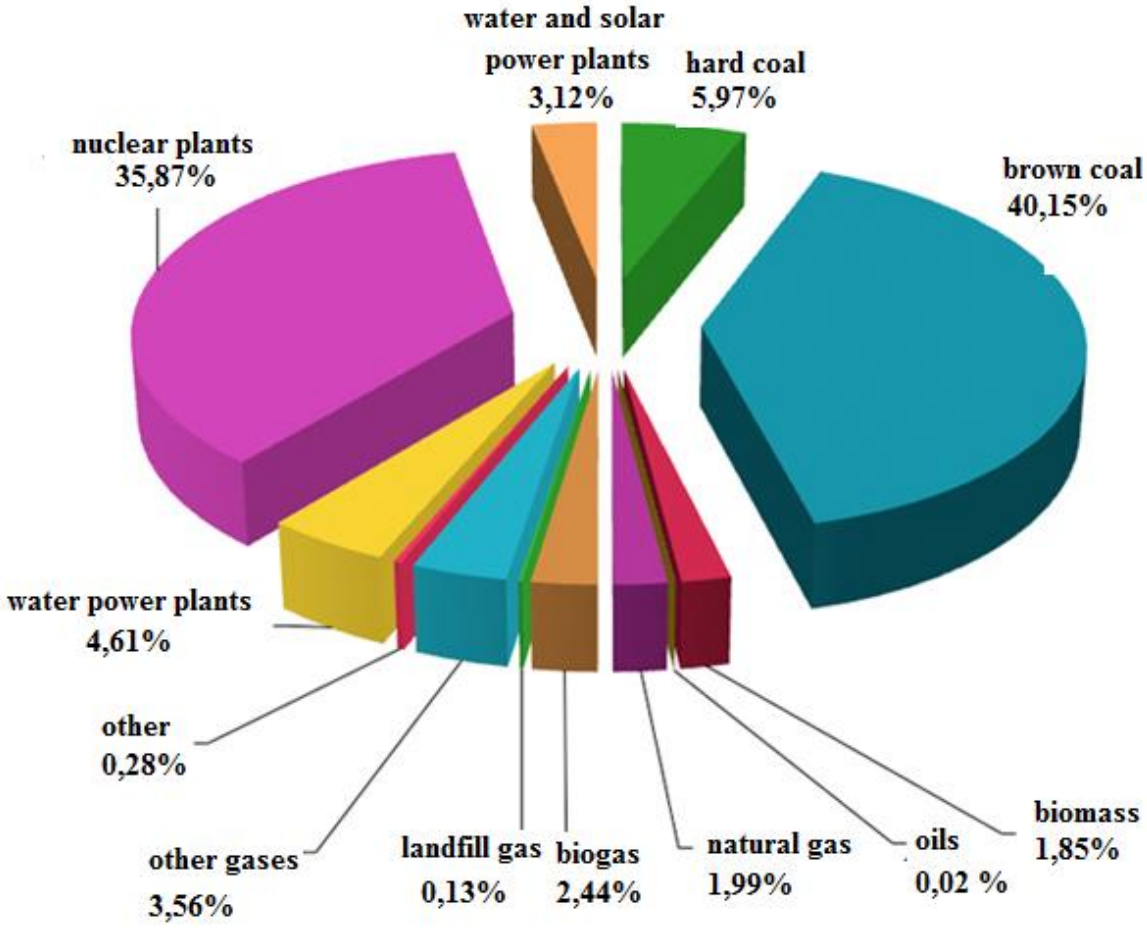
- The next advantage of thermal plants lies in low impact of their operation on the energy of watercourses.

Negative qualities:

Despite of the efforts of operators, the main negative quality of these plants lies in releasing of nitrogen and carbon oxides into the air.

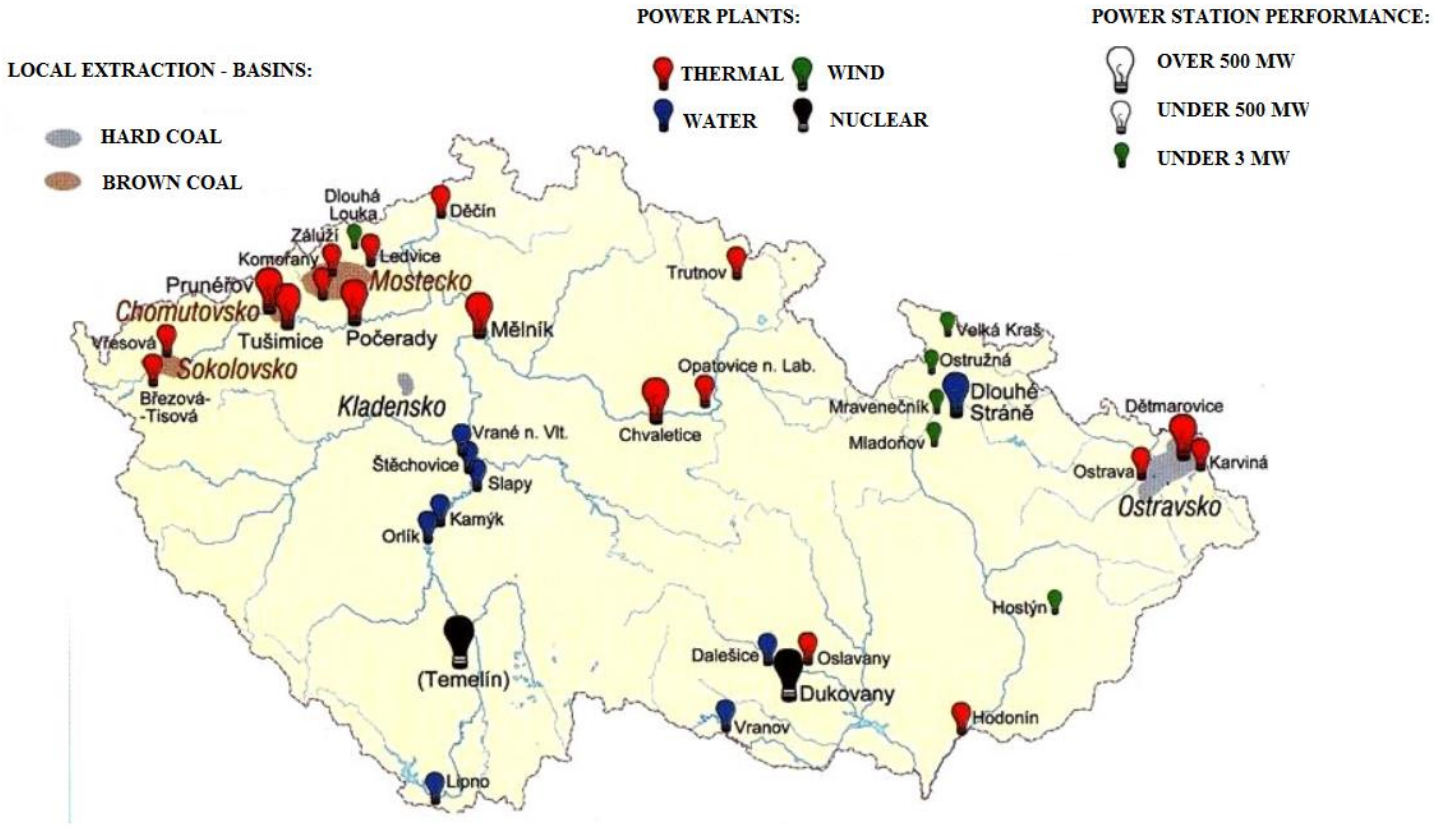
Thermal plants in the Czech Republic and Slovakia ???

The structure of electric power production in the Czech Republic (2014) according to the participation of individual energy sources



From the above diagram there comes out that thermal plants are the main source of energy in the Czech Republic. Their participation in the overall electric power production is decreasing every year due to installation of new energy generating plants which use renewable sources of electric energy. There is a substantial decrease in participation of coal-fired power plants in electric energy production because of the modernization, increasing performance of nuclear power stations and convertion of current coal-fired power plants into combined cycle power plants.

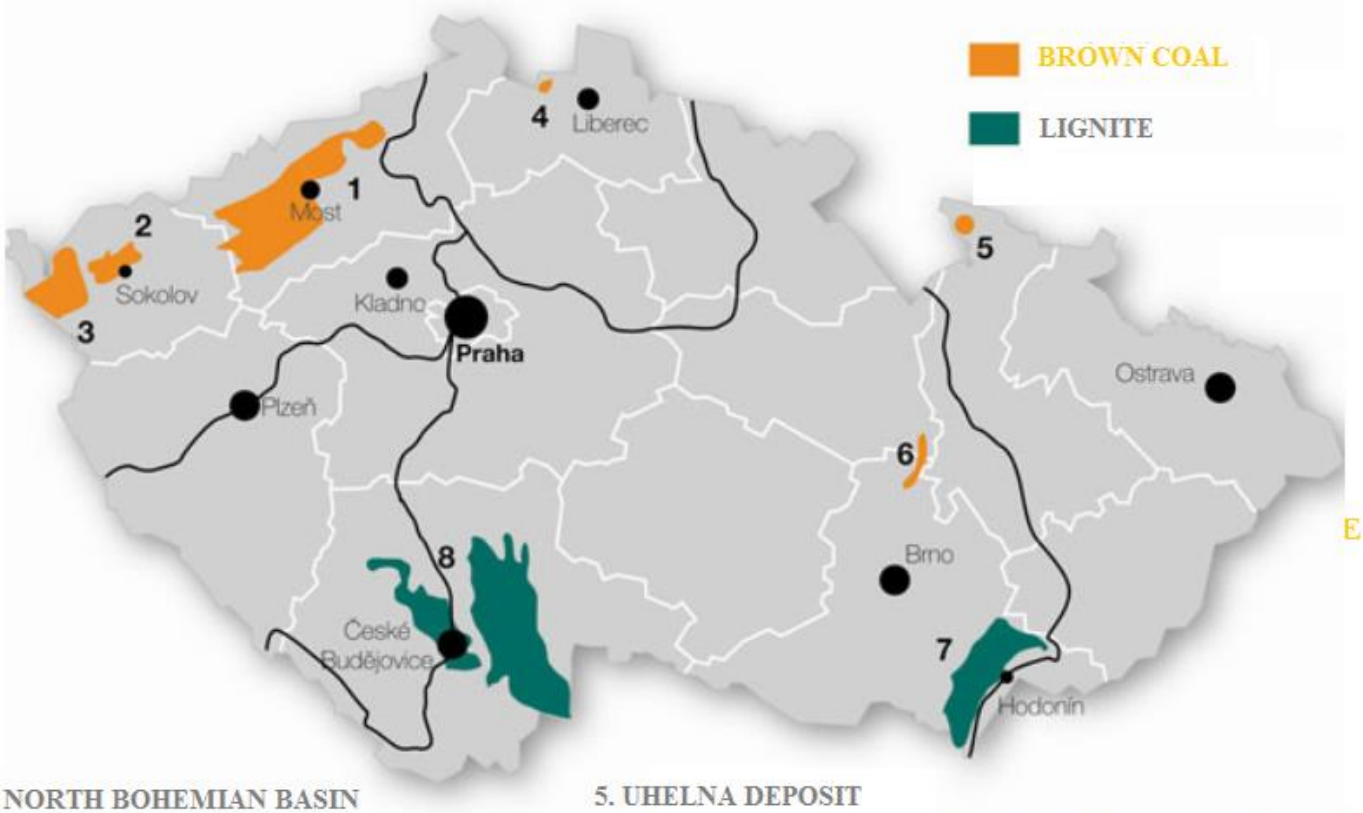
A schematic map of electric energy generating plants in the Czech Republic



From the given map there is obvious that the main thermal plants are situated in the areas where mineral materials are mined. This state can positively influence the price of the commodity because it saves expanse on delivery of mineral materials to a power plant. Nowadays, there is a decline of extraction and conversion of power plants into gas-fired ones. From the constructional perspective this energy generating plants are simplier because a gas turbine also includes a combustion chamber. However, the remaing problem is a fluctuating gas costs and transportation from a place of production to a place of consumption.

Surface and deep mining of brown and hard coal

Brown coal basins and brown coal and lignite deposits in the Czech Republic



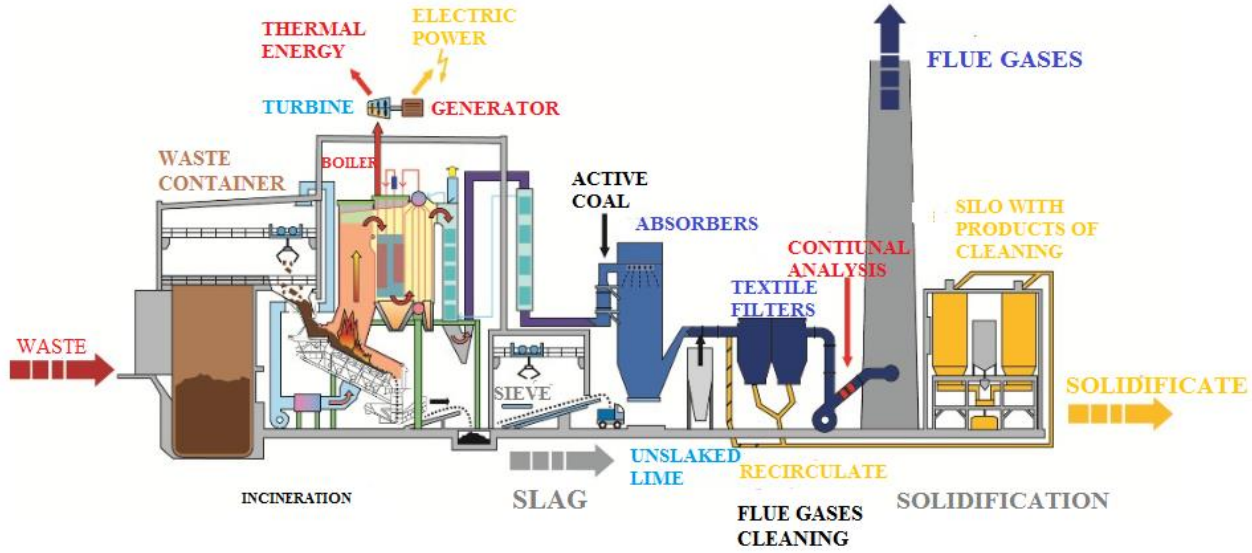
1. NORTH BOHEMIAN BASIN
2. SOKOLOV BASIN
3. CHEB BASIN
4. EASTERN UPPER LUSATIA
5. UHELNA DEPOSIT
6. CHALK-COAL DEPOSIT AROUND MORAVSKA TREBOVA
7. SOUTH MORAVIAN LIGNITE BASIN
8. SOUTH BOHEMIAN BASIN

Power plant Ledvice

The Ledvice power plant is a thermal power plant which burns brown coal. Its performance is 330 MWe. It consists of two production units Ledvice II – 2x110 MWe and Ledvice III – 1x110 MWe.. The source of fuel for this power plant is the Bílina Mine where brown coal is extracted. The operator of this power plant is ČEZ Group.

Incineration plant SAKO Brno

Technological process of an incineration plant



Incineration plant SAKO Brno

It is a cogeneration plant where the electric power and heat is produced and besides there is burnt communal and industrial waste. After bursting into flames the waste burns itself in the combustion chamber of boiler without any extra addition of fuel. From the incineration rests (slag)

there are separated ferrous and non-ferrous metals which are subsequently used as a secondary material. The incineration plant has the performance 17,5 MW.

Test – Thermal plants ???

Test: (choose the correct answer)

1. Choose the best quality coal from the given options

   (a) hard coal
   (b) brown coal
   (c) anthracite
   (d) lignite

2. Which of the given combinations are false and do not include renewable sources of electric power in all items
   (a) crude oil, natural gas, hard coal
   (b) crude oil, natural gas, biomass
   (c) hard coal, lignite, anthracite
   (d) uranium, brown coal, natural gas

3. Where are used turboalternators?
   (a) in photovoltaic power plants
   (b) in accumulation power plants
   (c) in thermal power plants
   (d) in windmills

4. What is meant by the term generator block transformer?
   (a) an electric static machine functioning for conduction the electric power from a power plant

(b) a transformer situated between the transmitting and distribution network

(c) it is a synchronous rotatory machine

(d) it is an electric device used for steam production

5. What is meant by the term turboalternator?

(a) a generator

(b) a three phase squirrel cage induction motor

(c) a salient-poles synchronous machine

(d) a non-salient pole rotor machine

6. What is the function of a cooling tower?

(a) to change water into superheated steam

(b) for dense steam production

(c) for cooling a boiler

(d) for cooling water coming out of a condenser

7. What is a turbine?

(a) a machine with blades, a stator and a rotor

(b) a generator

(c) a combustion engine

(d) a condenser

8. What is a boiler intended for?

(a) for power plants esthetical reasons

(b) for heating water to change it into steam

(c) to cool down steam

(d) for providing mechanical work and this way for production of the electric power

9. What kind of steam functions on the turbine of a thermal plant?

(a) wet steam

(b) dense steam

(c) superheated steam

(d) dense liquid

Correct answers:

(1c, 2b, 3c, 4a, 5d, 6d, 7a, 8b, 9c)

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