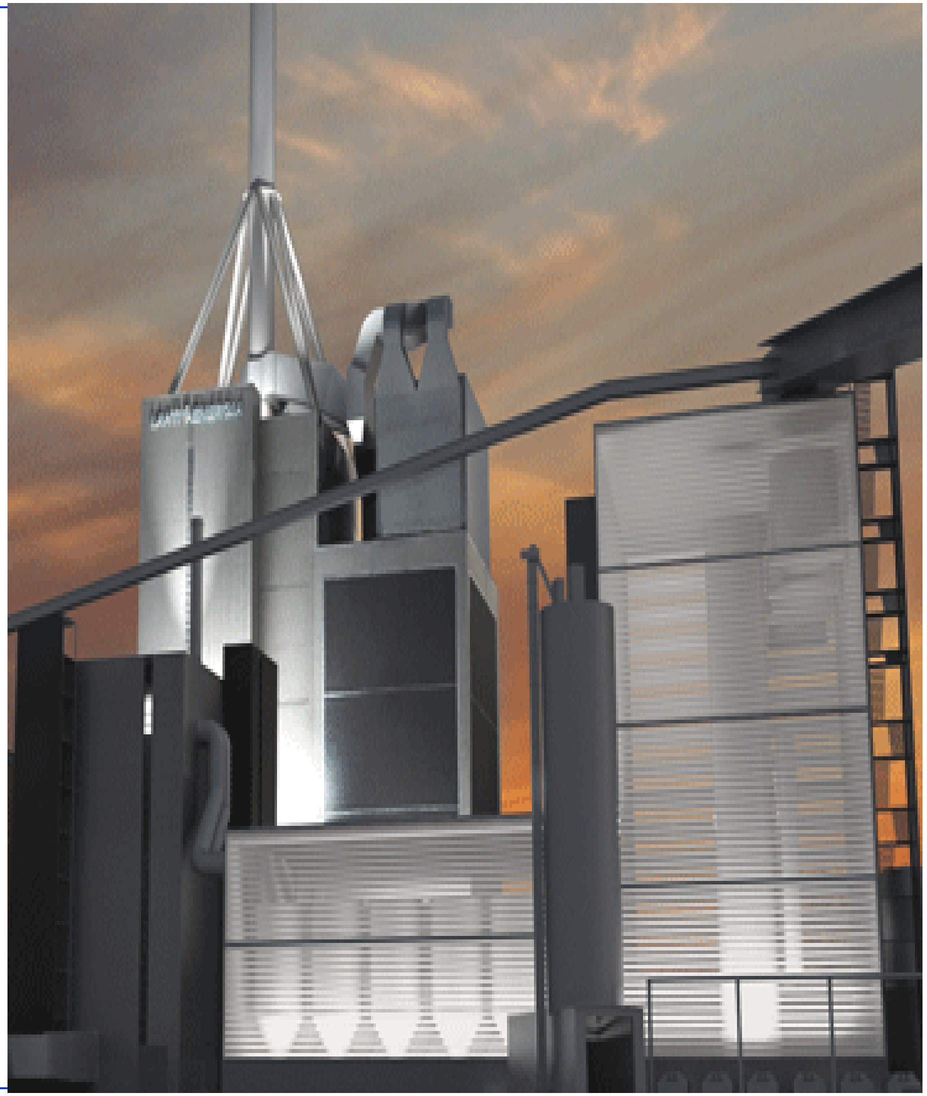
M2

Energy Forms – Transformation – Market Outlook



INTELLIGENT ENERGY EUROPE

UP-RES
Urban Planners with Renewable Energy Skills

Content

1. Energy Forms

1.1. Definitions and Conversions

- ”Energy” is always expressed in a certain period of time, an hour, a week, a year, etc.
- ”Power” is a momentary expression of the potential to produce, transmit or consume. It is the rate at which energy is consumed
- Energy = Power multiplied by time
- 1 MWh = 1000 kWh = 1000 000 Wh

Time:
- 1h = 3600 s

Energy:
- 1 Wh = 3600 J = 3,6 kJ

Capacity:
- 1 W = 3,6 kJ/h = 1 J/s
- 1 MW = 3,6 GJ/h

Multiples of thousands:
- 1
- 1000 = Kilo (k)
- 1000 k = Mega (M)
- 1000 M = Giga (G)
- 1000 G = Tera (T)
- 1000 T = Peta (P)

Source:
UP-RES Project Team/Aalto University

1. Energy Forms

1.2. Typical Properties of Fuels

Fuel	Lower heating value MJ/kg	Lower heating value MJ/m³	CO_2 emission g/MJ	SO_2 emission g/MJ
Natural gas		36	56	0
Coal	26		91	0,4
Oils	41		76	?
Peat	22		106	0
Waste wood	20		0	0

Based on the Table above:

- 1 kg of oil contains more energy than 1 kg of coal, here 58% more.
- 1 MJ of coal produces almost twice as much CO_2 emissions as natural gas
- Coal and heavy fuel oil fired plants would need desulphurization in order to reduce SO_2 emissions that are not relevant at the other plants.
- Desulphurization is expensive and it is used at large base load plants only.

Source:
UP-RES Project Team/Aalto University

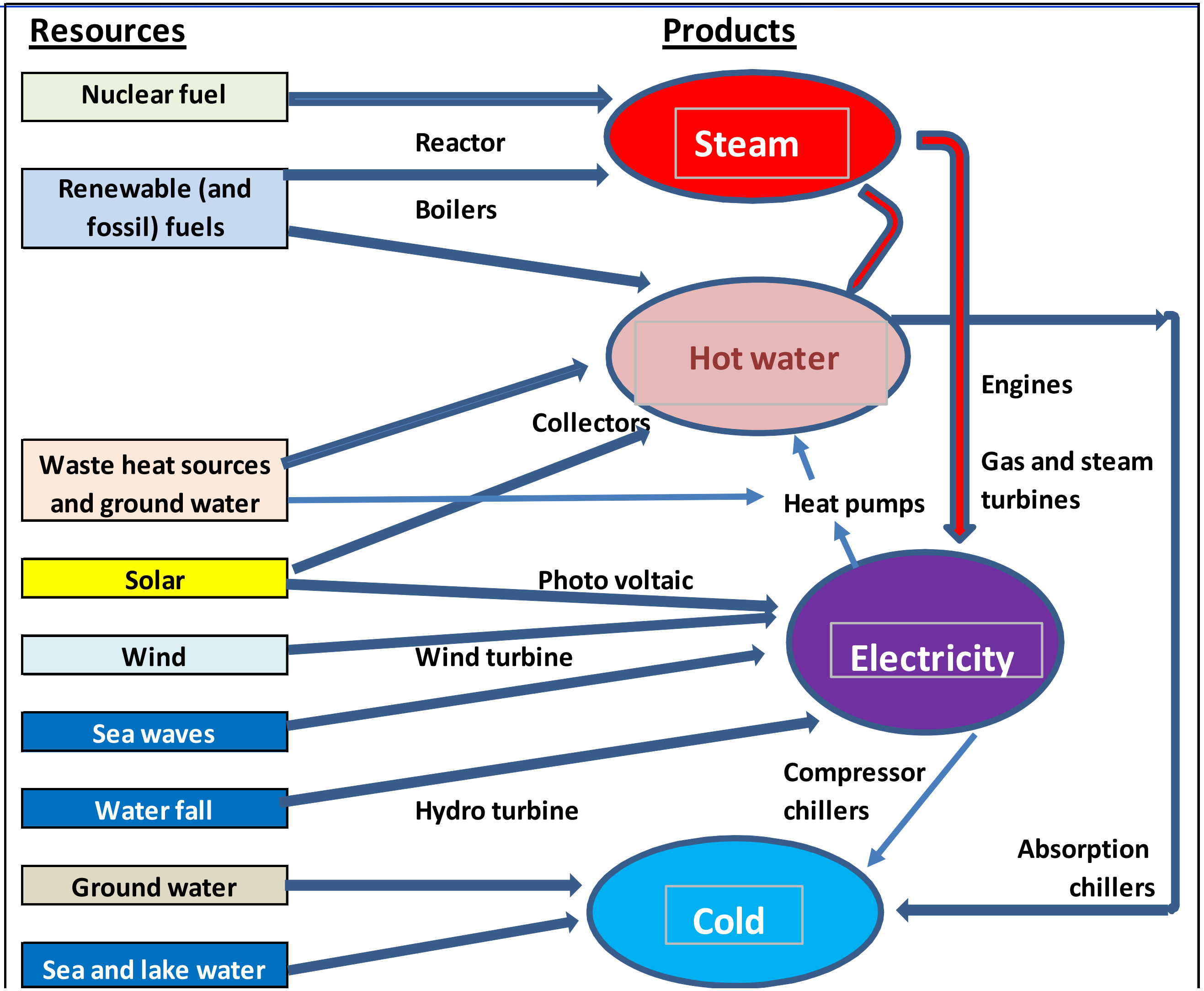
2. Energy Transformation

2.1. Common Ways of Transformation

From resources to products

Transformation efficiency varies per case

”Electricity” here covers both electric and mechanical energy



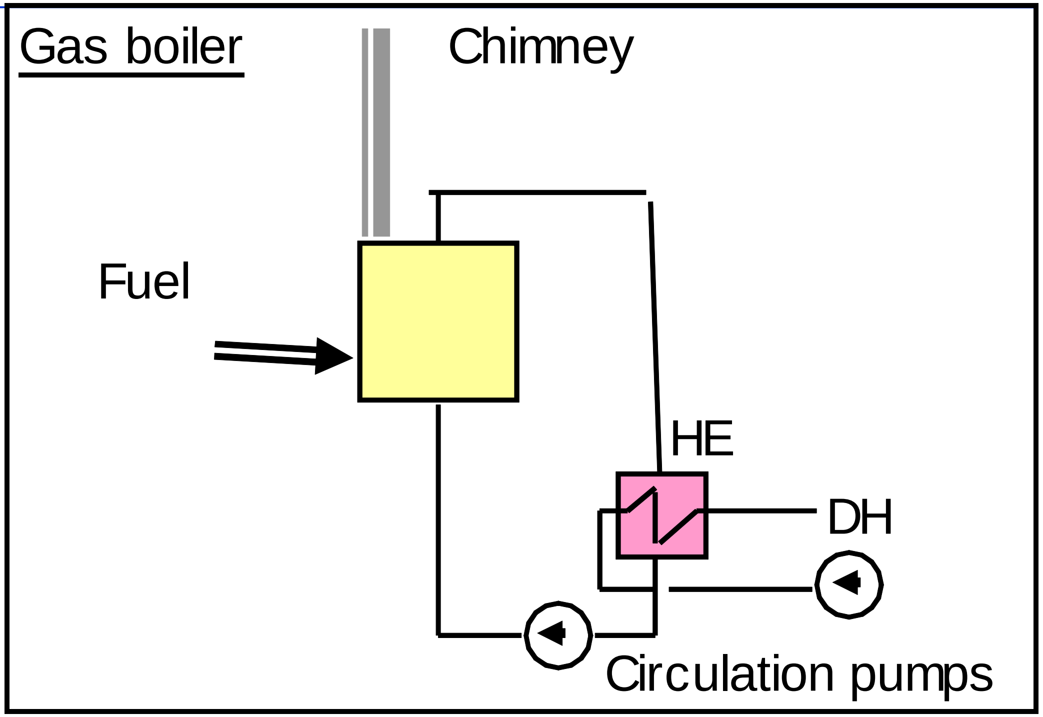
Source:
UP-RES Project Team/Aalto University

2. Energy Transformation

2.2. Steam and Water Boiler

- Gas fuelled water boiler as an example
- Typical efficiencies (= heat outlet/fuel inlet):
  - Gas: 94-97%
  - Oil: 91-93%
  - Coal: 87 – 93%
  - Biomass: 86-92%

- Steam boilers are used for electricity production and in process industry whereas water boilers in DH-only applications.



HE: Heat exchanger
DH: District heating

Source:
UP-RES Project Team/Aalto University

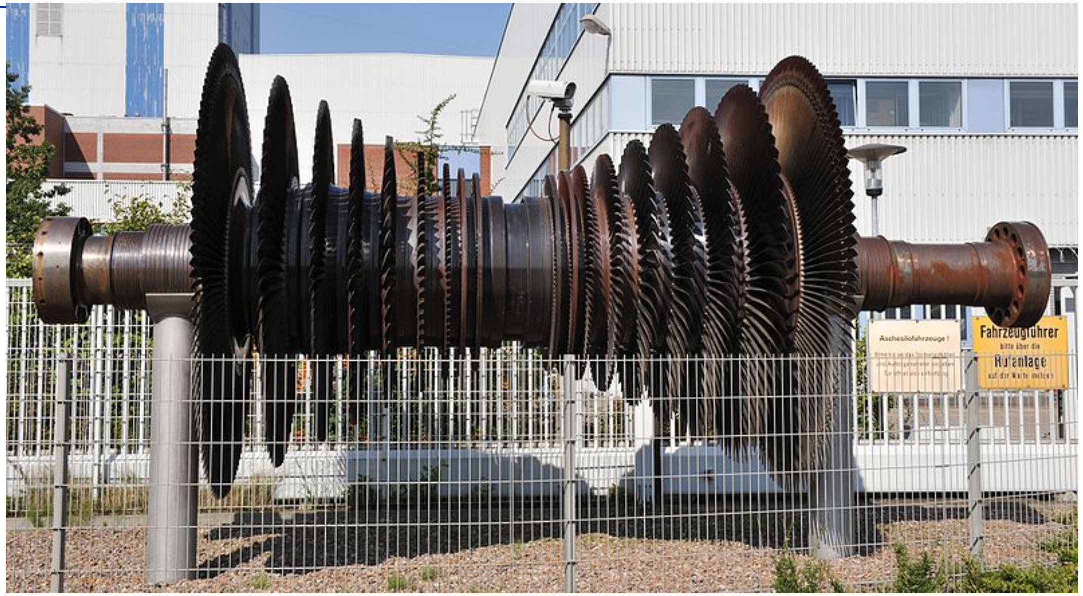
2. Energy Transformation

2.3. Steam Turbine with CHP (1)

The rotor consists of blades through which the steam flows and rotates the rotor.

The rotor runs the generator that produces electrical energy for the grid.

As the steam leaves the turbine, it will be condensed to water and returned to the boiler for re-heating and evaporation.



A two-flow turbine rotor. The steam enters in the middle of the shaft, and exists at both ends, thus balancing the axial force in the turbine.

CHP – Combined heat and power

Source: www.wikipedia.org

2. Energy Transformation

2.3. Steam Turbine with CHP (2)

The inlet steam pressure is typically 50 to 150 bar.

The inlet steam temperatures are usually 500-550 ^{o}C.

Blades of a steam turbine rotor under maintenance

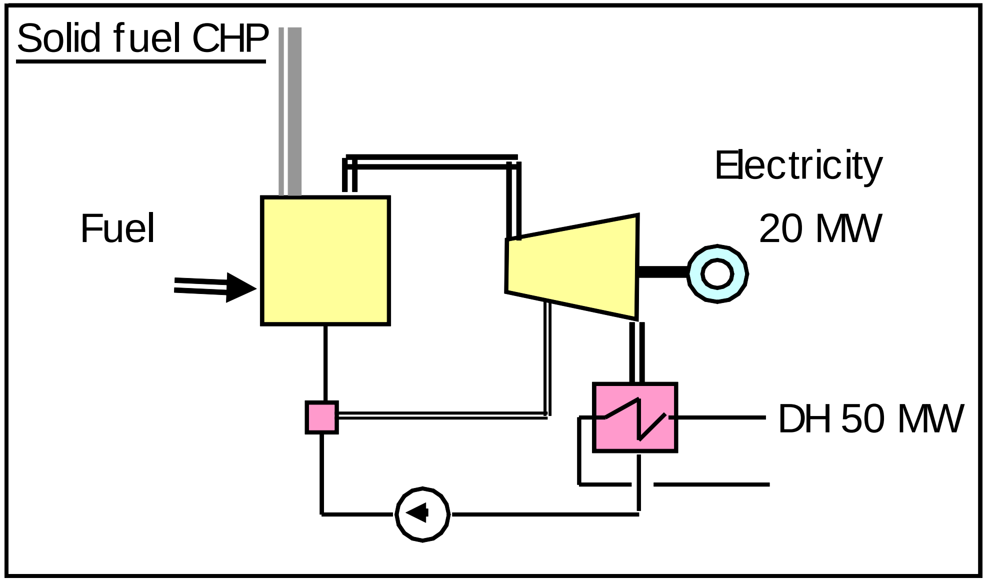
Source: www.wikipedia.org

2. Energy Transformation

2.3. Steam Turbine with CHP (3)

The steam power plant with solid fuel functions in steps as follows:

1. Fuel and air to steam boiler for combustion
2. Steam is delivered to steam turbine, in which the rotating rotor runs the power generator to produce electricity
3. Waste heat is taken from turbine extraction or the end of the turbine shaft to produce DH
4. The condensed water will return back to the boiler through feed water pumps and feed water tank.
5. In absence of DH, the heat would be mainly wasted to atmosphere (cooling tower) or to sea and lake water (heat exchanger).



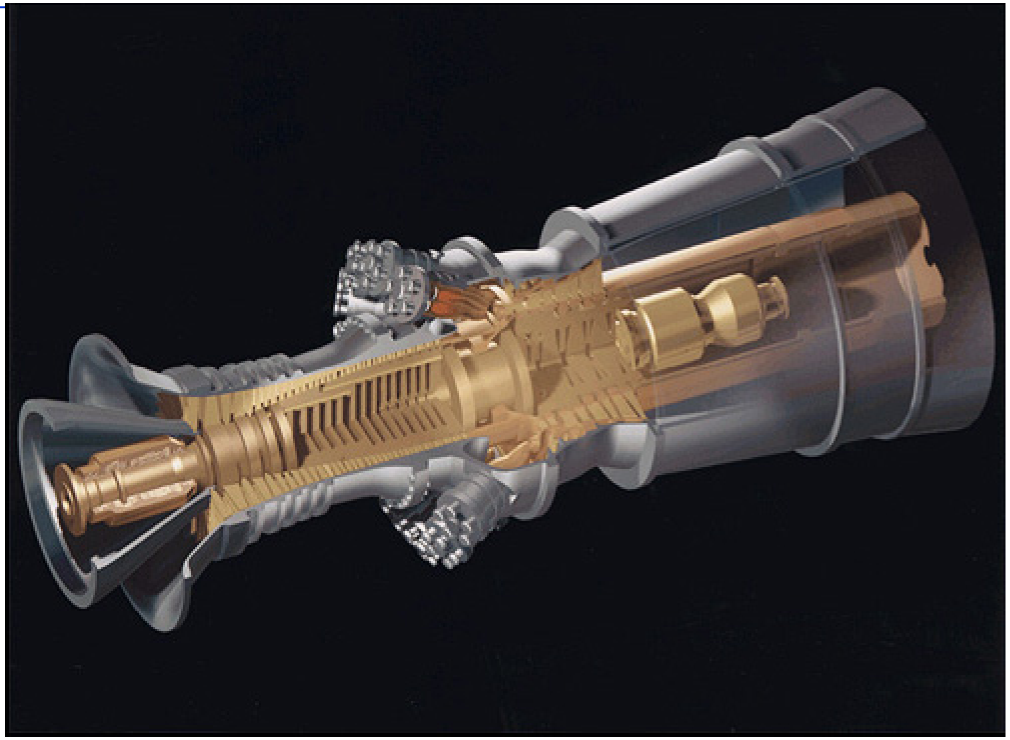
Source:
UP-RES Project Team/Aalto University

2. Energy Transformation

2.4. Gas Turbine with CHP (1)

Gas turbines function both with natural gas and light fuel oil.

In energy production, the gas turbine needs to have high exhaust gas temperature to produce DH or steam, in addition to electrical energy.



A large gas turbine for 480 MW power generation. On the left is the inlet air compressor, in the middle the combustion chamber with gas inlet and on the right the gas turbine part (manufacturer: GE)

Source: www.wikipedia.org

2. Energy Transformation

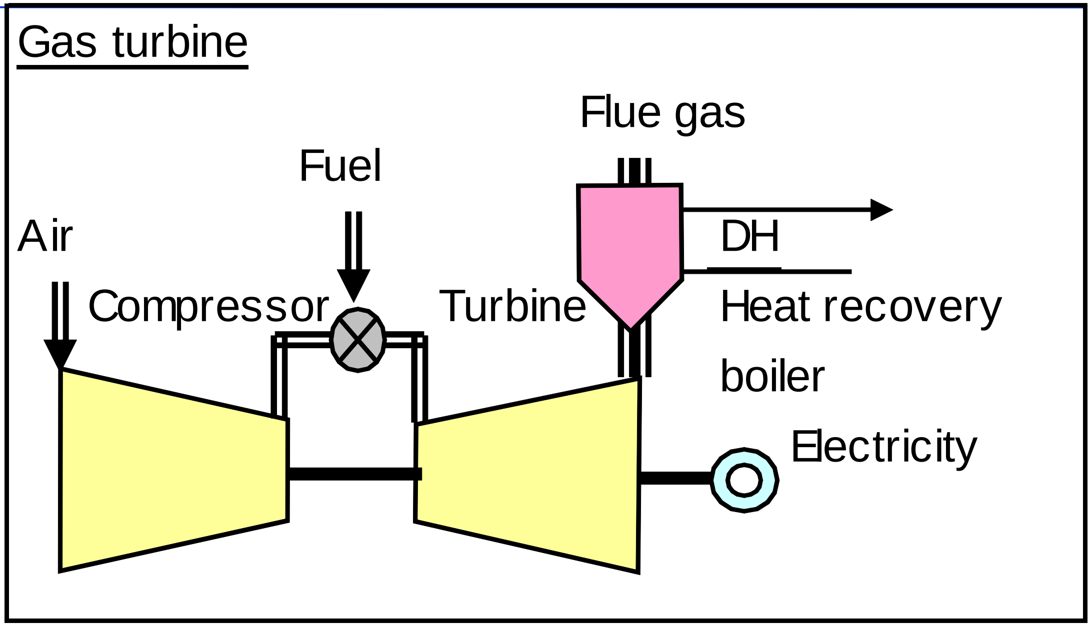
2.4. Gas Turbine with CHP (2)

The compressor, gas turbine and the power generator are in the same container.

Fuel with air burns in the combustion chamber at high pressure.

The exhaust gas in high pressure rotates the gas turbine rotor that makes the compressor and generator running as well.

The heat recovery boiler cools down the flue gases and the recovered heat is fed to the DH network.



A heat recovery boiler extracts the heat of the flue gases to the DH networks.

Source: UP-RES Project Team/Aalto University

2. Energy Transformation

2.5. Gas Engine CHP Plant

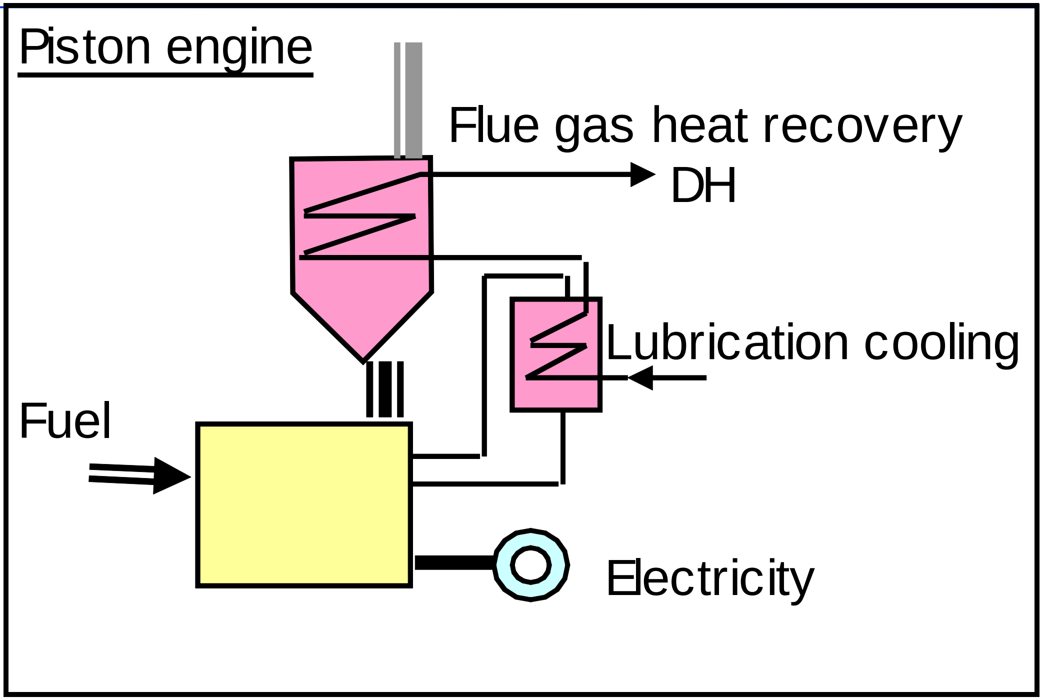
The engine is basically like any car engine but much larger.

Fuel with air combustion runs the engine to produce mechanical power that turns to electricity in the generator.

Heat can be recovered from two places:

- Cooling of lubrication oil
- Cooling of exhaust gas.

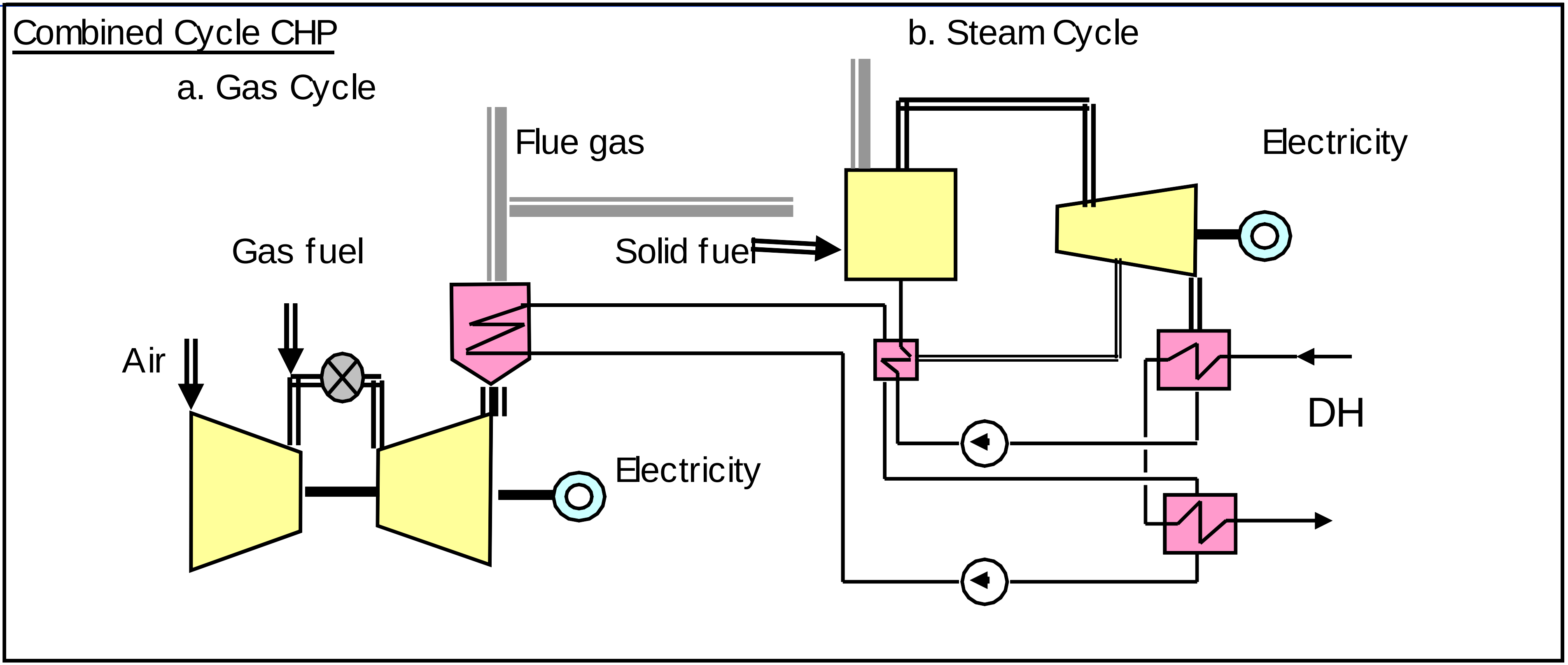
The benefits of a CHP engine are the nearly constant efficiency and the power-to-heat ratio over the whole capacity range, but it does need a lot of maintenance.



Source: UP-RES Project Team/Aalto University

2. Energy Transformation

2.6. Combined Steam and Gas Cycle CHP Plant (1)



A large combined plant integrates the steam and gas turbine processes with a high efficiency and high power-to-heat ratio.

Source: UP-RES Project Team/Aalto University

2. Energy Transformation

2.6. Combined Steam and Gas Cycle CHP Plant (2)

In the previous slide, two types of fuels were combined: gas and solid fuel, which provides flexible operation.

The solid fuel part can be an old power plant, with which the new gas turbine can be integrated afterwards. In such a way the combination can produce more electricity than the gas turbine and the solid fuel power plant alone. The synergy of combining these two processes together increases electricity generation by about 5% also increasing overall efficiency.

The combined cycle plant can also be built by combining 1 or 2 large gas turbines in parallel to a small steam turbine.

Source: UP-RES Project Team/Aalto University

2. Energy Transformation

2.7. CHP Comparision

Typical efficiency and power-to-heat ratios of various CHP plants and a gas boiler.

Gas turbines and engines alone can be small, from 2-60 MW, but multiplication may create large power plants.

Combined cycle plant is usually with at least two gas turbines and one steam turbine with more than 100 MW capacity.

Solid fuel power plants benefit from economy of scale as well: large ones are more efficient than small ones.

Typical Data		Total efficiency	Power to heat ratio
Solid fuel	Small	85 %	0,4
	Large	88 %	0,6
Gas turbine		91 %	0,4
Piston engine		89 %	1,0
Combined Cycle		94 %	1,1
Gas boiler		95 %	

Source: UP-RES Project Team/Aalto University

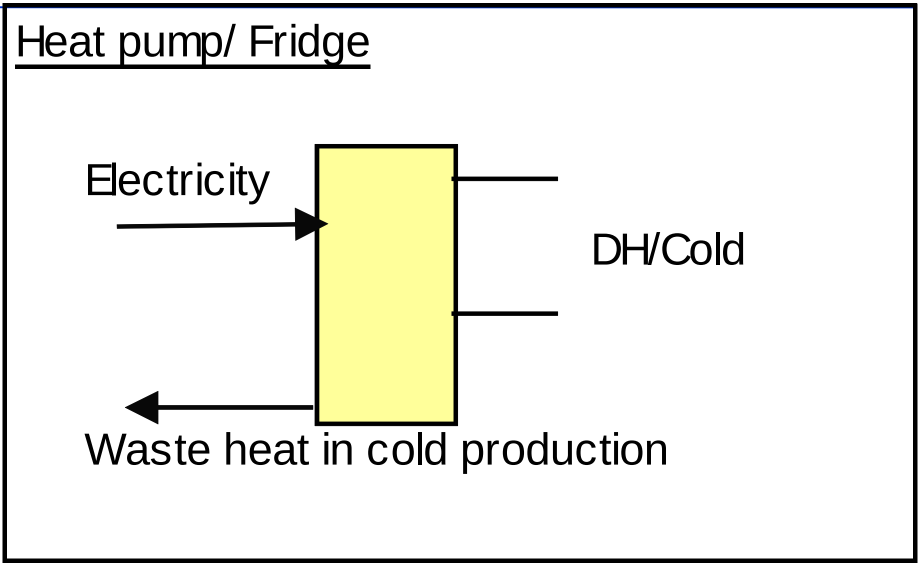
Compressor Heat Pumps

a) Heating:

Heat pump can produce 3-4 units of ***heat*** while using 1 unit of electric energy.

Thus, the ”coefficient of performance (COP)” is 3-4 as well.

The source from which heat is pumped (with compressor) to a higher temperature can be surrounding air, ground water, waste water, etc.



b) Chilling:

Heat pump can produce **cold** water and air as well as the ordinary fridge.

In producing cold, the waste heat has to be either ventilated out or can be used in the DH system.

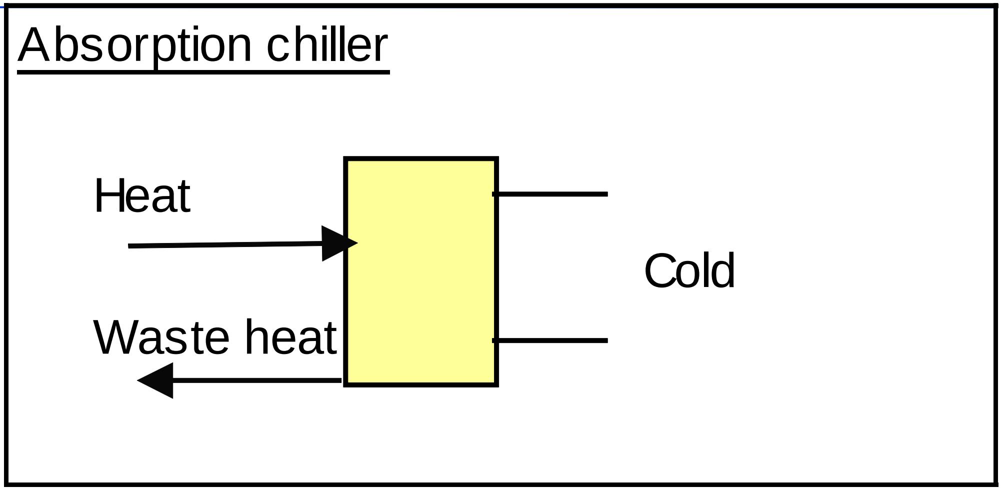
Source: UP-RES Project Team/Aalto University

2. Energy Transformation

2.8. Heat Pump

Absorption Heat Pump

- The absorption chiller is a chemical heat pump that uses heat as its driving force instead of electricity.
- Relatively expensive but is able to use district heat (waste heat in summer) to provide cooling of buildings.
- Waste heat is ventilated out as there is no use for it in summer.



Source: www.wikipedia.org

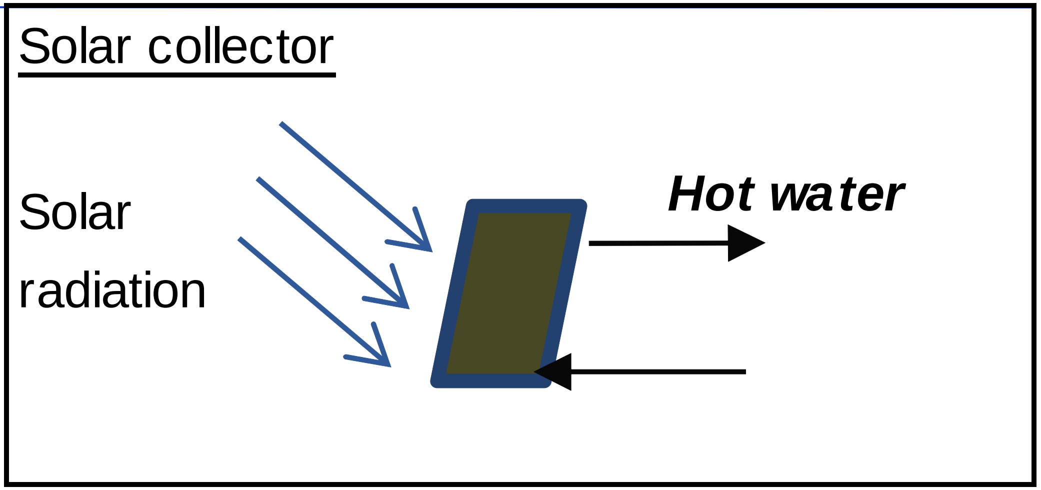
Solar Collector for Hot Water

Solar collector converts solar radiation to hot water.

In summer too much solar that may overheat the collector.

In other seasons there is less solar radiation and the angle to the sun must be nearer to optimal than in summer.

Therefore, the collectors are usually more nearer to vertical than horizontal.



Source: www.wikipedia.org

2. Energy Transformation

2.9. Solar

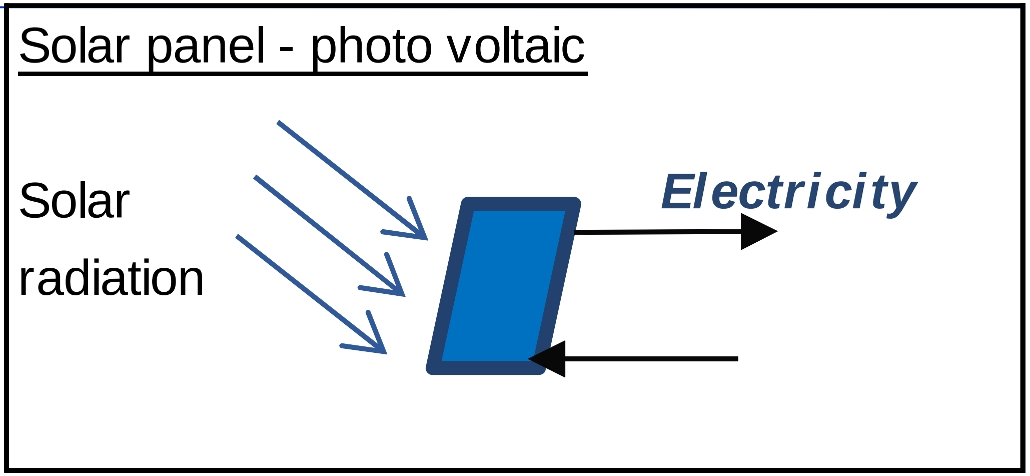
Solar Panel for Electricity – Photo Voltaic

Solar PV panel converts solar radiation to electrical energy.

In summer too much solar energy may overheat the panel.

In other seasons the sun is lower and the angle must be nearer to optimal.

Therefore, the panels are usually nearer to vertical than horizontal.



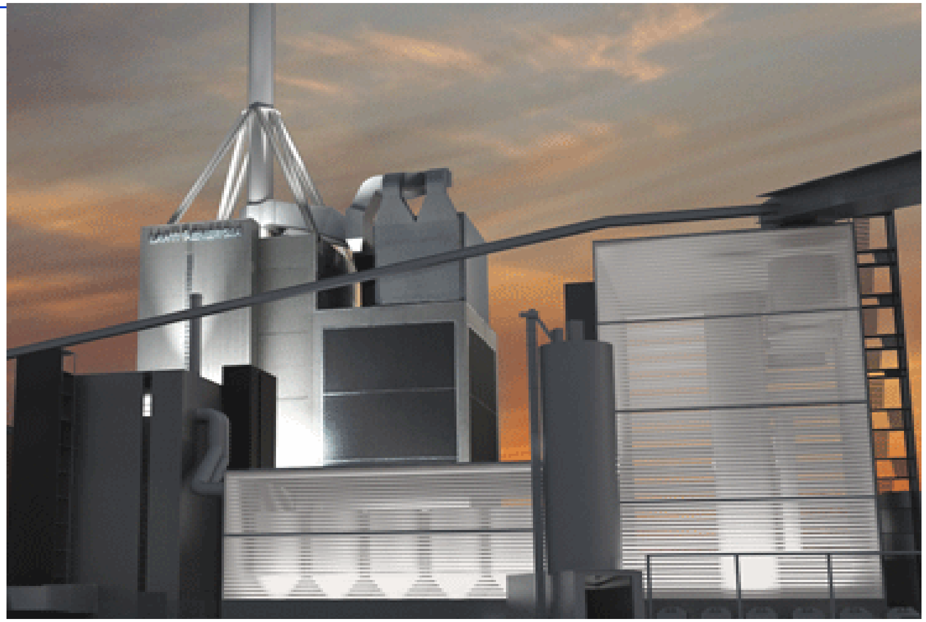
Source: www.wikipedia.org

2. Energy Transformation

2.10. Waste to Energy (1/2)

Benefits:

- Reduces the need for landfill extensions
- Substitutes fossil fuel usage and possible fuel import
- Creates new jobs in fuel logistics
- Reduces carbon emissions
- Minimizes all other emissions due to the sophisticated (and expensive) flue gas cleaning system
- Improves both national and local energy security
- Practically no fuel costs but gate fee collection instead
- Provides heat and electricity sales revenues.



- A large and modern municipal waste gasification CHP plant commissioned in 2012 in City of Lahti, Finland to produce 50 MW electricity and 90 MW district heating from 250.000 tonnes of waste based circulation materials a year
- (CFB - circulated fluidized bed gasification)

Source: www.lahtienergia.fi

2. Energy Transformation

2.10. Waste to Energy (2/2)

Requirements:

- High capital costs of about €200 million with 300.000 ton waste incineration capacity
- Economy of scale: needs to be a relatively large plant with about 200.000 tonnes of waste
- Heat production capacity of the plant should not be more than 60% of the peak load of the adjacent district heating and industrial heat load together

- The new municipal waste gasification CHP plant and the existing CHP plant in operation in Lahti, Finland.

Source: www.lahtienergia.fi

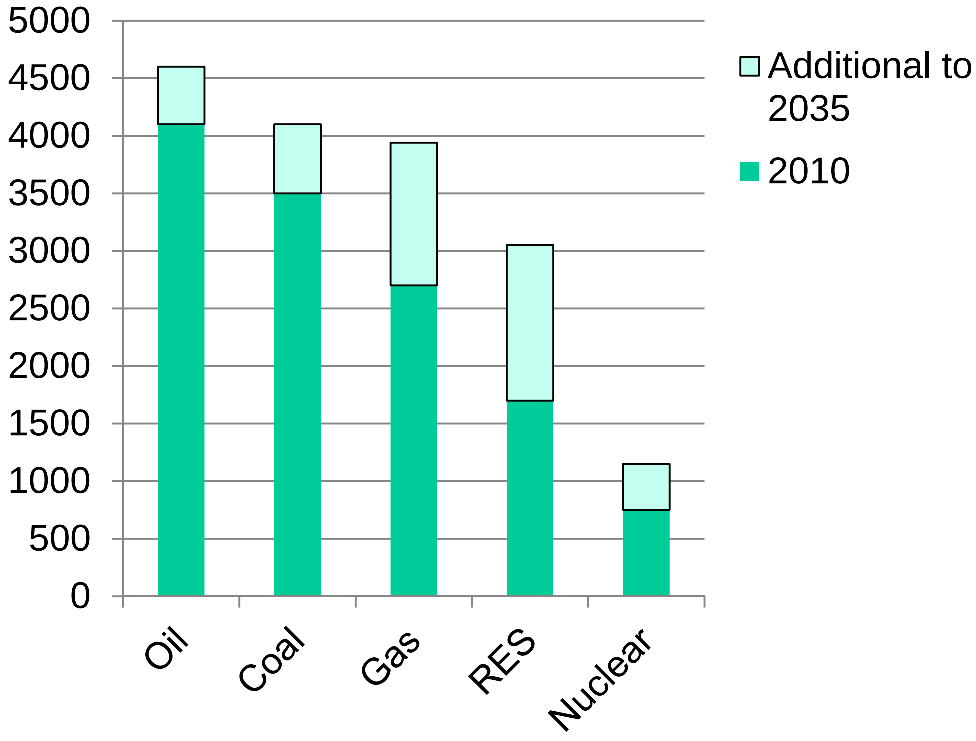
3. Energy Market Outlook

3.1. Primary Energy Demand (Mtoe)

Oil and coal still the most, but:

Natural gas and RES become increasingy important.

RES and natural gas together comprise two thirds of incremental demand in 2010-2035.



Mtoe: million ton of oil equivalent

Source:
International Energy Agency – World Energy Outlook 2011 - Presentation to Press, Nov 2011, www.iea.org

3. Energy Market Outlook

3.2. Oil Reserves

- Oil reserves in Europe: Russia, Norway, UK
- Oil shale reserves are huge, in North America in particular, but the need for chemicals makes it environmentally risky

Continent	Liquid oils		Oil shales	
Africa	17 719	11 %	23 317	3 %
Europe	12 519	8 %	52 845	8 %
North America	8 275	5 %	539 123	78 %
South America	16 762	10 %	11 794	2 %
Asia	9 382	6 %	51 872	8 %
Near-East	98 093	60 %	5 792	1 %
Oceania	284	0 %	4 534	1 %
Total	163 034	100 %	689 277	100 %

Source:
International Energy Agency – World Energy Outlook 2011 - Presentation to Press, Nov 2011, www.iea.org

3. Energy Market Outlook

3.3. Natural Gas Reserves

- Substantial gas reserves remain Europe, mainly in Russia but also in Norway and UK

Continent	Natural gas	
Africa	14 613	8 %
Europe	50 095	27 %
North America	9 688	5 %
South America	6 851	4 %
Asia	27 322	15 %
Near-East	75 668	41 %
Oceania	1 307	1 %
Total	185 544	100 %

Source:
International Energy Agency – World Energy Outlook 2011 - Presentation to Press, Nov 2011, www.iea.org

3.4. Conclusion

- There are enough fuel reserves in the world,

- But neither did Stone Age end after exhausting the stone reserves!

The UP-RES Consortium

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- **Spain : SaAS Sabaté associats Arquitectura i Sostenibilitat**
  www.saas.cat
- **United Kingdom: BRE Building Research Establishment Ltd.**
  www.bre.co.uk
- **Germany :**

  AGFW - German Association for Heating, Cooling, CHP
  www.agfw.de

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