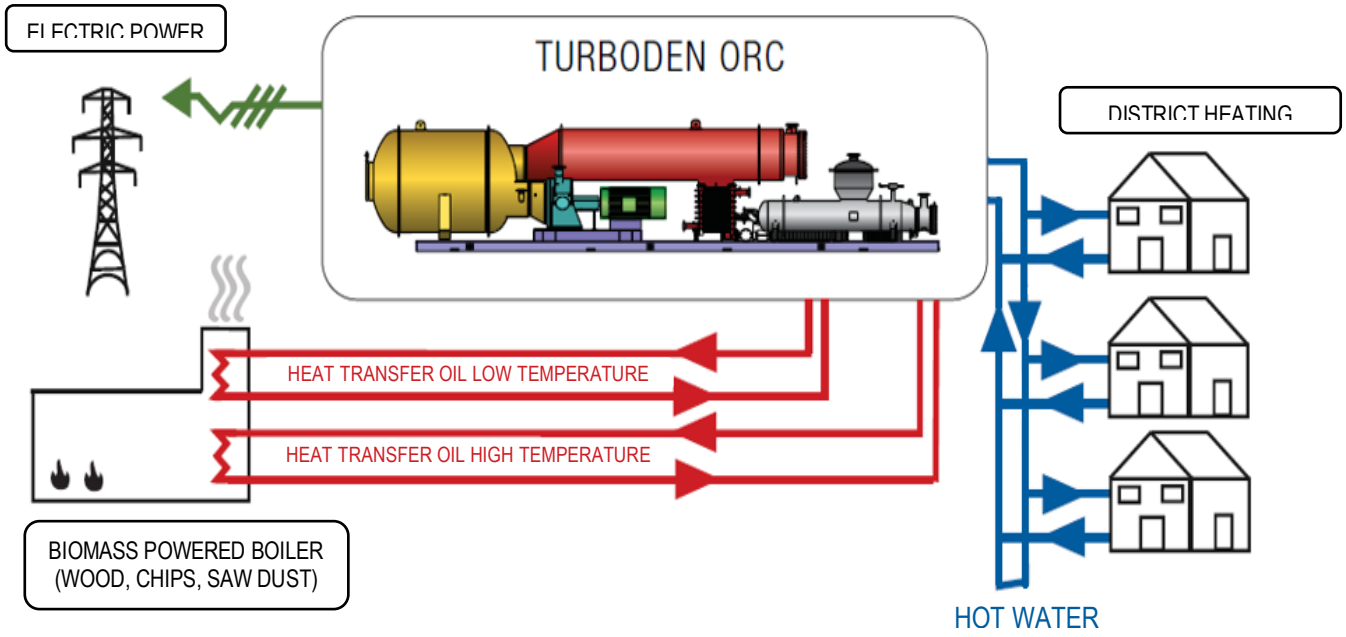
1) Power recovery from biomass combustion

Organic Rankine Cycle (ORC) technology is used to recover heat to electricity. One of the applications is for waste biomass combustion. The systems are flexible and can be used in district heating, pellet production factories, sawmills and tri-generation systems with absorption chillers.
An example of the technology is reported in the scheme below:



Data:

Input of woody biomass = 5254 kg/h
Wood biomass LHV = 9.36 MJ/kg
Heat transfer oil properties:

	Temperature	Enthalpy
Inlet Low Temp cycle	132 °C	200 kJ/kg
Outlet Low Temp cycle/ Inlet High Temp cycle	252°C	443 kJ/kg
Outlet High Temp cycle	312°C	578 kJ/kg

Mass flow of Low Temp cycle heating oil = 4.3 kg/s
Mass flow of High Temp cycle heating oil = 81.3 kg/s
Hot water outlet temperature from ORC system = 90°C
District heating water return temperature = 60°C
Water properties:

Temperature	Enthalpy
60°C	251 kJ/kg
90°C	377 kJ/kg

District heating water flow = 76.43 kg/s
Electric net power output of ORC Turboden plant = 2175 kW

Calculate

1) The boiler efficiency
2) The electrical efficiency of the ORC
3) The cogeneration efficiency of the ORC

2) Biomass CHP-plant from energy crops

A crop plantation yields 20 tons dry organic matter per year and per hectare (LHV: 17 MJ/kg). (corresponding to 2 kg/m^2, or also 1 W/m^2 storage efficiency, as seen in the course). Harvesting is in autumn. A CHP plant combusts the crop fuel during the heating season (6 months, 4000h). The idea is to supply as much as possible the local residents and their economic activity with heat and power from this plant. The power need averaged per person is taken as 0.8 kWel, the heat need (for the 4000h heating season) as 2.7 kW per person on average (values valid for Switzerland). The CHP plant drives a steam cycle with 21% efficiency, total cogeneration efficiency is 92%. A typical plantation size could be 1 km^2.
How many people-equivalents could such a plant supply with heat and power (during the 4000h heating season)?
How many such plants (and therefore how many km^2 of energy crop plantations) would be needed to cover the whole population-equivalent? (8 million in CH)
Discuss the outcome.

3) Biogas generation efficiency from manure

Manure biomass is transformed to biogas by anaerobic digestion (hydrolysis).
The manure's composition is, by weight (dry basis), 42% carbon, 6% hydrogen, 32% oxygen, 2.1% nitrogen, plus 18% of inorganics.
What will be the biogas composition ?
What is the energy balance of the process? I.e. how much energy is contained in the biogas compared with how much energy is contained in the manure?
(LHV CH_4 : 800 kJ/mole) (LHV NH_3 : 225 kJ/mole)
Hint: use the Buswell-Boyle formula