Exercise 1: wood pyrolysis energy balance

Input:

- 1 kg dry wood with LHV 17 MJ/kg
- 2.4 MJ heat supply for the pyrolysis (=delivered from burning the liberated gases)

Products:

- 200 L gas (with a LHV equal to 1/3rd of that of natural gas (10 kWh/Nm^3))
- 0.45 kg liquids (with a LHV equal to 1/3rd of that of oil (42 MJ/kg))
- 0.3 kg charcoal (with a LHV equal to that of coal (24 MJ/kg)

Compute the energy balance of the pyrolysis process.
Compute the energy balance only for the solid output (charcoal).

Exercise 2: wood gasification energy balance (downdraft gasifier, with air)

Input:
1 kg 15% humid wood (LHV of wood with 0% H_2O = 17.8 MJ/kg)

⇨ compute the LHV of the humid wood

Products:
2 m^3 'producer gas' of :
18% CO / 16 % H_2 / 2 % CH_4 / 14% CO_2 / 50% N_2
(LHV (CO): 305 kJ/mole; LHV (H_2) : 241 kJ/mole; LHV (CH_4) : 800 kJ/mole)

Compute the energy balance of this gasification process ('cold gas efficiency').

Exercise 3: 25 MW_{el} straw combustion plant

Data:

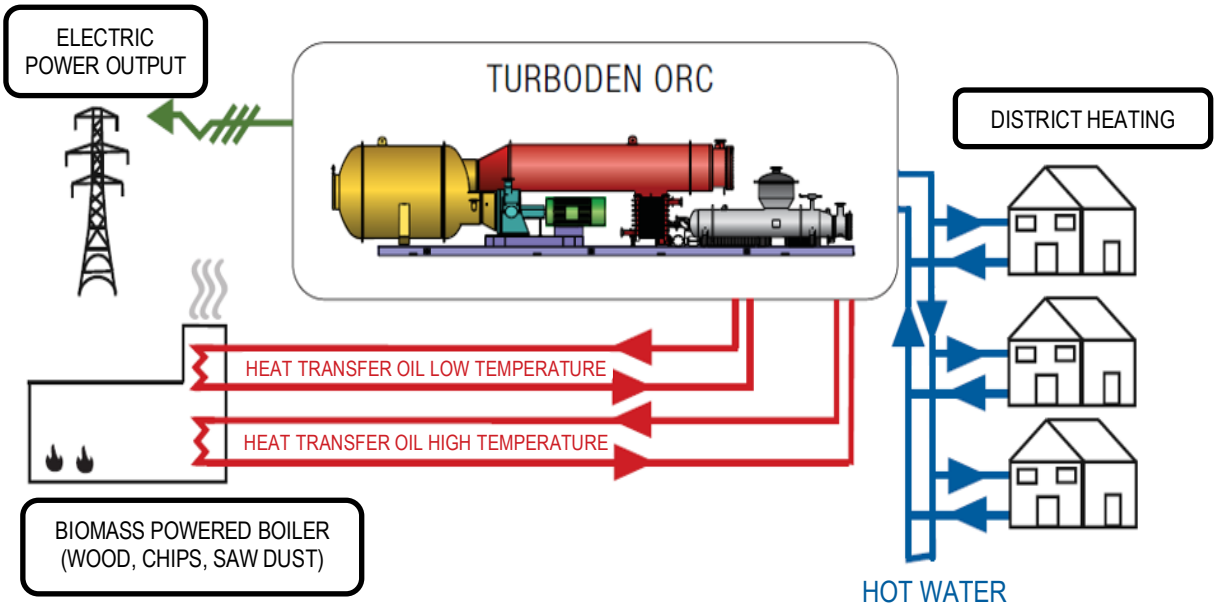
- 8000 h operation per year / production of 200 GWh_{el}
- consumption of 160'000 tonnes / yr of straw
- take a typical yield of 3 tonnes straw per hectare (=quite low yield!)

Questions:

- what is the electrical efficiency of the plant? (see course slides for the LHV for straw)
- what would be the straw collection area needed to 'feed' this plant?

Exercise 4: ORC with biomass combustion

The Organic Rankine Cycle (ORC) is a technology used with biomass applications. The systems are flexible and can be used in e.g. district heating, pellet production factories, sawmills and tri-generation systems with absorption chillers.
A possible application is reported in the scheme below:



Considering the following data:
Input of wood biomass = 5.254 ton/h
Wood biomass LHV = 2.6 kWh/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

Oil Mass flow Low Temp cycle = 4.3 kg/s
Oil Mass flow High Temp cycle = 81.3 kg/s

Hot water outlet temperature from ORC system = 90°C
District heating water return = 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 = 2.175 MWe

Calculate :

- the boiler efficiency
- the electric efficiency of the ORC
- the cogeneration efficiency of the ORC