Exercise 1: competition biomass/food

An adult human being is a 120 W machine. We get our energy 80% from vegetables (= 'direct' biomass) and 20% from meat (= 'indirect' biomass), assuming an efficiency from primary biomass-to-meat of 10%.

- How much MJ/day, and kWh/yr, do you need in food from primary biomass?
- How much primary biomass does the world population consume? (7.5 billion people)
- Assess the result in view of the biomass energy potential and agricultural production.

Exercise 2: estimate of residual biomass, primary and final energy

Assumptions:

a) Agriculture: from the total yearly human agricultural production (152 EJ), discount the energy requirement to feed humans (=exercise 1). Assume that from the remainder, ≈½ is used to feed animals, ≈¼ is used for composting, and the rest (10%) is recoverable as 'residual' energy from 'agro-waste'.
b) Forestry: assume 1 kg/m^2 new wood growth per year (LHV: 17 MJ/kg); assume 1% of the world's forest area is trimmed (from where this waste wood is recovered as energy)
c) Animal manure: assume a production of 1 m^3 of biogas per day (with 50% CH_4 content) per large farm animal and that there are half as many large farm animal-'equivalents' as people. (LHV of CH_4 = 36 MJ/m^3 = 10 kWh/m^3)
d) Solid organic wastes from our activities (food waste, parks and garden wastes, food industry,..): assume a waste of 1 kg dry organic matter per week per person, converted to 500 L biogas per dry kg, with a CH_4 content of 60%
e) Human liquid organic waste (sewage – waste water treatment plants): assume a production of 30 L biogas per day per person, with a CH_4 content of 65%.

From all this data, compute the total residual biomass primary energy potential and how this relates to the total human yearly primary energy consumption.

For the conversion to final energy, make realistic choices for the conversion technology (for power), and the corresponding conversion efficiencies.

Exercise 3: 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 4: 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 5: 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
- 200'000 t CO_2 emissions / yr avoided
- 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?
- what is the stated CO_2 emission value based on?