Biomass and biofuels

Implementation, role in the energy system

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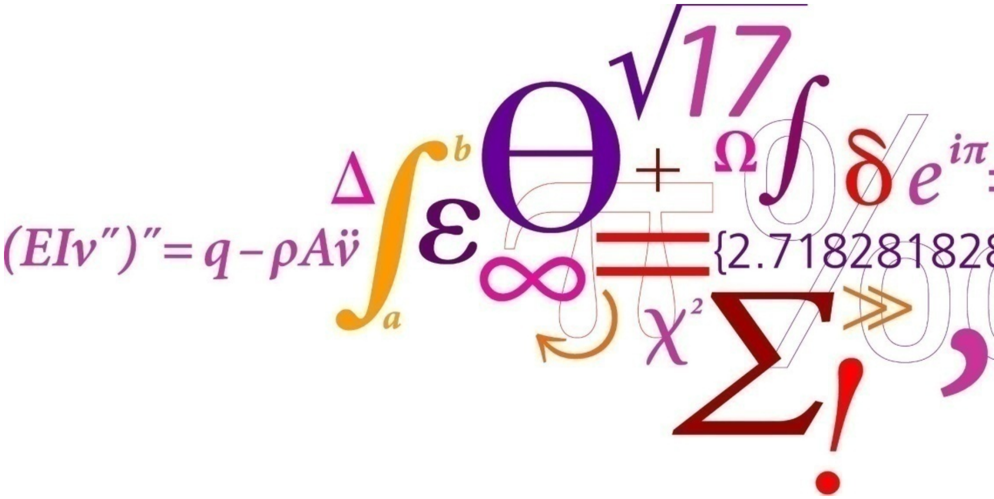


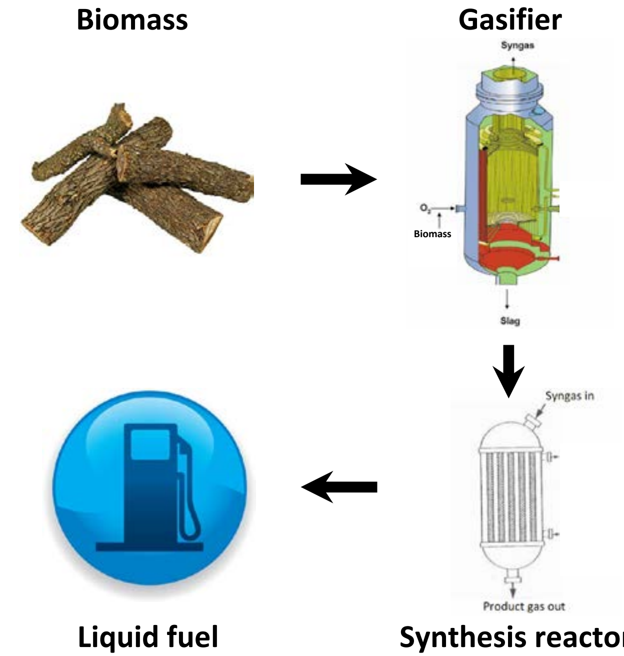
DTU Mechanical Engineering
Department of Mechanical Engineering

Thermochemical biofuel production

Exercise

If the cleaned and conditioned syngas from a gasifier consist of 2/3 of H_2 and 1/3 of CO (molar basis), and the energy efficiency from biomass to syngas is 80%, calculate:

- the energy efficiency from syngas to methanol
- the total energy efficiency (biomass to methanol).



Heating values:

H_2: 241.8 MJ/kmol

CO: 283.0 MJ/kmol

CH_3OH (Methanol): 638 MJ/kmol

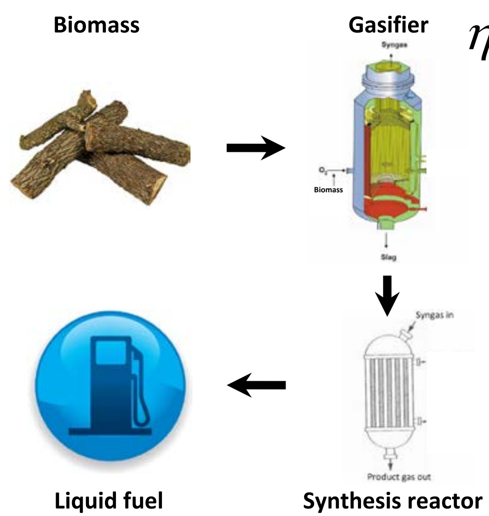
Methanol reaction: $CO + 2H_2 \rightarrow CH_3OH$

Thermochemical biofuel production

Solution to exercise

Methanol reaction: $CO + 2H_2 \rightarrow CH_3OH$

$$\eta_{syngas\ to\ methanol} = \frac{LHV_{methanol}}{LHV_{syngas}} = \frac{638\ ^{MJ}\!/_{kmol}}{283.0\ ^{MJ}\!/_{kmol} + 2 \cdot 241.8\ ^{MJ}\!/_{kmol}} = 83\%$$



$$\eta_{biomass\ to\ methanol} = \eta_{biomass\ to\ syngas} \cdot \eta_{syngas\ to\ methanol} = 80\% \cdot 83\% = 67\%$$

80% energy efficiency on gasifier

Heating values:

H_2: 241.8 MJ/kmol

CO: 283.0 MJ/kmol

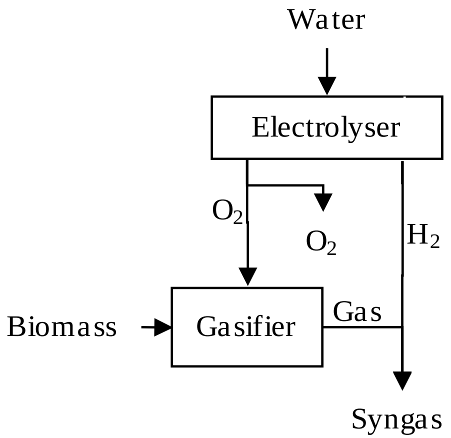
CH_3OH (methanol): 638 MJ/kmol

Thermochemical biofuel production

Exercise

By integrating electrolysis almost all the carbon in the biomass can be converted to fuel.

1. Calculate the potential output (kg) of methanol or CH_4 per kg of dry wood input.
2. Calculate the potential energy yield of methanol or CH_4 per energy input of dry wood.



Ultimate analysis of dry Wood (wt%): 47.2% C, 6.1% H, 45.1% O, 0.3% N, 0.02% S, 1.3% ash.

Heating values:

Wood (dry): 17.6 MJ/kg

CH_4 : 802.3 MJ/kmol

CH_3OH (Methanol): 638 MJ/kmol

Thermochemical biofuel production

Solution to exercise

By integrating electrolysis almost all the carbon in the biomass can be converted to fuel.

1. Calculate the potential output (kg) of methanol or CH_4 per kg of dry wood input.

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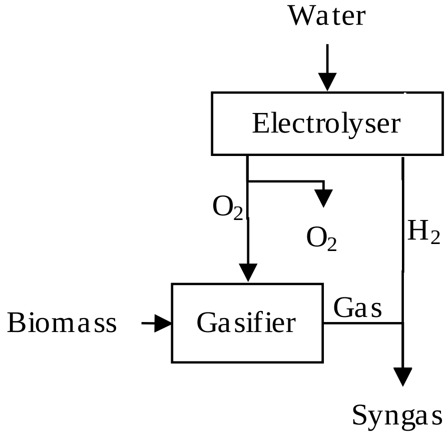


Carbon contents:

Wood: 0.472 kg_C / kg_wood

CH_4 : 12/(12+4)= 0.75 kg_C / kg_CH_4

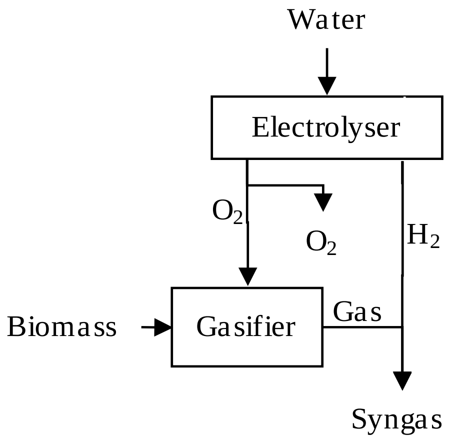
CH_3OH: 12/(12+4+16)= 0.375 kg_C / kg_CH_3OH

Per kg of wood the potential output of CH_4 must be: 0.472 / 0.75 = 0.63 kg_CH_4 / kg_wood

Per kg of wood the potential output of CH_3OH must be: 0.472 / 0.375 = 1.26 kg_CH_3OH / kg_wood

Thermochemical biofuel production

Solution to exercise



By integrating electrolysis almost all the carbon in the biomass can be converted to fuel.

2. Calculate the potential energy yield of methanol or CH_4 per energy input of dry wood.

Heating values:

Wood (dry): 17.6 MJ/kg

CH_3OH : 638 MJ/kmol / 32 kg/kmol = 19.9 MJ/kg

CH_4 : 802.3 MJ/kmol / 16 kg/kmol = 50.1 MJ/kg

Molar mass:

CH_3OH (Methanol): 12+4+16 = 32 kg/kmol

CH_4 : 12+4 = 16 kg/kmol

From question 1:

$$0.63\,\frac{kg_{CH_4}}{kg_{wood}}$$

$$1.26\,\frac{kg_{CH_3OH}}{kg_{wood}}$$

$$\text{energy yield } CH_4 = 0.63\,\frac{kg_{CH_4}}{kg_{wood}} \cdot \frac{50.1\frac{MJ_{CH_4}}{kg_{CH_4}}}{17.6\frac{MJ_{wood}}{kg_{wood}}} = 1.79\frac{MJ_{CH_4}}{MJ_{wood}}$$

$$\text{energy yield } CH_3OH = 1.26\,\frac{kg_{CH_3OH}}{kg_{wood}} \cdot \frac{19.9\frac{MJ_{CH_3OH}}{kg_{CH_3OH}}}{17.6\frac{MJ_{wood}}{kg_{wood}}} = 1.42\frac{MJ_{CH_3OH}}{MJ_{wood}}$$