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Comparison of fuel production costs for future transportation

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ABSTRACT

The purpose of this poster is to provide an overview of fuel production costs for two types of synthetic fuels – methanol and methane, along with comparable costs for first and second generation biodiesel, two types of second generation bioethanol, and biogas.

The model analysed is a 100% renewable scenario of Denmark for 2050, where the data for the transport sector has been changed to estimate the fuel production costs for eight different fuel pathways.

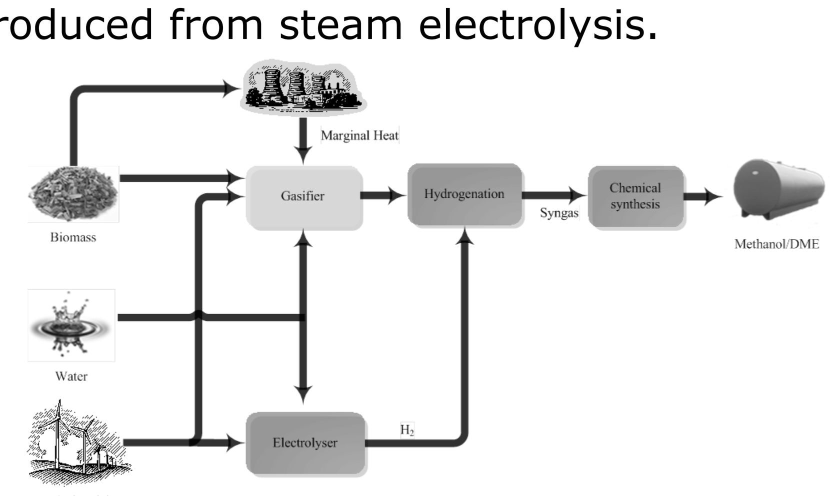
METHODOLOGY

- The scenarios have been analyzed using the energy system analysis tool EnergyPLAN. EnergyPLAN was chosen because it includes the balancing of the energy system in its fuel costs calculations.
- This aspect was important because electrolysers enable high share wind integration; therefore the costs are more accurate when including balancing costs. All scenarios were analyzed with technical optimization, meaning that the fuel consumption is minimized. This is important due to the level of biomass resource used in the scenarios.
- The scenarios vary depending on the pathways implemented in the transport sector, but in terms of primary energy supply the variations are mainly the ability to integrate wind capacity and the biomass demand for fuel.

THE SYNTHETIC FUEL PATHWAYS

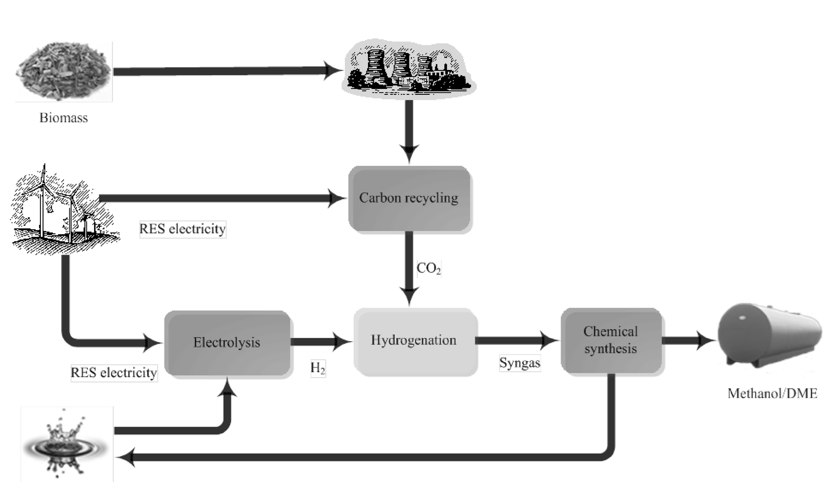
The fundamental difference between synthetic fuel pathways is in the carbon source.

Biomass hydrogenation uses direct input of biomass in the gasification process, and the produced gas is later on boosted with hydrogen produced from steam electrolysis.

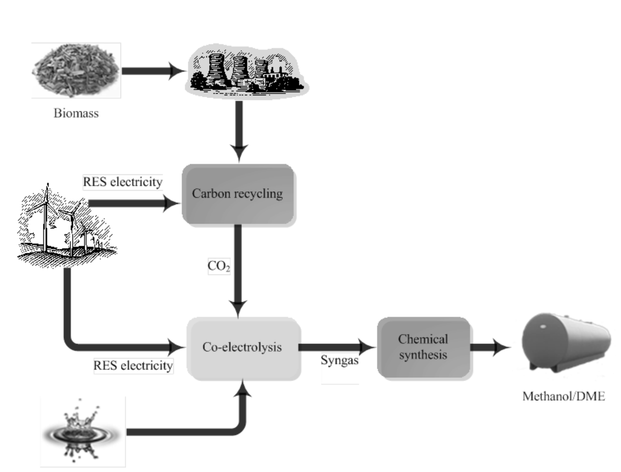


CO_2 recycling pathways (CO_2 hydrogenation and co-electrolysis) do not require any direct biomass input, instead they use emissions from the biomass used in the heat and power sector combined with electrolysis.

- The CO_2 hydrogenation pathway combines hydrogen from the steam electrolysis with recycled carbon dioxide to form a syngas.
- The Co-electrolysis pathway is using combined process of steam and CO_2 electrolysis called co-electrolysis, and the produced synthetic gas can afterwards be catalyzed.



CO_2 hydrogenation



Co-electrolysis

BIOFUEL PATHWAYS AND BIOGAS

- Four biofuel pathways were analyzed along with the biogas pathway. The biofuel pathways are chosen according to the existing technology and due to their current contribution as the most exposed renewable replacement for fossil fuels.
- The first generation biodiesel is used for analysis as it is the most commonly produced biofuel in Europe. It is based on a chemical modification of vegetable oil by transesterification. The second generation biodiesel represents the production by biomass-to-liquid process (BTL).
- Two second generation bioethanol scenarios were analyzed, one without and one with the C5 sugar utilization.
- Biogas is modelled by using animal manure treated in an anaerobic process. The output biogas is in this analysis completely upgraded into methane with hydrogen from water electrolysis.

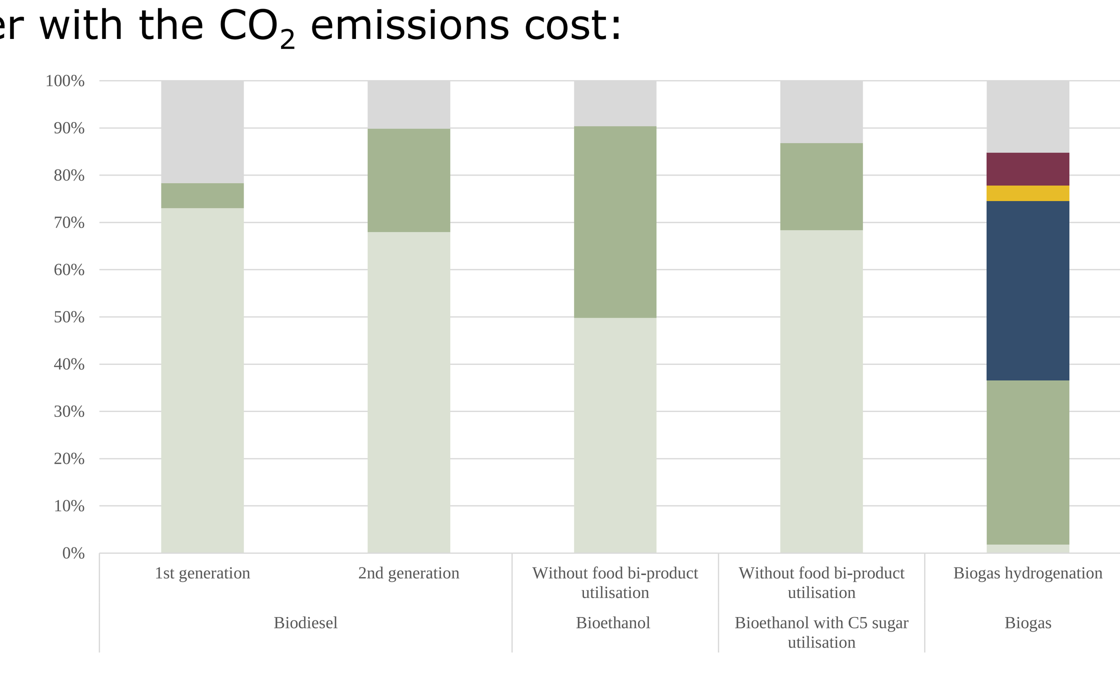
COMPONENTS OF THE FUEL PRODUCTION CHAINS

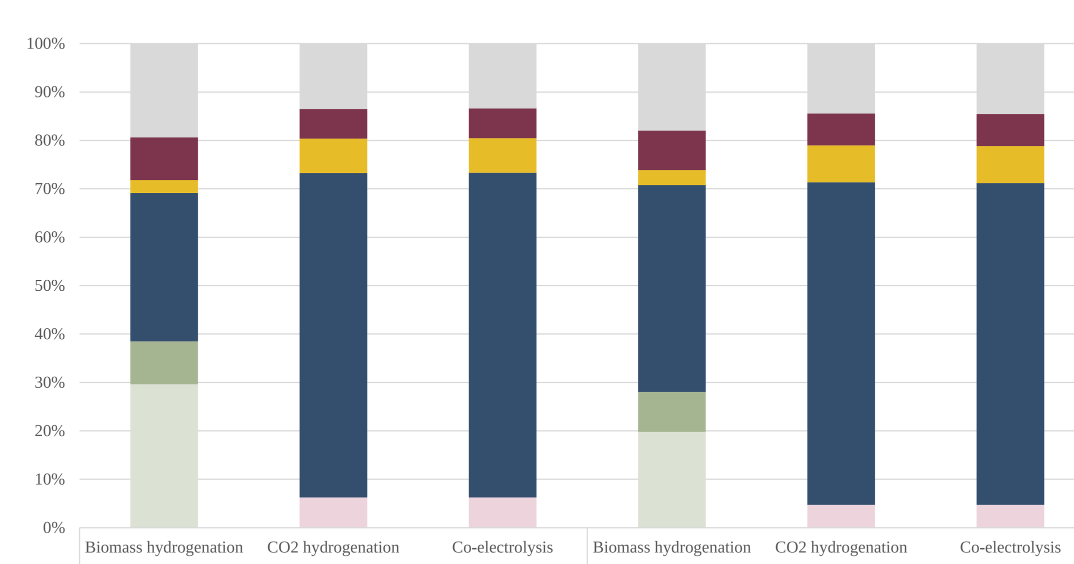
Table provides a matrix of all the system components that form the price in different pathways. Note that infrastructure such as building new gas networks for transporting gaseous fuels, CO_2 or syngas, were not included in the cost calculation because the aim was to give an overview of the fuel production costs and not the overall implementation costs of these fuels.

	Biodiesel/ Biodiesel 2nd generation	Bioethanol 1/ Bioethanol 2	Biogas hydrogenation	Biomass hydrogenation	CO_2 hydrogenation	Co-electrolysis
Carbon source	Biomass	Biomass		Biomass gasification	CO_2 emissions from biomass CHP plant	CO_2 emissions from biomass CHP plant
Bioenergy plant	Biodiesel plant	Bioethanol plant	Biogas plant	Gasification plant		
Resource	Energy crops (grass or corn) / Straw or wood incl. pellets	Straw or wood incl. pellets	Manure	Straw or wood incl. pellets		
Electricity source			Offshore wind	Offshore wind	Offshore wind	Off shore wind
Electrolysis			SOEC	SOEC	SOEC	SOEC
Fuel synthesis			Chemical synthesis	Chemical synthesis	Chemical synthesis	Chemical synthesis

THE BREAKDOWN OF COSTS

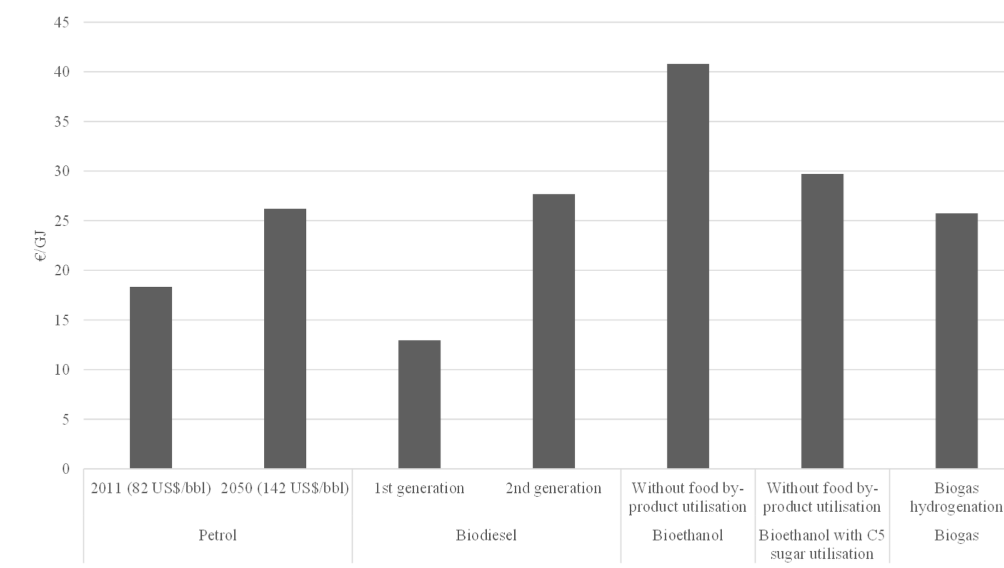
Figures below show the breakdown of costs for biofuels, biogas and synthetic fuels to the production units, feedstock and fuel handling costs, together with the CO_2 emissions cost:

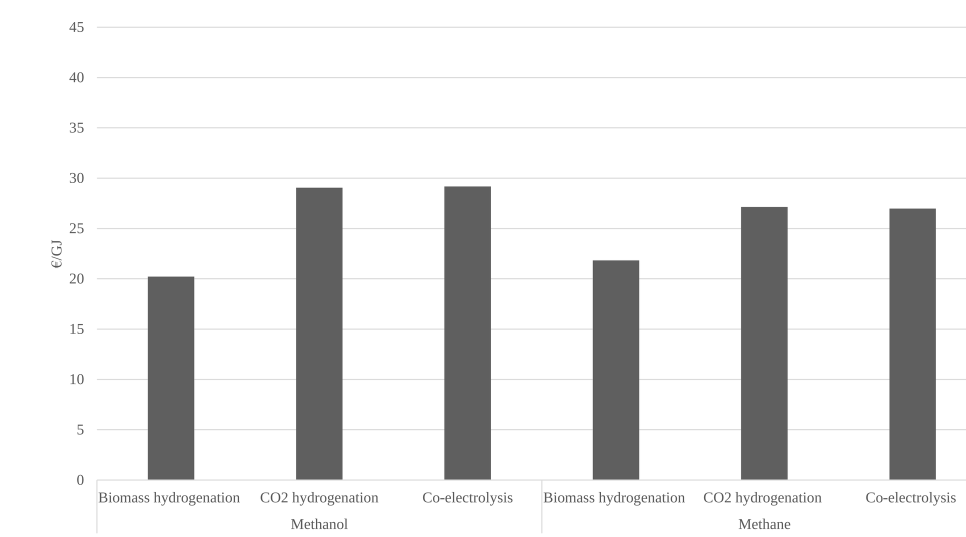




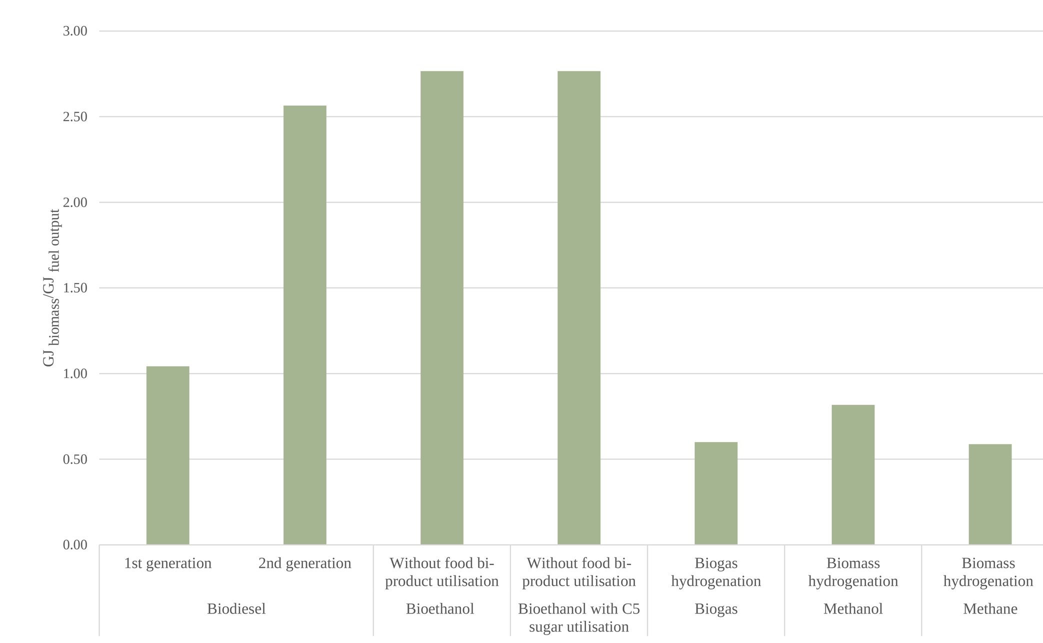
FUEL PRODUCTION COSTS

The calculated fuel price per GJ of produced fuel can be seen below for all pathways:





The Figure below shows the correlation between biomass consumption and fuel output for each pathway that has fuel production based on biomass resources. This figure shows directly the biomass consumption per scenarios.



CONCLUSION

- The pathways with higher share of biomass in their production process are not as flexible in terms of wind integration and the fuel output as other proposed scenarios. The synthetic fuel pathways enable the wind integration which varies from lowest for the biomass hydrogenation pathways to highest for CO_2 recycling pathways.
- Synthetic fuel production enables flexible fuel choice, which was shown by the production of both methanol and methane. These pathways have higher production costs due to the technologies that they use for the production process, yet they are still lower than the costs of second generation bioethanol.
- The major finding was that the production costs of synthetic fuels are comparable with petrol production costs when the associated CO_2 emissions are accounted for. Taken together, these results suggest that these fuels have a potential to be a future fossil fuel replacements in the transport sector.

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SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS

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