3-PLATFORM (BIOCRUDE, SYNTHESIS GAS, ELECTRICITY&HEAT) BIOREFINERY USING WOOD BIOMASS FOR GASOLINE, REFINERY GAS, PROPYLENE, ELECTRICITY & HEAT WITH ENTRAINED FLOW GASIFICATION AND DME SYNTHESIS

The case study analyses possibilities for integration of gasification systems into conventional oil refineries for the production of synthetic bio-fuels. The wood biomass feedstock is gasified with steam to produce producer gas which contains a mixture of compounds. The producer gas must be cleaned and conditioned to get a mixture of CO and H_2 - the synthesis gas - which is then converted to di-methylether (DME) via a catalytic reaction system (DME synthesis) (see very basic diagram Figure 1). The final quality of the transportation synthetic biofuels is reached in the refinery upgrading. Butane, propane & polypropylene are valuable side products.

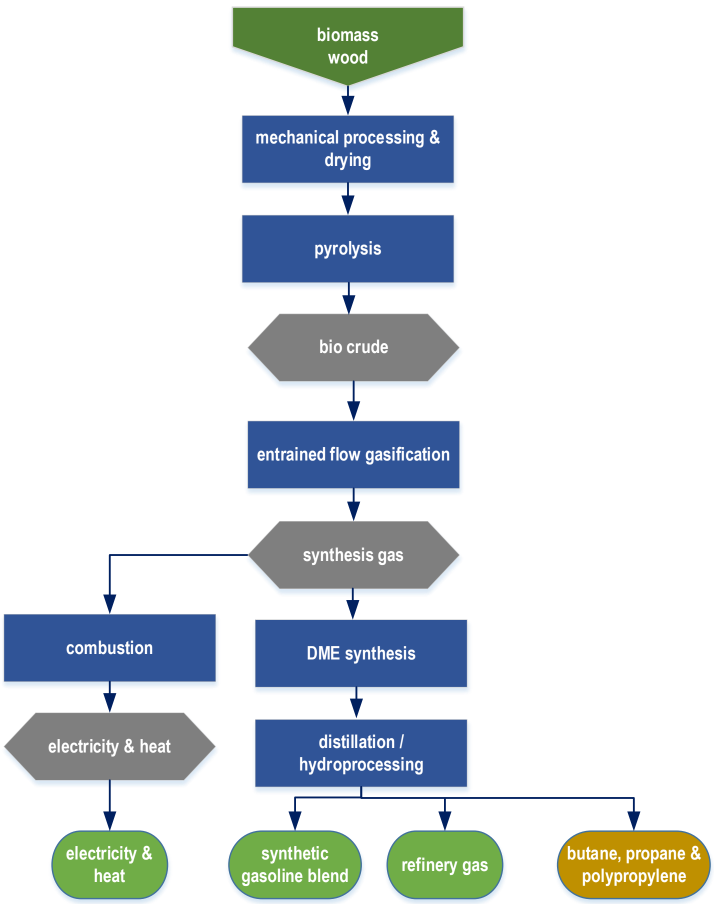


Figure 1: Accumulated results for the DtG system.
Basic flow chart of DME processes for high-quality gasoline blend

PART A: BIOREFINERY PLANT

DtG

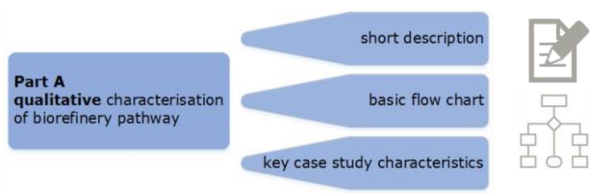


Figure 2 highlights that only a rough ninefold amount of biomass is needed for the production goal of synthetic gasoline. Other resources follow this trend, as less oxygen and energy are needed. While side product yields are also lower than for the MtG case (other fact sheet available), gasoline can be produced with a higher efficiency, indicating a highly specific but overall efficient process. Detailed results are listed in Table 1.

Table 1: Detailed overview over in- and outputs (in kt/a), energy inputs and outputs in (PJ/a) and efficiencies.

Inputs		Outputs	
Biomass	*889.153*	*Synthetic gasoline*	*100,000*
Oxygen	*305.291*	*Butane*	*13,571*
		Propylene	*4,233*
		Propane	*265*
Energy Inputs		**Energy Outputs**	
Biomass	*12.89*	*Steam*	*2.4*
		District Heat	*0.27*
		Electricity	*0.01*
		C3-C4 products	*0.83*
		Refinery gas	*0.45*
		Synthetic gasoline	*4.24*
Overall efficiency	***66.94 %***		
Product efficiency	***41.19 %***		
Gasoline efficiency	***34.44 %***		

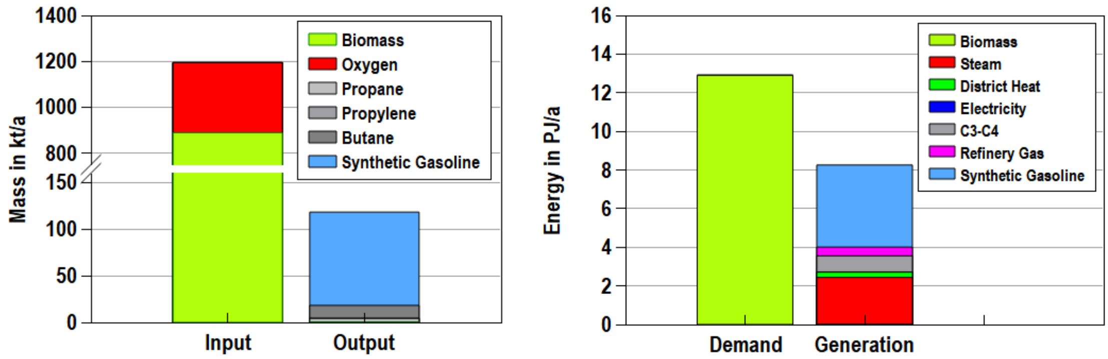
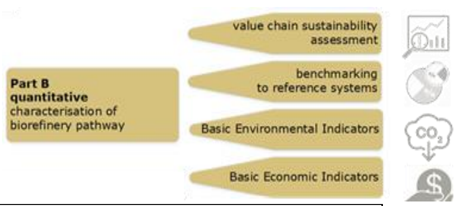


Figure 2a (left) displays the mass balances of the DtG system. 2b (right) shows the energy input in form of biomass compared with the energy content of the products and energy carriers obtained in the transformation.

PART B: VALUE CHAIN ASSESSMENT

For the economic evaluation CAPEX of 0.22 €/L and OPEX of 0.63 €/L were reported by Rauch and Koroveshi. [1] Results for the economic evaluation are found in Figure 3.



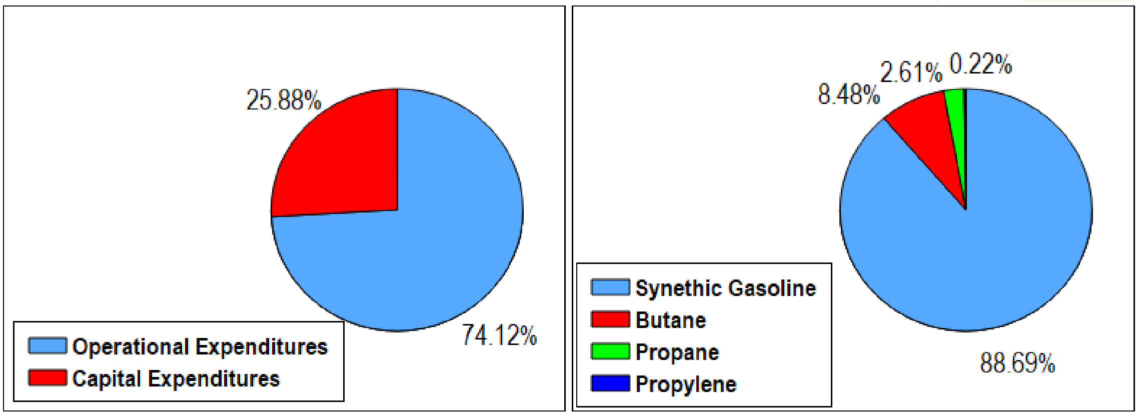


Figure 3a & b: 3a (left) shows the share of total costs between CAPEX and OPEX. 3b (right) shows the share of revenues generated by the products types.

While the OPEX values for DtG lie only 1c lower per litre compared to the MtG case (other fact sheet available), the CAPEX value is 11€-cent higher per litre. This is in accordance with the literature presented above which forecasted savings in initial investments. In the balance sheet the savings of roughly 2 million € in the CAPEX are eradicated by an increase in OPEX by circa 15 million €/a compared to the CAPEX in the MtG case. Besides the technical complexity the lower TRL of DtG is not able to fully utilize economies of scale such as the more established MtG process under this assumptions. Products from the MtG process are dominated by aromatic and branched aliphatic hydrocarbons belonging to the gasoline fraction, and the gasoline selectivity is about 80%. MtG gasoline has a high-octane number of 90–95 and needs no enhancement. The MtG process thus has actual advantages in terms of product selectivity and lower plant investment cost. While the fuel efficiency is higher than for the MtG case, higher production cost and lower yields from side products result in a negative balance as presented in Table & Table and Figure with the specific assumptions taken into account.

Table 2: CAPEX and OPEX of the DtG plant.

CAPEX (€/l) & (€/kg)	**0.22**	**0.31**
in %	25.88	74.12
OPEX (€/l) & (€/kg)	0.63	0.70

Table 3: Costs and revenue of the gasification plant, in Million €.

	Cost	**Revenue**
CAPEX	29.79	0
OPEX	85.14	0
Synthetic Gasoline	0	84.37
Propylene	0	0.21
Propane	0	2.48
Butane	0	8.07
Total	***114.86***	***95.14***

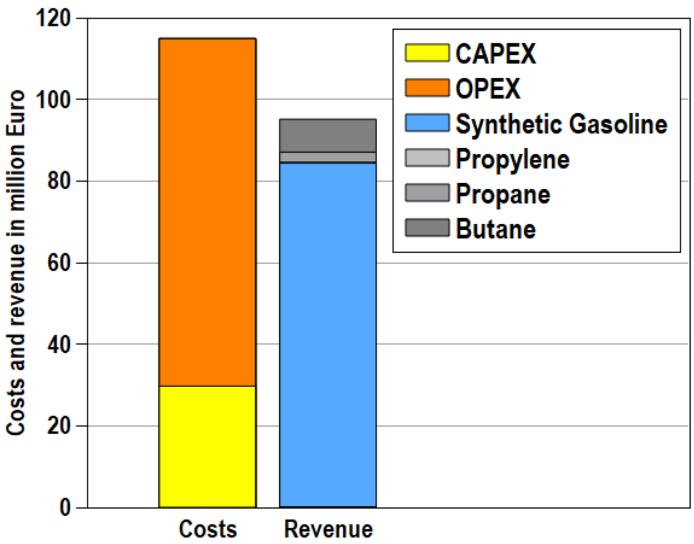


Figure4: Costs and revenues and their detailed composition.

GHG, PED and NREU emissions were also compared for the DtG process in Figure 5 & Figure 6. According to the RED [2] energy from renewable energy should carry no burden, therefore in this comparison bioenergy is far superior to the fossil references. All values are lower when compared to

MtG (other fact sheet available). The reasons are obvious, as less biomass is used and fewer side products are produced, thus the renewable energy input, as well as fossil energy demand as well as greenhouse gas emissions go down. While economic figures favoured MtG, the environmental data outlines DtG as more energy-efficient. However, MtG's reference system emits more GHGs as more by-products are obtained. In this sense on a static comparison the preferences go to MtG over DtG but are again very case specific relying on the basic assumption of the biorefinery set-up. In addition to featuring a high-octane number, the DTG-produced gasoline has high aromatics and paraffins content, and relatively low content of naphthenes and olefins. Many countries currently set limits on aromatics and olefins contents in gasoline; the DTG gasoline would need to be refined to meet the new regulations in the most countries, and it also can be used as a blending agent in gasoline pool. These additional aspects can only be added in a qualitative discussion and can hardly be depicted quantitatively in the the respective case studies.

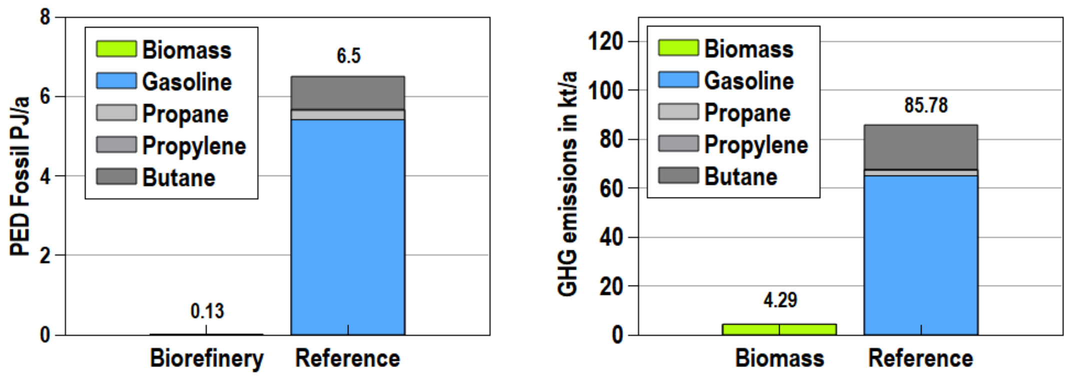


Figure 5: Figure 5a (left) shows the fossil primary energy demand and Figure 5b (right) the GHG emissions of the reference products.

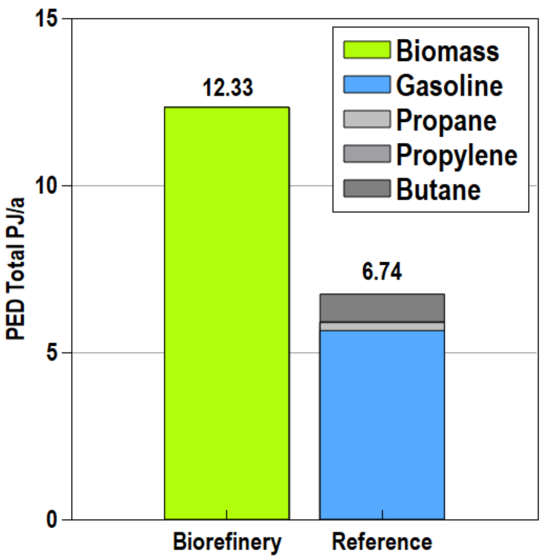


Figure 6: The total primary energy demand including renewable energy is compared between the benchmark and the biorefinery.

This is in accordance to previously discussed points as it was concluded that the biorefinery turns low-energy-density materials into high-energy-density materials. Figure 7 shows a graphical abstract of the two systems compared and Table 4 summarizes results for energy and GHG emission savings.

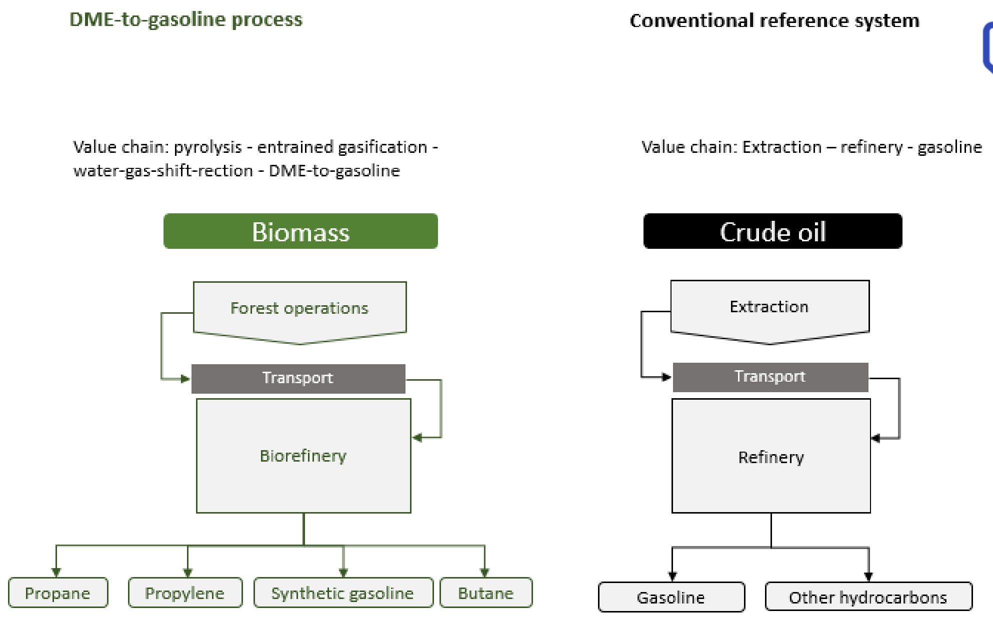


Figure 7: Biorefinery and reference system - value chain (cradle to gate)

Table 4: Accumulated results for the DtG system.

Greenhouse gas emissions		
Biomass	0	kt CO_2-eq/a
Biorefinery auxiliary materials and supplies	4.29	kt CO_2-eq/a
Crude oil refinery reference system	85.78	kt CO_2-eq/a
Savings	-81.49	kt CO_2-eq/a

Cumulated (total) Primary energy demand		
Fossil Reference system	6.74	PJ/a
Biomass	12.33	PJ/a
Reference system versus biorefinery total primary energy demand	+5.59	PJ/a
Reference system versus biorefinery fossil primary energy demand savings	-6.37	PJ/a

REFERENCES

[1] R. Rauch and X. Koroveshi, ‘Gasification for the application in biorefineries’, Karlsruher Institut für Technologie, Feb. 2021, https://www.ieabioenergy.com/wp-content/uploads/2022/01/Gasification_case_story_03.pdf

[2] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources

MORE DETAILED INFORMATION ON THE DATA BASIS AND THE METHOD APPLIED ARE AVAILABLE IN THE ACCOMPANYING REPORT AT HTTPS://TASK42.IEABIOENERGY.COM/PUBLICATIONS/TEE-ASSESSMENT-GASIFICATION/