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Photofuel - Biocatalytic solar fuels for sustainable mobility in Europe

Deliverable D7.1

Business case description

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Editorial		
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Publishable Summary

The overarching goal of the European Horizon2020 research- and innovation-project Photofuel is the biocatalytic production and secretion of drop-in or widely blendable fuel components by photosynthetic cyanobacteria or microalgae. This document describes the business cases considered in the Photofuel project. More specifically, it gives an overview to current regulation and markets describing the drivers supporting algae based fuel components as well as considers the technology development outlook.

The analyses concentrated on butanol as a gasoline component and octanol as a diesel component. Business case development has been based on other work packages in the Photofuel project. Cost estimation and profitability are described in the deliverable 6.4. However, its results have been used for business case evaluation in this deliverable.

As a result this report presents considerations and conclusions on overall business potential, and further development in certain areas required to progress towards commercialization.

Regulation related considerations

- Algae is classified as an advanced biofuel feedstock in RED II Annex IX part A, it is expected to be applicable for biocatalytic algae based fuel production technologies
- Produced fuel would have market potential due to advanced biofuel mandatory sub target of 3,5 % of total transportation fuel use (in energy share)
- GHG emissions need to be reduced by at least 65 % in comparison with fossil fuel (gasoline/diesel)
- Tightening competition of waste and residue feedstocks for FAME and HVO feedstocks will potentially make alternative feedstocks more viable options
- Vehicle CO2 regulation will incentivise the production of electric vehicles at a fast rate. Liquid fuels and biofuels will still have a demand for decades, at least for the duration of the existing fleet's lifetime.
- Penalty fees for fuel suppliers which fail to meet biofuel obligations are defined for 24 Member States, the impact of which will depend on actual volumes missing. Total penalty costs may rise to 100's of millions to billions of euros, which could make alternative fuels more attractive investments.

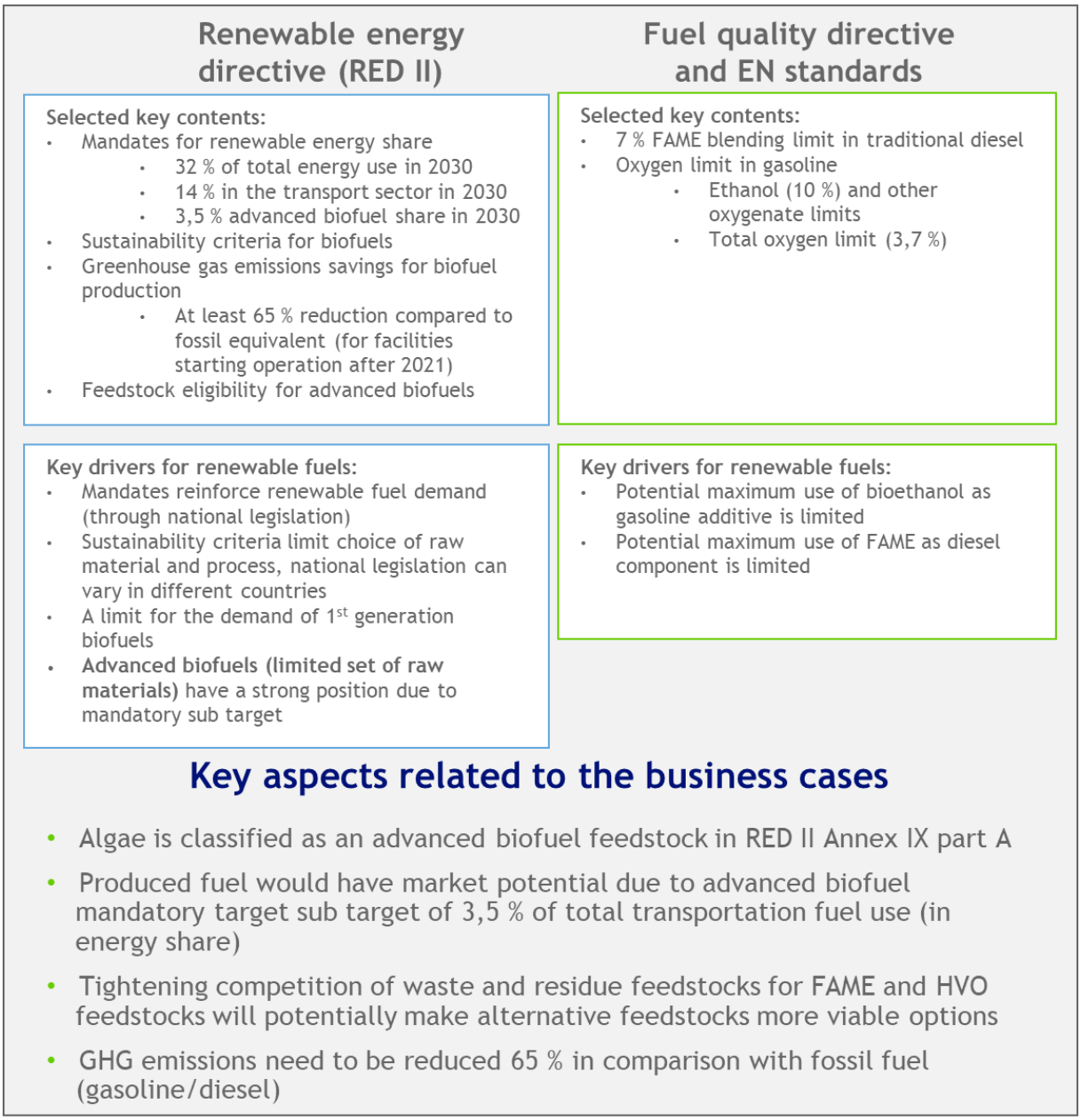

Figure 1. Summary of key contents of RED II, FQD and EN standards, and their effect on the demand of biofuels.

Markets related considerations

- Traditional fuel markets are declining and are projected to decline also in the future mostly due to EV's
- Regulation development supports demand growth in renewable fuel components, e.g. ethanol, FAME and HVO
- Competing end-uses should not hinder the renewables demand in fuels if the regulation is right, as there is no clear high demand for renewables in other end-uses, especially no signs of discussion of advanced renewable materials.
- Butanol and octanol prices are quite high compared to fuel price, but closer to other renewable fuel components' prices. Thus, the price should not be too much of a limitation. Also, the price competitiveness is increased when considering the penalties on not meeting the biofuel quotas.

Product usability considerations

- EU fuel standards limit the content of the considered components and it is unlikely that those will be adjusted in the near future
- For butanol the limiting factor is the oxygen content and in accordance to the standard butanol can be blended into gasoline with 15 v-%
- For octanol the limiting factor is cetane number. In accordance to the standard the high cetane HVO would be the optimum blend component. Octanol can be blended into diesel up to 20 v-%, but blending to HVO can be much higher.

Technology development, risks, and scalability considerations

- Demo- (and future production) plant should be located on degraded or desert land in the Mediterranean area
- The suitability of low cost, low effort cultivation systems should be studied.
- Separation was found to be energy and cost intensive and development efforts should be directed to that
- Further utilization of the residual biomass is crucial. In the project HTL was considered, combining production of an additional fuel commodity with recycling of a part of the nutrients and the CO2 for fuel production
- Biocatalytic fuel production is scalable regarding availability of degraded land in the Mediterranean area, seawater for production and cooling, no need for rare elements, regional blending of product to fuel or sufficient upgrading capacity in refineries.
- Technology risks mainly concern efforts for product separation and control of microbial contaminants. These challenges may be overcome with the countermeasures suggested in the report.

Conclusion

The table below summarises factors considered affecting the success of the business case. The regulation related to biofuels has been identified as the main supporting factor. Technology development is seen as a key in solving many other challenges related to feasibility. The success of the technology development and the timeframe is of course uncertain, but based on the results in this project there is a major potential to be seen. The technology development can be concluded to be feasible.

Summary of the business cases for butanol and octanol.

	Butanol as gasoline component	**Octanol as diesel component**
Market price (EUR/t)	approx. 950-990 EUR/t	approx. 1 260 EUR/t
Substitute market price (EUR/t)	Ethanol approx. 660 EUR/t	HVO approx. 1 270 EUR/t, FAME approx. 870 EUR/t
Production cost in Photofuel project (EUR/t) (D6.4)	2-Ha, High productivity **3 720 EUR/t** 2-Ha, Low productivity **44 641 EUR/t** 100-Ha, High productivity **2 250 EUR/t** 100-Ha, Low productivity **27 030 EUR/t** Pervaportation standard **10 000 EUR/t** Pervaportation advanced **4 000 EUR/t** Fuel from optimized process **1661 EUR/t**	-

	? **The price is high compared to the current alternatives, but regulation may support the high cost as described below.**	
Technology development and risk	Biocatalyst development towards higher butanol concentrations and more extremophilic process conditions for improved process stability. Production process development towards extensive, low-cost systems. Both seem feasible. ? **Opportunity in long term with development efforts**	Biocatalyst development towards higher fuel productivity and more extremophilic process conditions for improved process stability. Production process development towards extensive, low-cost systems. Both seem feasible. ? **Opportunity in long term with development efforts**
Regulation and incentives related drivers	Mandates reinforce renewable fuel demand Algae is classified as an advanced biofuel feedstock in RED II Annex IX part A and advanced biofuel mandatory target sub target of 3,5 % of total transportation fuel use (in energy share) → Advanced biofuels have a strong position due to mandatory sub target GHG emissions need to be reduced 65 % in comparison with fossil fuel (gasoline/diesel) →Penalty fees will create a large cost for fuel suppliers which fail to meet these obligations, however, the production costs for biobutanol (even with high productivity) will also be quite high, and lower cost alternatives will be favoured to reach mandated volumes. ✓ **Regulation supports algae based fuels**	
Market drivers for competing end-uses	Demand for butanols is generally growing across end-uses, with minor volumes of biobased options in development for fuel applications. Propylene raw material costs determine the pricing of butanols	Octanol price and demand follow the ethylene market, which has resulted in low price levels. 1-octanol is a small market with low growth across end-uses and regions
Fuel standard limitations	Currently limits the blending of butanol to gasoline to 15 v-% ? **Currently limiting**	For proposed 20 v-% blending with diesel, cetane number is below the standard requirement. can be solved if blended in to HVO ✓ **Opportunity with HVO blending**
Characteristic considerations	Higher caloric value and characteristics are closer to gasoline compared to ethanol ethanol ✓ **Characteristics are beneficial compared to ethanol**	In fuel uses octanol has favourable characteristics: a great potential to reduce soot and particle emissions ✓ **Potential to reduce soot and particle emissions**

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