Final report

BIOFIT

BIOENERGY RETROFITS FOR EUROPE'S INDUSTRY

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CONTEXT AND OBJECTIVES

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In the last few decades, it has become increasingly clear that fossil fuel resources are scarce, finite and their use can harm the environment and our climate. Increasing the share of renewable energy in the current energy mix will, besides reducing our CO_2 emissions according to the Paris Agreement (2015), ensure enhanced security of supply, stimulate innovation, create new jobs, and contribute to economic development. In 2018, the share of energy from renewable sources in gross final energy consumption reached 18% in the EU, which is more than double the share compared to 2004 levels (8.5%).[1]

Bioenergy is an essential form of renewable energy, providing an estimated 57% of EU's (EU28) renewable energy production in 2018. Bioenergy solutions are manifold, with each of them having an important role in the decarbonisation of our economies. It is mainly used in the form of heat with both residential and industry as main consumers. In fact, 73% of the final energy consumption of bioenergy came as heat production. The remainder can be attributed to biofuels for transport (14%) and bioelectricity (13%). In the future, bioenergy will remain important; in its 2021 roadmap[2], the International Energy Agency (IEA) notes that bioenergy will play an essential role in providing low-emissions energy to all sectors in 2050, showing an increase in bioenergy supply from 63 EJ in 2020 to 102 EJ in 2050.

BIOFIT was a Horizon 2020 project co-financed by the European Commission from 2018 to 2022, which had as central aim to facilitate the introduction of bioenergy retrofitting in five industrial sectors

- FIRST-GENERATION BIOFUELS
- PULP AND PAPER
- FOSSIL REFINERIES
- FOSSIL FIRING POWER
- COMBINED HEAT AND POWER (CHP) PLANTS

Core actions included the development of 10 retrofit case studies in collaboration with industrial partners, and the translation of the lessons learned throughout the project into policy recommendations, which will serve as input for more informed policy, market support and financial frameworks.

SHARES 2018, Eurostat.
IEA Net Zero by 2050. A Roadmap for the Global Energy Sector, 2021

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A CONSOLIDATED APPROACH TO FACILITATE BIOENERGY RETROFITTING

A CONSOLIDATED APPROACH TO FACILITATE BIOENERGY RETROFITTING

Retrofitting is the replacement of a part of a factory or installation with state-of-the-art equipment. Advantages of retrofitting instead of erecting greenfield plants are that the capital expenditure can be lower, lead times can be shorter, implementation can be faster, and consequently, the loss of production time is reduced. To ensure wider use of bioenergy retrofitting, BIOFIT implemented a wide but consolidated approach:

Evaluation of framework conditions to identify - generic and industry-specific - barriers and enablers. Critical factors for social acceptance were identified and five Digital Support Tools were developed.

Providing advice to policy makers by drafting a multi-disciplinary policy recommendations report regarding preferable conditions for retrofitting bioenergy. This report presents the main conclusions of the project.

Development of concrete proposals for bioenergy retrofitting by pairing industrial partners with scientific partners. Specifically, a total of 10 case studies were investigated, 2 for each sector, within 8 focus countries. The case studies focussed on the market, techno-economic, and sustainability aspects.

Involve, engage and support stakeholders and market actors through Working Groups (Industry Fora), an industrial advisory board, business to business matchmaking events and various study tours.

Obtaining an accurate and complete overview of options and associated conditions for bioenergy retrofitting in the selected focus sectors. This is achieved by mapping of the industry and succes cases, and the elaboration of a handbook.

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SECTOR WIDE RETROFITTING OPTIONS AND SUCCESS CASES

SECTOR WIDE RETROFITTING OPTIONS AND SUCCESS CASES

BIOFIT revealed that the use of bioenergy is already widespread in the target sectors, that retrofitting is in fact the dominant mode of implementation, and that there are large differences between countries. A wide spectrum of sector-specific retrofitting options exists and is being implemented, which shows high interests in the opportunities from all stakeholders.

FIRST GENERATION BIOFUELS

The first-generation (1G) biofuels sector in Europe involves the production of biodiesel (fatty acid methyl esters, or FAME), hydrogenated vegetable oil (HVO) and bioethanol from various food crops. The main advantage of these fuels is that they can be blended with regular transport fuels. There are several opportunities for retrofitting in the 1G biofuels sector

1. **Cellulosic ethanol add-on to first generation bioethanol.** This involves the coupling of the 1G bioethanol with the second generation (2G) technologies that use lignocellulosic feedstock. Different concepts of such integration can be developed. Synergies could result from utilizing lignocellulosic parts of the starch crops, sharing general infrastructure or parts of the downstream section at the plant site, or using lignin as a renewable fuel for heat provision.

2. **Alcohols for aviation (the ATJ process).** Within this process, short-chain alcohols (ethanol, propanol, or butanol) are converted to long-chain hydrocarbons and separated in various fuel fractions. Depending on the processing parameters, kerosene fractions with and without aromatics can be produced. Biodiesel and naphtha are usually produced as by-products.

3. **Multi-feedstock biodiesel add-ons.** Biodiesel plants built for processing vegetable oil can be retrofitted to multi-feedstock biodiesel plants that can also process used cooking oil (UCO) and waste animal fats. Pre-treatment steps are required to separate impurities in waste fat feedstock types.

CLICK HERE FOR SUCCESS CASE:
SUIKER UNIE BIOETHANOL PLANT

CLICK HERE FOR SUCCESS CASE:
VOLOS BIODIESEL PLANT

SECTOR WIDE RETROFITTING OPTIONS AND SUCCESS CASES

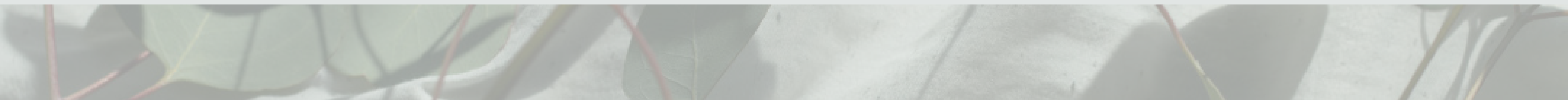
FOSSIL REFINERIES

Fossil fuel refineries convert crude oils into finished products by breaking them down and processing them to new products such as fuels for transport. The main challenge of the refining sector is how to manage the transition to a low-carbon economy. The major opportunities for bioenergy retrofitting in the refinery sector are:

1. **Hydroprocessing of renewable liquid oils.** Here, renewable liquid oils, such as palm oil and UCO are upgraded to renewable transport fuels such as HVO or HEFA. By-products are green naphtha and green jet fuel. HVO can be used for both road transport and aviation. HVO is already an ASTM D7566 certified sustainable aviation fuel since 2011.

2. **Pyrolysis oil integration into refineries.** Pyrolysis oil is a relatively homogeneous bioliquid which makes it suitable for co-feeding in refineries. Co-feeding of pyrolysis oil can be done in the Fluid Catalytic Cracker (FCC) of a refinery. The FCC product spectrum merely depends on the co-feeding ratio and the degree to which the pyrolysis oil has been de-oxygenated. Fully deoxygenated liquids should behave similarly to the usual feed for FCC, while untreated pyrolysis oil yield more coke and gas.

CLICK HERE FOR SUCCESS CASE:
MARGHERA REFINERY



SECTOR WIDE RETROFITTING OPTIONS AND SUCCESS CASES

PULP & PAPER

The pulp & paper industry is the fourth largest industrial energy consumer in Europe. The industry has reduced its carbon emissions by 26% since 2005 by using solid by-streams for energy purposes. In 2017, the biomass consumption in pulp and paper industry was 710 PJ, which is nearly 60% of fuels consumption. Largest fossil source was natural gas with 392 PJ consumption. There are several opportunities for retrofitting in the pulp & paper sector:

1. **Ethanol production from brown liquor.** In the acidic sulphite pulping process, the hemicellulose part from the wood is converted into simple sugars. These sugars can be directly fermented into ethanol by yeast or digested to produce biogas.

2. **Utilisation of by-products from the Kraft pulping process.** In the Kraft pulping process, a small amount of methanol is produced. After separation, methanol can be purified and used as transportation fuel additive. Furthermore, crude tall oil is obtained when separation off the soap in the Kraft pulping process. Tall oil is an attractive feedstock for biofuels production due to its low oxygen content. Lignin can also be extracted instead of combusting it in the recovery boiler. Lignin can be used as a bioenergy product (e.g., fuel in the lime kiln) or converted into advanced biofuel.

3. **Bark gasification.** Bark is produced as a by-product of debarking at pulp mills, and typically combusted to produce additional heat and power. Through bark gasification, lime kilns can be converted from oil to gasifier gas.

4. **Hydrothermal liquefaction (HTL) or hydrothermal carbonization (HTC).** HTL is an attractive process to increase the energy content of wet organic streams without drying, producing bio-oil. The biocrude can be further refined to biofuels. HTC is a process that separates water and produces a coal like product, biocoal, from wet lignocellulosic biomass feedstock.

5. **Anaerobic digestion of sludge.** Another option to treat sludge from wastewater treatment plant is anaerobic digestion, which produces biogas while reducing the amount of sludge. Since the wastewater includes large amounts of organic matter the biogas potential is substantial.

CLICK HERE FOR SUCCESS CASE:
METSA FIBRE JOUTSENO PULP MILL

CLICK HERE FOR SUCCESS CASE:
UPM PULP AND PAPER MILL

SECTOR WIDE RETROFITTING OPTIONS AND SUCCESS CASES

FOSSIL FIRED POWER & CHP

Fossil fuels contributed to 65.1% of the world's gross electricity production in 2016; coal alone amounted to 38.3% of the total amount. CHP plants produce both heat and electricity at the same time, thereby reaching higher total efficiencies and exhibiting a better use of energy resources compared to heat-only or electricity-only installations due to primary energy savings. Main opportunities for retrofitting in the power/CHP sectors are

1. **Co-firing of biomass.** Co-firing can be done with a large variety of biomass types and in many technical configurations. Direct co-firing is the most common and economic solution. Parallel and indirect co-firing schemes are more suitable for biomass fuels containing problematic compounds or when the ash quality is of importance for subsequent sale or disposal.

2. **Biomass repowering (full bioenergy retrofitting).** Biomass repowering is the evolution of direct co-firing to very high shares of biomass in the fuel mixture, often up to 100%. This option requires changing the fuel feeding, milling and burning system to something suitable for biomass.

CLICK HERE FOR SUCCESS CASE: THUNDER BAY GENERATING STATION

CLICK HERE FOR SUCCESS CASE: RETROFIT OF VILNIUS CHP PLANT

BIOFIT ONLINE MAP

The BIOFIT project industry sector experts collected data on existing retrofitted installations within the five industry sectors, which is made accessible in an online map. This allows users to visualize opportunities of bioenergy retrofitting. Check out the existing retrofitting installations by clicking on the map!

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CASE STUDY SELECTION AND HIGHLIGHTS

CASE STUDY SELECTION AND HIGHLIGHTS

Ten concrete case study proposals have been elaborated in BIOFIT where each case study showed and confirmed the advantages of retrofitting instead of erecting greenfield plants. In essence, opting for retrofitting over greenfield technology increases the share in bioenergy production while avoiding substantial capital costs, and even has the potential to improve the economic and sustainability performance of the production process. The highlights for all case studies below reveal the CAPEX reduction potential and the CO_2 reduction potential.

BIOCARBURANTES DE CASTILLA Y LEON I BIOFUEL REFINERIES

CASE STUDY SELECTION

For the facility in Babilafuente, two retrofitting case studies were investigated in order to incorporate the production of advanced biofuels into the existing maize-based 1G ethanol production facility

1. Production of 11,000 litres/year of advanced bioethanol using sustainable feedstocks listed in RED II, Part A of Annex IX, and other waste streams from different industrial processes.

2. Integration of a 2G facility to produce an additional 19 million litres/year of advanced ethanol from corn stover.

LESSONS LEARNED

It was found that the production of advanced bioethanol has higher GHG emissions compared to 1G bioethanol because of the increased energy demand of the steam boilers, which are fuelled with natural gas. Renewable steam generation would reduce GHG substantially. Furthermore, valorisation of the by-product DDGS is vital as it constitutes a significant part of the economic balance.

HIGLIGHT 1.

↓ 99,9%

HIGLIGHT 2.

↓ 57%

SWEDISH BIOFUELS I BIOFUEL REFINERIES

CASE STUDY SELECTION

This case study aimed to identify the benefits of the integration of an alcohol-to-jet (ATJ) process into an existing 1G ethanol plant. The retrofit of a current maize-based bioethanol plant was studied using Swedish Biofuels ATJ (SB ATJ) technology to produce a sustainable aviation fuel (SAF), namely synthetic paraffinic kerosene with aromatics (ATJ-SKA). ATJ-SKA can be blended up to 30% with conventional kerosene following the requirements of ASTM D7566.

LESSONS LEARNED

It was found that the combination of SB ATJ with an existing 1G ethanol plant has various advantages. For instance, utilities can be shared but would require significant changes in the ethanol plant. Furthermore, the CO2, produced at the fermentation stage of the ethanol plant, and green hydrogen can be used as an additional feedstock to ethanol. As a result, feedstock can be diversified and increased for fuel production, land use for biomass production can be reduced, and potentially lead to negative carbon emissions.

HIGLIGHTS

CO_2 ↓ 67%

CASE STUDY SELECTION AND HIGHLIGHTS

TOTAL | FOSSIL REFINERIES

CASE STUDY SELECTION

This case study investigated the co-feeding of pyrolysis oil in the FCC of a fossil refinery, for the production of advanced transportation fuels. Distributed / decentralized production of pyrolysis oil can take place, followed by transport to a single refinery location. Advantages of such a concept are that only limited new infrastructure is required, namely the pyrolysis oil production plants. These are relatively small, can be constructed relatively fast (i.e., 1 year), and capital requirements are modest in comparison with the costs of a refinery.

LESSONS LEARNED

One important aspect that needs to be addressed is the development of a standard for renewable gasoline to quantify the renewable content of gasoline from co-processing, whereafter it will be accepted by the market. Another key finding was that the legal framework regarding co-processing is quite different among EU Member States, where France had quite favourable conditions for co-processing. Regarding the technical aspects of the case study, it was found that a 5% substitution of Vacuum Gas Oil (VGO) with fast pyrolysis bio-oil is financially viable with a CO2 emission reduction potential well above the RED II threshold. Financial viability was mainly dependent on subsidies.

HIGLIGHTS

$ ↓ 46%

HIGLIGHTS

CO_2 ↓ 75%

HELPE | FOSSIL REFINERIES

CASE STUDY SELECTION

This case study investigated the co-processing of UCO along with conventional straight run Light Gas Oil (LGO) into an existing Diesel Hydrotreater unit at Hellenic Petroleum (HELPE)'s Thessaloniki refinery in Northern Greece. 5% of the processing mixture will be replaced by UCO. As a result, an annual production of 22,000 tonnes HVO is expected, which will be an integral part of the final diesel product.

LESSONS LEARNED

A key technical aspect that was identified relates to the UCO quality. UCO collected from various sources (i.e., consumers, businesses) will not have a stable quality. Currently, there are no specifications for the quality of UCO in place. Also, UCO prices are highly volatile, and its supply is rather insecure as the collection system is not regulated and developed in Greece. Yet, UCO co-processing is an important aspect of HELPE's market strategy. The retrofit activity strengthens the market position of the company aiming to be in line with the EU regulation regarding the energy transition goals, the share of biofuel consumption in the transport sector and the emission savings set by RED II.

HIGLIGHTS

$ ↓ 61%

HIGLIGHTS

CO_2 ↓ 5.5%

CASE STUDY SELECTION AND HIGHLIGHTS

AUSTROCEL HALLEIN | PULP & PAPER

CASE STUDY SELECTION

This case study focussed on the fermentation of sulphite spent liquor from the pulp production facility in Hallein. The retrofit aims at the production of 30 million litres of advanced bioethanol per year. A notable achievement of this case study is that the advanced bioethanol production plant has been build and is already in operation.

LESSONS LEARNED

Lessons learned
The company stated that the retrofit was difficult to implement due to the technological limitations of the existing facility. The main technical challenges were

1. The integration of bioethanol production into the chemical cycle
2. The careful treatment of the chemicals
3. The variable quality of brown liquor

The construction of a greenfield plant would have been easier from a technology point of view, however, this was not a promising business case. Furthermore, the political framework was not implemented yet, which led to uncertainties and caused difficult discussions between stakeholders concerning prices and volumes.

HIGLIGHTS

C-GREEN | PULP & PAPER

CASE STUDY SELECTION

This case study focussed on the HTC of pulp mill wastewater sludge with the C-Green's innovative OxyPower HTC technology at a pulp mill for sludge disposal and production of HTC biocoal. Currently, the sludge from its pulp and paper mill's wastewater treatment plant is disposed by incinerating it in the recovery boiler, which produces heat and electricity. In the suggested retrofit, 2,700 tons/year of dry HTC biocoal can be produced with a heat value of 10,900 MWh.

LESSONS LEARNED

The current sludge treatment at the pulp mill was found to be quite optimized and efficient, and therefore hard to compete with. Consequently, negative values were obtained from the techno-economic evaluation. Instead of retrofits, it could be considered for newly built plants if market demand for the product grows. So far, there is no market for HTC biocoal as it is declared as waste. Therefore, the priority is reaching an End of Waste (EoW) status in order to generate a market. Yet, some potential applications were identified, such as the use of HTC biocoal as solid fuel or for soil improvement.

HIGLIGHTS

4%

HIGLIGHTS

77%

CASE STUDY SELECTION AND HIGHLIGHTS

ELEKTROPRIVREDA BIH (TUZLA) I FOSSIL FIRING POWER

CASE STUDY SELECTION

Biomass co-firing was investigated in the coal-fired power plant in Tuzla. The proposed technology is direct co-firing in the existing pulverized fuel boiler Unit 6, having a capacity of 223 MWe. Therefore, biomass will be combusted in the same furnace as coal. A wide range of local biomass (e.g., sawdust, forest residues, agricultural residues, energy crops grown in reclaimed mining areas, etc.) and waste (RDF) sources have been considered, with the aim to substitute up to 15 wt.% of the brown coal currently used as fuel.

LESSONS LEARNED

It was found that there is a significant difference between the CAPEX required for conversion and the CAPEX required for a green field biomass option, thereby highlighting the value of a retrofit. The most challenging aspects of this retrofit were the biomass market developments and the policy instruments in place. Shortages of biomass supply can be tolerated to a certain extent. Even though the co-firing operating mode allows for a fall-back into coal, this is not an economical solution. Due to the carbon pricing scheme that is set in place, decreasing biomass co-firing would result in higher carbon pricing costs.

In this case, coal will continue to be the main fuel input, which is a scenario not supported by RED II and, consequently, will not be considered as renewable energy producer. Yet, the Tuzla coal region is recognized as a just transition region and would therefore allow some derogation of the RED II legislation.

HIGLIGHTS

$ ↓ 88%

EP PRODUZIONE I FOSSIL FIRING POWER

CASE STUDY SELECTION

The Fiume Santo power plant, located on the Italian island of Sardinia, consists of two operating coal-fired units, each unit has a gross capacity of 320 MWe. The total net capacity of the plant is 599 MWe. The suggested retrofit foresees a 100% conversion of Unit 4 from coal to industrial wood pellets, supplemented by a small share of locally sourced wood chips.

LESSONS LEARNED

The Unit operation of the Fiume Santo plant has a net electrical efficiency level greater than 36% and shows GHG emission savings above the current RED II threshold, thereby meeting the criteria imposed by RED II. The GHG emission savings were also found to be above the threshold currently included in the proposal for RED III (i.e., 80%) under the Fit-for-55 package. Yet, the main barrier for implementing the Fiume Santo biomass conversion is the uncertainty regarding the latest policy developments. The proposal for the amendment of RED II published in June 2021 states that Member States should discontinue support for electricity-only plants from 2026 onwards, unless the installations are in regions with a specific use status as regards their transition away from fossil fuels or if the installations use carbon capture and storage. Neither exeption applies to Fuime Santo.

HIGLIGHTS

$ ↓ 85%

HIGLIGHTS

CO_2 ↓ 79-85%

CASE STUDY SELECTION AND HIGHLIGHTS

ELEKTROPRIVREDA BIH (KAKANJ) I CHP

CASE STUDY SELECTION

In the Kakanj thermal power plant, the full biomass repowering of Unit 5 was investigated, which has a capacity of 118 MWe. Apart from providing electricity for the grid, the unit also supplies heat to a local district heating network. The retrofit focussed on the conversion of the existing pulverized fuel boiler to a Bubbling Fluidized Bed (BFB) boiler. The conversion will allow the plant to process a wide range of locally available biomass feedstocks with minimal pre-processing.

LESSONS LEARNED

It was found that there is a significant difference between the CAPEX required for conversion and the CAPEX required for a green field biomass option, thereby highlighting the value of a retrofit. Like the Tuzla case study, the most challenging aspects of this retrofit were the biomass market developments and the policy instruments in place. Biomass shortages leads to a decrease in production capacity but will remain economical to a certain extend. The current net electrical efficiency of Unit 5 does not meet the criteria imposed by RED II (i.e., 36%). Consequently, electricity will not be considered as renewable. Yet, the Kakanj coal region is recognized as a just transition region and would therefore allow some derogation of the RED II legislation.

HIGLIGHTS

90%

HIGLIGHTS

CO_2 99%

SOLVESBORGS ENERGI OCH VATTEN I CHP

CASE STUDY SELECTION

In this case study, the utilisation of bio-oil in the existing central boilers of Sölvesborgs Energi och Vatten in Sölvesborgs, Sweden, was investigated. The heating boilers have a capacity of 16 MW in total. The main objective was to investigate the possibilities and prerequisites for the conversion of fossil oil to light or heavy bio-oil.

LESSONS LEARNED

Switching to bio-oil has both economic and sustainability advantages. The four bio-oils investigated in this case study all showed lower OPEX requirements compared to the current fossil oil since the bio-oils are significantly cheaper. In addition, respectable GHG emission savings can be achieved and is dependent on the type of bio-oil. Light oils exhibit better sustainability performances compared to heavy oils. Some uncertainties are still a concern for this investment. One such concern is a prospective amendment to the current financial framework. Currently, biofuels for heating have no tax in Sweden, but a potential shift in such policy could be detrimental to the retrofit.

HIGLIGHTS

89-96%

HIGLIGHTS

CO_2 40-58%

5

DIGITAL SUPPORT TOOL

DIGITAL SUPPORT TOOL

Drivers for bioenergy retrofitting are very case specific, varying in different applications, countries, and markets. In addition, technologies are under development at different stages. Consequently, there is not a standard retrofit solution available, instead, a tailor-made solution and case-specific feasibility analysis are needed. Now, BIOFIT aids in this by determining the benefits of retrofitting through 5 easy-to-use Digital Support Tools (DSTs), one for each focus industry sector.

The DSTs are based on the mass and energy balance as well as the economic and environmental calculations performed in the BIOFIT case studies. The DST is a fully interactive tool where users can adjust technical and economic parameters according to their preferences, understandably within certain limits, after which the results will instantly be demonstrated by the tool. All five DSTs can be accessed via the icons on the right.

1G BIOFUELS

This DST is based on the BIOFIT case study of Biocarburantes de Castilla y Leon and examines two alternative retrofits in a 1st generation biofuel production facility.

FOSSIL REFINERIES

This DST is based on the BIOFIT case study of TOTAL which studied the economic and environmental benefits of co-feeding pyrolysis oil in the FCC of its refinery.

PULP & PAPER

This DST is based on the BIOFIT case study of C-Green which investigated the use of its HTC technology to treat the wastewater sludge produced by a Nordic pulp mill to produce biocoal.

FOSSIL POWER

This DST was developed having in mind the case of a coal-fired plant that wishes to convert fully or partially (co-firing) to biomass.

CHP

This DST is based on the BIOFIT case study of Sölvesborgs Energi och Vatten in Sweden which studied the replacement of fossil oil with light or heavy bio-oils in a peak-load district heating plant.

6

PUBLIC PERCEPTION OF BIOENERGY

PUBLIC PERCEPTION OF BIOENERGY

Although the overall framework of the BIOFIT project is primarily focused to industries and market actors in the field of bioenergy retrofitting, BIOFIT fully recognized the importance of other stakeholders, such as the general public, as enables or barriers of bioenergy retrofitting. Their involvement (or lack thereof), engagement and support are acknowledged as vital to bioenergy retrofitting's feasibility and opportunities. Currently, bioenergy is not without controversy. To further enhance investments in retrofitting existing bioenergy or fossil fuel installations, BIOFIT identified conditions for creating acceptance for bioenergy production and retrofitting

Handle public communications and information about bioenergy technology implementation with care and transparency.
Our results show that the balance between acceptance and scepticism is a shaky one. This assumption is supported by a certain degree of ambivalence among citizens, as at the same time, bioenergy technologies are generally also perceived as a form of greenwashing to some extent.

Improve citizens' knowledge of renewable energy technologies.
It has come to light that citizens with a relatively high level of subjective knowledge regarding renewable energy technologies attributed bioenergy production more as values-driven industrial activity and perceive bioenergy initiatives less as greenwashing.

Concentrate on consequences of bioenergy production.
Particularly with respect to economic and environmental consequences, it is recommended that when bioenergy production technologies have both positive and negative effects it is important to communicate about these consequences.

Realise that credibility is crucial in gaining and maintaining acceptance and trust.
Our results show that the more citizens attribute bioenergy initiatives to being values-driven, the more trust they have in industries that engage in bioenergy technologies and the less they perceive bioenergy efforts to be a form of corporate greenwashing.

Be aware of possible interference of perceptions of other (fossil-based) industries on acceptance of bioenergy.
The type of industry in which bioenergy technologies are implemented matters in how citizens view such activities, given that implementation of bioenergy technologies in fossil-based industries overall are perceived relatively negative. Greater efforts are required from the fossil-based industries, particularly fossil refineries, to contribute to public acceptance for activities to increase bioenergy production.

7

STAKEHOLDER ENGAGEMENT

STAKEHOLDER ENGAGEMENT

To foster market uptake of retrofitting technologies, gather feedback and recommendations from the industry, as well as exchanging knowledge and experiences among different industries, a broad spectrum of industry representatives have been involved throughout the BIOFIT project. Four EU wide outreach activities have been organized as part of the BIOFIT Industry Platform in order to inform, facilitate dialogue with and support the industry:

THE INDUSTRIAL ADVISORY BOARD (IAB)

The main objective of the IAB was to introduce market experiences, to represent a global perspective from outside of the project and to keep a critical eye on the projects' work. Expertise, feedback and advice was asked for key project outcomes, such as the sectoral recommendation papers and policy recommendation papers.

INDUSTRY FORA

The Industry Fora combined five Working Groups (WG), one for each sector, in which stakeholders, policy makers, NGO's, representatives from industry and research as well as project members were invited to exchange information with each other. In total, eight WG meeting have been held and were organized in the form of a series of interactive workshops. The general outcomes as well as relevant conclusions on the market situation, retrofitting conditions and technical options for retrofitting were then summarized in the respective sectoral recommendation papers.

B2B MATCHMAKING

To foster bi-lateral discussions among industry representatives and help them to develop ideas and strategies for retrofitting, B2B matchmaking between and among the different target groups were planned during other BIOFIT events, such as the industry fora.

STUDY TOURS

BIOFIT organized a total of 19 Study Tours to collect and share experiences of retrofitting in different plants and industries. The Study Tours and activities covered all the industry sectors addressed in the BIOFIT project, namely 1G biofuels (e.g., BCyL), pulp and paper (e.g., Äänekoski Bioproduct mill, Mörrum pulp mill, AustroCel Hallein), fossil refineries (e.g., Thessaloniki Refinery of HELPE), fossil firing power (e.g., Twence power plant, Drax power station), and CHP (e.g., Keljonlahti CHP plant). Part of the activities were organized as virtual events due to the Covid-19 pandemic.

POLICY RECOMMENDATIONS AND MAIN CONCLUSIONS

The synthesized policy recommendations represent the main conclusions of the project taking into account the findings from, amongst others, the case studies and social acceptance study, which were verified and complemented by external experts whom participated in the BIOFIT Industry Platform in one way or another:

1 **Research and funding should be allocated for studying the possibilities for broadening the feedstock base for bioenergy and biofuels production, including biomass from marginal, underutilized, contaminated (MUC) lands.**

2 **New collection systems for residues and waste should be established** in order to improve availability of residues and waste streams, as these are scattered and difficult to mobilize.

3 **National and EU legislation should be revised in order to remove obstacles for and/or promote the sustainable collection of agricultural and forestry residues.**

4 Biomass feedstock supply for refineries could be promoted by **stimulating technologies related to intermediate bioenergy carriers (IBCs)** so that the required volumes of IBCs become available, and they can be traded like a commodity.

5 Regulations and governance should set economic incentives and construct step-by-step supply chains to **enhance the collection of UCO and animal fats.**

6 **Support for further research of alternative pathways towards a cost-effective and sustainable advanced bioethanol production** is needed to make 2G bioethanol production more cost competitive.

7 Investments having **high risk and high CAPEX need to be tackled with a stable and long-term policy framework.**

8 **R&D funding and investment support should be targeted at new technologies that allow efficient side-stream utilization and increase overall energy-efficiency** to facilitate market uptake of emerging technologies for bioenergy retrofitting.

9 **Standard calculation formulas should be developed and implemented to quantify the renewable content of all transport fuels.**

10 **Development of a supportive technology neutral policy environment for the successful deployment of renewable jet fuel technologies.**

11 **Careful and transparent communication and information to the public is needed** to maintain and strengthen public trust.

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Date: March 2022

Publisher: BTG Biomass Technology Group BV
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Funding support: European Commission Horizon 2020
Research and Innovation Programme
Grant agreement no. 817999
01/10/2018 – 31/3/2022
www.biofit-h2020.eu

CONSORTIUM

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Ciemat	CIEMAT – Centro de Investigaciones energéticas, medioambientales y Technológicas Spain | www.ciemat.es
energikontor sydost	ESS – Energikontor Sydost AB Sweden | www.energikontorsydost.se

CONSORTIUM

	EPBiH – Elektroprivreda BiH Bosnia and Herzegovina | www.epbih.ba/eng
	TFMC – Technip Benelux BV The Netherlands | www.technipenergies.com
	WR – Stichting Wageningen Research Wageningen, The Netherlands | www.wur.nl
	SB – Swedish Biofuels AB Sweden | www.swedishbiofuels.se
	HELPE – Hellenic Petroleum S.A. Greece | www.elpe.gr
	BCyL – Biocarburantes de Castilla y León S.A. Spain

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 817999.