BIOENERGY RETROFITS FOR EUROPE'S INDUSTRY – THE BIOFIT PROJECT (HORIZON 2020)

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ABSTRACT: Bioenergy has evolved in the last decades from relatively simple heat and power production to a vast array of technologies for advanced biofuel production, intermediate bioenergy carriers, etc.. Besides erecting entirely new bioenergy plants, retrofitting – which means replacing a part of a factory or installation with state-of-the-art equipment – can be a very good alternative to replace fossil fuels or to upgrade outdated renewable technology. Bioenergy retrofitting provides significant benefits compared to building new plants, notably lower capital expenditure, shorter lead times, faster implementation and less production time loss. The **BIOFIT** project (www.biofit-h2020.eu) is an initiative funded through Horizon 2020 that aims to facilitate the market uptake of bioenergy retrofitting concepts in five specific industries in Europe, namely first-generation biofuels, pulp and paper, fossil refineries, fossil firing power and Combined Heat and Power (CHP) plants. Core actions in the **BIOFIT** project are: Mapping bioenergy retrofits in the EU, development of concrete retrofit proposals for specific case studies, engagement with stakeholders via an Industry Platform, evaluation of framework conditions and formulation of policy recommendations. The **BIOFIT** consortium consists of fourteen partners from eight European countries. The consortium is a mix of industrial and academic / research partners.

Keywords: Bioenergy, Retrofitting, Market uptake, Industry, Industrial scale application

1 INTRODUCTION: PROJECT OBJECTIVES

Bioenergy is an essential form of renewable energy, providing an estimated 60% of EU's renewable energy production in 2017 [1]. In the future, bioenergy will remain important; in its 2017 Roadmap [2] the International Energy Agency (IEA) notes that bioenergy plays an essential role in its 2DS (2°C Scenario), providing almost 20% of the global cumulative CO_2 emission savings by 2060. Bioenergy is a complex and sometimes controversial topic. There is an increasing understanding that only bioenergy that is supplied and used in a sustainable manner has a place in a low carbon energy future.

Modern bioenergy takes on many forms. Relatively straight-forward applications, such as space heating by combustion of wood are implemented alongside biogas production through anaerobic digestion and production of transport fuels. Spurred by innovation, technologies are becoming more advanced and diverse, leading to the production of variety of advanced transport fuels (first and second-generation bioethanol, biodiesel and bio-kerosene), intermediate bioenergy carriers and high-efficiency, low carbon emission production of power, heating and cooling.

Besides erecting entirely new bioenergy plants, **retrofitting** – which means replacing a part of a factory or installation with state-of-the-art equipment – can be a very good alternative to replace fossil fuels or to upgrade outdated renewable technology. Retrofitting means often lower capital expenditure (CAPEX), shorter lead times, faster implementation, less production time losses and lower risks.

In the BIOFIT project, bioenergy retrofitting is promoted in five exemplary industries, namely **first-generation biofuels, pulp and paper, fossil refineries, fossil firing power and Combined Heat and Power (CHP) plants)**. Bioenergy retrofits can be related to the production of bioethanol, biodiesel, bio-kerosene, intermediate bioenergy carriers and other advanced biofuels and renewable fuels as well as biomass-based heat and power generation.

The **overall objective** of the BIOFIT project is to facilitate the introduction of bioenergy retrofitting in said industries, leading to an increase in the share of renewable energy in the final EU energy consumption.

To ensure further market uptake of bioenergy retrofits in the selected industries, the following **specific objectives** have been defined: 1) *Develop concrete proposals (case*

studies) for bioenergy retrofitting for each of the named industries, together with industry and market actors that are committed to implementing the results. 2) *Obtain an accurate and complete overview of options for bioenergy retrofitting* in said industries, as well as insight into the conditions under which each type of bioenergy retrofit is feasible and communicate this to the target groups. 3) *Involve, engage and support stakeholders and market actors*, especially from industry, at several levels by i.a. communicating results, disseminating knowledge, providing opportunity for dialogue, and providing best practices and tools. 4) *Evaluate framework conditions* (legal, institutional and political) to identify – generic and industry-specific - barriers and enablers, and 5) *Provide advice to policy makers* at national and regional level to serve as input for more informed policy, market support and financial frameworks.

Acceptance of bioenergy in industry and by the general public is an important issue for bioenergy market uptake. BIOFIT will be studying this barrier regarding bioenergy retrofitting, and will contribute to the transformation of the industries towards acceptable, sustainable bioenergy generation. Key issues related to public acceptance will be highlighted and guidelines will be issued to industries on how to deal with these issues.

BIOFIT focuses mostly on the following **target countries:** Sweden, The Netherlands, Germany, Spain, Finland, Austria, Bosnia-Herzegovina and Greece. In all these countries at least one BIOFIT project partner is located, ensuring access to in-depth knowledge about national framework conditions. The emphasis on bioenergy retrofit CAPEX reduction and market benefit ensures, however, that results will also be applicable to other EU countries. Additionally, some BIOFIT case studies are foreseen to be implemented in other European countries.

2 OPTIONS AND METHODS FOR BIOENERGY RETROFITTING

Options for bioenergy retrofitting are industry specific. For each industry there are different technical options based on their inputs, outputs, market environment and structure. This is reflected in the BIOFIT approach, and in the industry specific case studies that are being developed.

2.1 First Generation (1G) biofuels

The 1G Biofuels sector in Europe involves the production of biodiesel (fatty acid methyl esters - FAME), hydrogenated vegetable oil (HVO) and bioethanol from various food crops. FAME and HVO are produced from oil bearing crops such as rapeseed; bioethanol is produced from sugar or starch containing crops such as sugar beet, grain and wheat. Main advantage of these fuels is that they can be blended with regular transport fuels.

Figure 1: The 1G biofuel plant of Biocarburantes de Castilla y Leon (Spain). In BIOFIT the partial conversion to 2G biofuels production will be studied

Opportunities for retrofitting are the conversion of 1G biofuel plants to produce also – or only – 2G biofuels, by (e.g.) cellulosic ethanol add-ons, multi-feedstock biodiesel add-ons or biogas add-ons. Other retrofit options include improving the GHG performance (e.g. by producing biogas from waste streams) or more advanced electrofuel enhancements.

In the BIOFIT project two case studies will be elaborated:

- The project partners Biocarburantes de Castilla y Leon and CIEMAT will investigate the integration of the production of 30 million liters/year of second-generation ethanol from unutilized components of the current feedstocks into the existing cereal-based ethanol production facility in Babilafuente, Spain.
- The project partners Swedish Biofuels and DBFZ will investigate the scenario in which an existing biofuel plant is retrofitted (repurposed) using Swedish Biofuels ATJ technology to produce bio kerosene (ATJ-SPK), which can be blended up to 50 % with conventional kerosene following the requirements of ASTM D7566.

2.2 Pulp and Paper

The Pulp and Paper industry sector in Europe is already using biomass for nearly 60% of their total primary

energy consumption, which was more than 1150 PJ in 2016. There are roughly 150 pulp mills and 750 paper

Figure 2: Case study partner AustroCel Hallein will explore the production of advanced biofuels

mills in Europe [3]. Their main renewable energy source is bioenergy from wood handling residues. The industry has undergone some consolidation, while at the same time there is ample interest in high-valued biobased products such as biofuels, bio-composites and bio-based plastics. Because many pulp mills are no longer integrated to paper mills, their own energy consumption is decreasing, which opens up the opportunities for production of higher-valued bioenergy products from their residues. Bioenergy retrofitting in pulp and paper industry can be used to replace fossil fuels used at site for energy production with renewable alternatives or to enable producing renewable fuels from process side streams.

Opportunities for retrofitting in the sector are e.g. use of residues such as bark for energy generation via

gasification, biogas or biochar production from pulp mill sludge, and upgrading of spent liquor or tall oil to second-generation biofuels.

In the BIOFIT project the following case study will be elaborated:

- Together with project partner BE2020+, the fermentation of liquor from the pulp production at AustroCel Hallein in Austria will be investigated. Retrofitting could lead to the production of 30 million liters of advanced bioethanol per year.

2.3 Fossil refineries

Fossil refineries are usually very large industrial complexes where crude oil is processed and refined into more useful products, such as petroleum naphtha, gasoline, diesel fuel, asphalt base, heating oil, kerosene, and liquefied petroleum gas (LPG). The crude refining capacity of the around 100 operational refineries in the EU is 15.5 million barrels / day, representing 16% of world capacity. The transport sector in the EU is currently for 95% dependent on by liquid (fossil) fuels, and is responsible for more than 25% of GHG emissions in the EU. It is widely accepted that one of the refining industries' main challenges is the transition to a low-carbon economy, against a backdrop of decreasing demand and increased competition.

Figure 3: The Thessaloniki refinery of Hellenic Peutroleum in Greece: case study site for HVO production

Opportunities for retrofitting in refineries are the production of HVO biodiesel in existing refineries. Other options are to upgrade intermediate bioenergy carriers produced from lignocellulosic biomass, like pyrolysis oil or bio-oil from hydrothermal liquefaction to transport fuels.

In the BIOFIT project the following case studies will be elaborated:

- Together with project partners TFMC and BTG, the co-feeding of pyrolysis oil in the FCC (Fluid Catalytic Cracker) of a fossil refinery will be investigated. Pyrolysis oil is a liquid bioenergy carrier produced from lignocellulose material. The retrofit could result in 20,000 tons of 2G transport fuels.
- Project partners Hellenic Petroleum, CERTH and TFMC will investigate the integration of new equipment for the production of hydrotreated vegetable oil (HVO) into the Thessaloniki refinery of Hellenic Petroleum in Greece. The expected production capacity is 25,000 tons of biofuel.

2.4 Fossil fired power.

Despite a decrease of 41 % since 1990, about 20.2% of power production in the European Union still comes from solid fossil fuels such as coal and lignite [4]. As of July 2016, there are more than 300 coal power plants operating in the EU, with 738 separate generating units [5].

Figure 4: The Elektroprivreda BiH 200 MWe coal-fired power plant in Tuzla, Bosnia and Herzegovina. Opportunities for co-firing will be investigated

Significant installed capacity is located in Germany, Poland, Bulgaria, Czech Republic, Romania and Greece; the reliance of many Western Balkan countries on coal for power produced should also be noted. Power generation from coal is considered as a reliable and cost-effective option, however it is under political and economic pressures related to the reduction of carbon emissions and other pollutants emissions. Several countries (e.g. the Netherlands, UK, France, Finland) have announced plans to phase out coal power production completely.

Opportunities for retrofitting: Partial or complete substitution of coal with (solid) biomass, e.g. co-firing or conversion respectively, is the main retrofitting options for such fossil power plants. The coal industry has already a lot of experience with co-firing of biomass, because of relatively low CAPEX requirements, scalable solutions and a lot of options to co-fire. IEA Bioenergy Task 32 maintains a database that lists 150 co-firing initiatives [6]. Co-firing can be carried out directly (in the same combustion chamber), indirectly (after pre-treatment), in parallel (separate combustion), and completely (full conversion to biomass). It is also interesting to note the possibility of using thermally treated (e.g. torrefied or stream exploded) biomass as a substitute for coal, an option which can simplify the handling of the biomass and require an even lower CAPEX than the co-firing or conversion using untreated biomass.

Application of co-firing or conversion is heavily dependent on national framework conditions, e.g. limits in biomass share in the fuel mixture, allocation of financial support and recognition as a renewable energy source, etc. The adoption of the new Renewable Energy Directive (RED II) will lead to a more homogenous policy framework in the EU. However, RED II places some restrictions in the adoption of large-scale biomass use for power generation, e.g. as concerns biomass sustainability and GHG savings along the value chain, minimum biomass share, plant efficiency, etc. It is expected that at least in the EU, retrofits will mostly go in the way of full repowering rather than co-firing.

In the BIOFIT project the following case studies will be elaborated:

- Project partners Elektroprivreda BiH and CERTH will

investigate biomass cofiring in one of their existing brown coal units in Tuzla TPP (Unit 5 - 200 MWe). Local biomass sources (e.g. sawdust, agricultural residues) will be considered in order to substitute up to 30 % of the thermal input from coal.

- Together with project partner CERTH, the full biomass conversion of one of EP Produzione´s existing 320 MWe hard coal power units in Fiume Santo, Italy, will be investigated.

2.5 Combined heat and power

Heating and cooling accounts for more than 50% of energy consumption in Europe, serving domestic, commercial and industrial consumers. Most of the thermal energy is produced from fossil fuels (81%), with gas being the dominating fuel (37%); Of the energy that is produced

Figure 5: The boilers from the Swedish district heating provider Sölvesborgs Energi: conversion to bio-oil is investigated

from renewables (19%) the large majority (87%) comes from biomass use [4]. CHP plants produce renewable heat and power at the same time, thereby benefitting from higher efficiencies that can be reached compared to heat-only or power only production.

Opportunities for retrofitting: Retrofitting of fossil-fuel fired CHPs, especially those connected to district heating networks, to (solid) biomass CHPs is (or has been) taking place in several European countries in the Nordic area (Sweden, Denmark, Lithuania, Finland) or in the East (Poland). For example, the main fuel in Swedish CHP systems is biomass, and Lithuania is expected to follow in a few years. Other opportunities for retrofitting are the replacement of fossil oil with liquid biofuels. An industrial example is the laundry "Lindbytvätten", Sweden. An example from the heat providing industry is "Karlshamn Energi", Sweden. On a small scale, introduction of Organic Rankine Cycle (ORC) technology helps to convert heat-only systems into CHP.

In the BIOFIT project the following case studies will be elaborated:

- Project partners Elektroprivreda BiH and CERTH will investigate full biomass repowering of one unit (118 MWe) in the Kakanj thermal power plant. The unit currently uses local brown coal and, apart from power, also supplies heat to the local district heating network. Two pathways will be considered 1) wood pellets and 2) thermally treated wood pellets.
- Together with project partner ESS, the utilization of bio-oil in the existing peak-load central heating boilers of Sölvesborgs Energi och Vatten in Sölvesborg, Sweden, will be investigated. This would replace the fossil oil that is currently used for peak loads, and thus increase the percentage of renewable energy generated. The heating boilers have a capacity of 16 MW in total. Adapting the system to also produce power via an Organic Rankine Cycle (ORC) will be investigated.

3 FIRST BIOFIT RESULTS

The BIOFIT project has only recently started. Two early activities have already tangible results:

An **interactive map of retrofitted installations** in

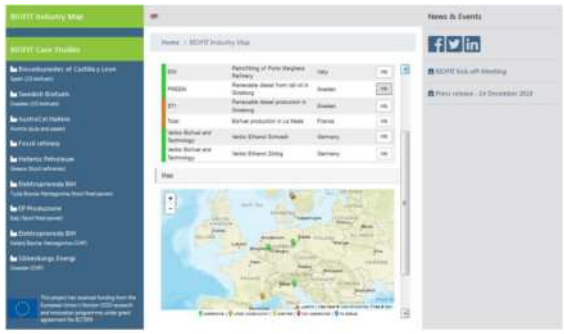

Figure 6: Screenshot of the bioenergy retrofitting online map

Europe is now online (https://www.biofit-h2020.eu/biofit-industry-map/). In this map, successful retrofits are graphically depicted on a map. The data displayed in the online map can be viewed as a list of facilities or as pins on a map. Filters for industry sector, retrofit technology, feedstocks or products can be applied to shorten the list or reduce the number of pins displayed respectively. For sectors (like CHP) where there are a very large number of retrofits the map shows a selection.

A second result is the release of a number of **fact sheets of succesfull bioenergy retrofits**. These fact sheets show key information on the retrofit (type of sector, retrofit measure, timing, capital expenditure, etc.) as well as GHG emission reduction and plant outputs before and after the retrofit.

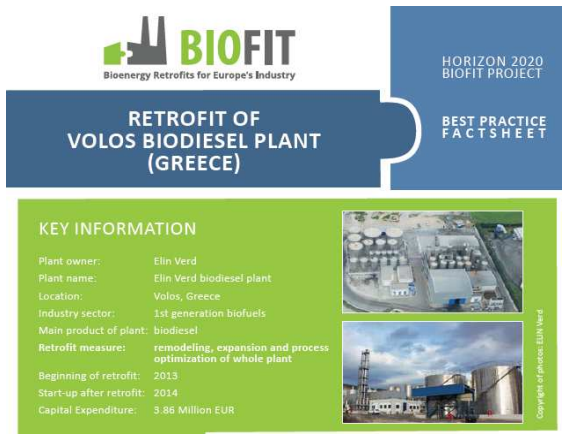

Figure 7: BIOFIT has produced a number of fact sheets of successful bioenergy retrofits

Besides this basic information, the fact sheets also

include a description of the initial state of the plant, the motivation behind the retrofit, the planning and execution, and a description of the current state of the plant. These bioenergy retrofit examples are to serve as lighthouse examples for other industrial partners in the sector and will also allow for the formulation of recommendations on how bioenergy retrofits can be facilitated. The following fact sheets are currently available:

Table I: Overview of fact sheets currently available

Name	Type of retrofit	Sector
Volos biodiesel plant (GR)	1G biofuels to 2G biofuels	1G biofuels
Metsä Fibre Joutseno pulp mill (FI)	Natural gas to gas from bark gasification	Pulp and paper
UPM pulp and paper mill (FI)	Add-on to produced 2G transport fuels	Pulp and paper
ENI Porto Marghera	Fossil transport fuels to HVO	Fossil refineries
Avedøre power station (DK)	Coal to biomass combustion	Fossil fired power
Thunder bay Unit 3 (CA)	Coal to advanced biomass pellets	Fossil fired power
Veolia Vilnius CHP plant 2	natural gas to biomass combustion	CHP

All fact sheets can be downloaded from the project website (www.biofit-h2020.eu).

4 CONCLUSIONS AND NEXT STEPS IN THE PROJECT

In the BIOFIT project, bioenergy retrofitting is promoted in five exemplary industries, namely first-generation biofuels, pulp and paper, fossil refineries, fossil firing power and Combined Heat and Power (CHP) plants) aiming to facilitate the introduction of bioenergy retrofitting in said industries, leading to an increase in the share of renewable energy in the final EU energy consumption. BIOFIT is studying the issue regarding bioenergy retrofitting, to overcome barriers and contribute to the transformation of the industries towards acceptable, sustainable bioenergy generation.

Work is well underway in the BIOFIT project to prepare an accurate **overview of the options for bioenergy retrofitting** in the five selected industrial sectors. A handbook for non-technicians on "Technical Options for Retrofitting Industries with Bioenergy" is being drafted. This handbook will be based on scientific results, but presented in an easy to understand way. A *survey* to identify the motivations and perceptions in companies that have undertaken retrofits is being carried out at the moment. These activities, alongside work related to identifying framework conditions will be summarized in a policy brief that is expected to be ready at the end of this year (2019).

Another major activity that will be carried out in the near futures is the development of a dedicated **Industry Platform**. The industry platform will serve to inform and engage stakeholders. Part of the Industry Platform is five industry fora, where industry-specific information can be exchanged, and information can be given. Via a variety of activities (physical meetings, B2B matchmaking, study tours and business missions) stakeholder are engaged and industry is supported. Both industrial and non-industrial stakeholders are warmly invited to participate in the BIOFIT Industry Platform, to gain knowledge on industrial bioenergy retrofitting and to help shape the further market uptake of industrial bioenergy. The first Industry platform activity aimed at the 1G biofuels sector is planned on 11 September 2019 in Leipzig, Germany.

Interested stakeholders can contact DBFZ – directly or via the BIOFIT website - to take part in one or more activities of the Industry platform.

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Bioenergy Retrofits for Europe's Industry

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7 PROJECT PARTNERS