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Report

D 3.6 Lessons learned from the case studies

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1 Introduction

This report presents the lessons learned from the case studies. For each case study, lessons learned and barriers identified have been discussed in a final meeting. The main topics of discussion were the technological challenges, operation of the supply chain, cost and environmental assessment, as well as market penetration benefits.

For each case study, a baseline scenario, a retrofit scenario and an alternative greenfield scenario were defined. The baseline scenario describes the current situation, whereas the retrofit scenario describes the suggested retrofit. For comparison of economic and ecological parameters also a fictional alternative greenfield scenario was defined. It shows whether a retrofit has economic or ecologic advantages compared to a greenfield scenario.

Each case study was discussed in a team consisting of:

- The Case Study Team Leader
- The Case Study Company
- BTG, who carried out all techno-economic assessments
- BEST, who carried out all market and supply chain assessments
- CERTH, who carried out all sustainability assessments

2 Methodology

During the final meetings, partners were asked to provide input based on the following questions:

- Which challenges did we encounter?
- What did we find difficult?
- Which key aspects did we identify?
- What has surprised us?

These questions may be applicable to different topics and different phases of the work in the case study team:

- Technological challenges analysed in the case study
- Operation of the supply chain
- Cost assessment
- Environmental assessment
- Market penetration benefits
- Risk assessment
- Overall results of the case study
- Communication within the case study team

A summary of the outcomes for each case study is provided in the next chapters.

3 Lessons learned from the case studies

3.1 Case Study 1: Biocarburantes de Castilla y Leon (1G biofuels)

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

- Scenario 1 aims to produce 11,000 liters/year of advanced bioethanol using sustainable feedstocks listed in the Renewable Energy Directive (RED II, Part A of Annex IX) and other waste streams from different industrial processes
- Scenario 2 involves retrofitting the existing first-generation process to additionally produce 19,000 million litres/year of advanced ethanol from corn stover, thereby designing an integrated facility that produces both first-generation and advanced ethanol.

The Case study team leader was surprised by the lack of policy support, which is essential for this kind of retrofit.

The Case study company is aware of the increasing interest to process waste streams for advanced bioethanol production, according to RED II (Part A of Annex IX). However not all waste streams are technically suitable for bioethanol production, therefore it is expected that suitable residues will get more expensive due to the increasing demand. A surprising outcome for the case study company was that the production of advanced bioethanol has higher GHG emissions compared to first-generation bioethanol, because of the increased energy demand of the steam boilers, fuelled with natural gas. Renewable steam generation would reduce GHG emissions substantially. A new facility would be planned with renewable steam generation, but it is challenging to exchange an existing one.

The Techno-economic assessment showed that the impact of the by-product DDGS (Dried Distillers Grains with Solubles), which is a significant part of the economic balance, was underestimated. It was surprising that Scenario 1 is not economically feasible if the advanced ethanol (double counting) selling price is lower than 750 €/m^3. It is important to highlight that currently the selling price of advanced ethanol (Double Counting) is continuously increasing and has even reached 1200 euros/m^3, which makes it a very economically profitable case.

Results of the Market assessment demonstrated a surprising increase of the advanced bioethanol production facilities planned in the EU. Results of a literature research showed that the feedstock availability for this case study is not a burden.

Concerning the Sustainability assessment, a significant challenge was the definition of the system's boundaries of all scenarios, in order to determine which processes should be included in the simplified life cycle assessment. The definition of the boundaries is critical in order to ensure the accuracy of the LCA results. In addition, the appropriate definition of the functional unit is critical to provide comparable results among all scenarios, as well as with the fuel comparators provided by RED II. Another demanding step was the allocation procedures for co-products in the simplified LCA analysis.

Results of the sustainability assessment showed that natural gas consumption is responsible for the most significant share of GHG emissions. The most surprising result in Scenario 2 was the fact that the environmental benefits from the utilization of waste as feedstock (i.e. industrial waste, wine alcohol and corn stover), reversed from the increased demand for energy consumption in the process

3.2 Case Study 2: Swedish Biofuels (1G biofuels)

This case study identifies the benefits of the integration of an alcohol to jet (ATJ) process into an existing 1G ethanol plant from a technical, economic, and environmental perspective. 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).

It was found that the combination of SB ATJ with current ethanol production has synergies when waste from the production of ethanol, fusel oils, and hydrated ethanol can be processed, without the need of dewatering in molecular sieves. Further synergies can result from heat and power integration, but would require significant changes in the existing ethanol plant and were not studied in detail.

Furthermore, it was discussed that by using SB ATJ technology, the CO_2, produced at the fermentation stage of the current ethanol plant, and green hydrogen can be used as an additional feedstock to ethanol. This will increase the feedstock for fuel production, reduce the land used for biomass production, increase the GHG emissions reductions and potentially even lead to negative carbon emissions. The use of hydrogen and CO_2 was not part of the current study as there is no green electricity available at the ethanol plant site for the production of hydrogen.

The Techno-economic assessment concluded that in this case study the revenue is much higher than the investment, but there are a number of risks. In particular, the sensitivity analysis showed that small changes in feedstock costs may have a strong effect on the economic feasibility of the retrofit.

Results of the Market assessment evidenced the ambitious plans for use of sustainable aviation fuels, e.g. from European and national authorities as well as ICAO (International Council of Aviation Organization), highlighting the direction of the market development. Feedstock-wise, a significant increase of advanced bioethanol production facilities is planned in the EU. Accordingly, a literature research showed that the feedstock availability for this case study is not a burden.

The Sustainability Assessment showed that the ATJ plant is CO_2, neutral but the current ethanol plant is severely affected by the unavailability of sustainable power for the production process, namely electricity and natural gas. A transition from fossil to sustainable heat and power on the national level will contribute to a significant improvement of GHG emissions savings from the current ethanol plant. A finding was the importance of using renewable energy both in the ethanol production and in the ATJ process. It was shown that, with future electricity generation mixes with an increased proportion of renewables, significant GHG mitigation, up to 67% as compared to conventional fossil fuels, can be reached. With further improvements of replacing the natural gas with a sustainable alternative for the current ethanol production, e.g. producing steam from renewable energy, GHG emission reductions of ~95% can be achieved.

The comparison of the retrofit to stand alone ATJ plant showed that the retrofit of the existing ethanol facility with the ATJ process exhibits ~4% higher GHG emissions savings than the stand-alone ATJ-SKA plant. Based on the results of this study the recommendation is made to encourage a retrofit of existing ethanol productions with ATJ processes to accelerate the availability of the SAF volumes on the European market.

3.3 Case Study 3: AustroCel Hallein (Pulp & paper)

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. The advanced bioethanol production plant has been built and is already operating. The investment volume was about 40 million euros.

The Case study company stated that the retrofit was difficult due to the technological limitations of the existing facility. The main process (pulp production) sets the boundary conditions, which cannot be changed for a by-product. This situation is limiting for bioethanol production, which would require a more flexible plant design. The main technical challenges were:

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

The construction of a greenfield plant would have been easier from a technology point of view, but a greenfield plant was not a business case. For the investors, off-take agreements were needed. The political framework was not finalized, which lead to uncertainties and caused difficult discussions between stakeholders about prices and volumes. The uncertain framework is seen as a major risk for the entire biofuels sector, in which secured investments are needed. Overall, there were several obstacles to stay in time and budget, but surprisingly it was possible, even during the pandemic.

The key results of the Market assessment were:

- There is an overcapacity for first generation bioethanol in the EU
- Advanced biofuel targets could be met in 2022 (0.2%) with the planned production capacity, but it is not sufficient for 2025 (1%)

- Advanced bioethanol is needed since it is ready for the market and implementation of electric vehicles will be not fast enough to meet climate goals. If demand for ethanol is decreasing for passenger cars, it can be further processed to jet fuel and used as aviation fuel (alcohol to jet)

- Advanced bioethanol production costs are often presented in a low, medium and high scenario. Since AustroCel Hallein is using by-products from the own process, the low scenario is expected to be the most valid one.

A challenge of the Sustainability assessment was the definition of the system boundaries, due to the fact that in the baseline scenario the main product is dissolving pulp, whilst the retrofit one focuses on bioethanol. It was difficult to gather comparable data from databases and also ensure transparency of results when using relevant literature data. Two surprising results were the high contribution of natural gas for starting up the boiler and the impact of the brown liquor combustion on global warming potential.

3.4 Case Study 4: C-Green (Pulp & paper)

This case study focussed on the hydrothermal carbonization (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 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, C-Green's OxyPower HTC Technology is used to treat the wastewater sludge. As a retrofit product, 2,700 tons of dry HTC biocoal/a will be produced with heat value of 10,900 MWh.

The Case study team leader reported that this case study is uneconomic. However, if for example the limit of the recovery boiler would be stretched to maximum production, the case could look different and would be more profitable. This option will be added in the case study report out of interest.

The case study company, operating the pulp mill, was not surprised by the negative numbers, as the plant is already quite efficient and therefore hard to compete with. However, the company was happy to learn about the HTC biocoal technology and the expected effects of its implementation in the mill. Instead of retrofits, it could be considered for newly built plants if market demand for the product grows.

Using sludge from other industries, which is more challenging to incinerate and more costly to dispose, could be an interesting opportunity for some other companies.

The most challenging aspect of the Techno-economic assessment was that the gained OPEX was not sufficient for the CAPEX. One explanation is that sludge treatment at the plant is already quite optimized. When the existing system is already optimized, big investments would be necessary in order to obtain a benefit.

The Market assessment and the analysis of the legal aspects were very challenging to carry out, because there was no market for this product so far. However, some potential applications were identified, such as the use of HTC biocoal as solid fuel or for soil improvement.

The main issue of the Sustainability assessment was the definition of boundaries. It was a tricky case study, since the baseline scenario was already environmentally friendly. Biogenic emissions from the end-users were not considered, since they were out of scope of the case study. Expanding the boundaries could be beneficial for environmental parameters.

3.5 Case Study 5: Total (fossil refineries)

This case study investigated the co-feeding of pyrolysis oil in the Fluid Catalytic Cracker (FCC) of a fossil refinery, for the production of second-generation (advanced) transportation fuels. Distributed production of pyrolysis oil can take place, followed by transport to a single location, such as a refinery. Advantages of this concept are that only limited new infrastructure needs to be build, namely the pyrolysis oil production plants. These are relatively small, can be constructed fast (in 1 year), and capital requirements are modest in comparison with the costs of a refinery. Retrofitting costs at the refinery are low. The whole value chain is financially viable and the resulting CO_2 emission reductions are substantial, and well above the RED II thresholds.

The Case study team leader reported that having a catalyst manufacturer involved in this case study would have made results more accurate, because manufacturers can provide a deeper insight on the effect of alkali metals on the activity of FCC catalyst. Moreover, large scale testing is required to validate results and promote the technology.

Another important remark is that before renewable gasoline will be accepted by the market a standard should be developed to quantify the renewable content of gasoline from co-processing. This could be done according to the mass balance method of RED-II.

Downstream modifications on the product recovery section have not been part of this study and should be included in further assessments.

One of the advantages of this retrofit is that it is possible to switch back to 100% fossil fuel, if problems occur while co-processing. Only the investment costs in the refinery would be lost.

A challenge of the Techno-economic assessment was to apply the economic calculations to a subsection of a refinery, because the products of this subsection are further treated and are not directly sold. Consequently, it is difficult to assign a monetary value to such products. The key findings of the techno-economic assessment were:

- The importance of subsidies. Without subsidies the retrofit would not be possible, and the value of the subsidies have a huge impact.
- The economic risk involved. The large volumes of materials and products involved in the process result in a risk. A successful retrofit would lead to high profits, but if something goes wrong, the investment costs will be lost. These costs are modest for the refinery, but higher for the pyrolysis oil production plants

A challenging aspect of the Supply chain assessment was that, although there is data regarding the theoretical biomass availability and trade of biomass feedstocks in France, the actual available biomass for pyrolysis oil production and its quality was hard to estimate. Current utilization of biomass residues seems to be high and therefore entering the biomass market will likely result in competition, which makes the cost estimates also hard.
In order to estimate the current utilization of the selected biomass feedstocks it would have been helpful to consult a local expert on the biomass market around the refinery (national partner). Moreover, contacts with biomass suppliers regarding actual availability and costs would be needed.

A key finding was that the legal framework regarding co-processing is quite different among EU Member States, and in France legal framework is really favourable.

In the Sustainability assessment, several challenges were encountered:

- The definition of the system's boundaries of both the baseline and retrofit scenario: The system's boundaries determine which processes will be included in the simplified life cycle assessment, thus, the definition of the boundaries is critical in order to ensure the accuracy of the LCA results.
- The lack of data regarding the baseline scenario. Gathering background inventory data from either databases or from similar case studies reported in the relevant literature was a demanding step in the simplified LCA analysis, which was based on a comprehensive literature review. Validation of the calculations was necessary in order to ensure the transparency of the case study findings.
- The appropriate definition of the functional unit so as to provide comparable results between the baseline and retrofit scenario, as well as, with the fuel comparators provided by RED II.
- The allocation procedures for co-products in the simplified LCA analysis.

Regarding the results of the Sustainability assessment, the main lessons learned are summarized as follows:

- The substitution of 5% of VGO (Vacuum Gas Oil) with fast pyrolysis bio-oil results in replacement of high-GHG feedstock with renewable (low-GHG) feedstock and therefore, in improved GHG emissions performance.
- The selection of the location for the pyrolysis oil production plants is not an important factor from an environmental perspective.
- The fuel use stage is responsible for the majority of GHG emissions (about 75% of the total life cycle emissions). It is imperative, therefore, to investigate the whole life cycle of vehicle fuels in order to quantify their actual environmental performance.
- A surprising result was the significant, environmental-wise adverse impacts associated with the production stage of the VGO fuel from the crude oil distillation process.

3.6 Case Study 6: Hellenic Petroleum (fossil refineries)

This case study investigated the co-processing of UCO (Used Cooking Oil) along with conventional straight run LGO (Light Gas Oil) into an existing Diesel Hydrotreater Unit at Hellenic Petroleum (HELPE)'s Thessaloniki refinery in Northern Greece. The unit is currently used to desulfurize the LGO stream coming from the CDU (Crude Distillation Unit) stripper column. UCO will consist of 5% volume of the processing mixture. As a result, an annual production of 22,000 tonnes HVO (Hydrotreated Vegetable Oil) is expected, which will be an integral part of the final diesel product. HVO is characterized as a premium "drop-in fuel" that can replace diesel without modifications to existing refuelling systems and/or vehicles.

A key aspect identified in the Technical Description was the UCO quality. UCO collected from various sources (consumers, businesses) will not have a stable quality. Currently there are no specifications for the quality of UCO in place.

In the Technical Description, it was a challenge to compare the retrofit case for HELPE refinery to a grassroot plant of same capacity since it is on a small scale compared to others. Specifically, the case study examined the production of 22 ktpa HVO when other grassroot refineries produce HVO in the range of hundreds of ktpa.

The Case study company reported that UCO co-processing is an important aspect of the 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. The retrofit is considered as a small-scale project and was not a CAPEX intensive action. This retrofit acts as a first step for other activities in which additional volumes of biocomponents can be used as feedstock within the refinery premises. At present the company investigates the implementation of up to 10% UCO co-processing in the refinery of Thessaloniki, in line with max cap UCO usage of 1.7% on energy content for the domestic market.

In the Techno-economic assessment, it was found that green premium is a key aspect. Without a higher price for biofuels, the entire retrofit becomes uneconomical. From an assessment point of view, fixing the price of UCO and the price of LAGO was challenging. The price of UCO is challenging since it depends on specific contracting. The price of green LAGO product is challenging since it is not a final product. Moreover, it highly depends on the green premium that can be obtained.

The key aspects of the Supply chain assessment are the security of supply and price volatilities of UCO. Increased UCOME and HVO production in Europe and countries, exporting UCO to Europe, could lead to decreased availability. Another key aspect is the uncertain legal framework, such es the current amendment of the RED-II. A surprising result was the strong expected growth of the UCOME and UCO-based HVO market in the next years and the resulting uncertainties regarding UCO supply and price. A major challenge of the Supply chain assessment was to find recent UCO prices, since UCO is a negotiable commodity between buyers and sellers and therefore not public. A significant challenge was also to find available data about the collectible and collected UCO in Greece since the collection system is not regulated and developed yet. Another challenge was to find accurate data for UCO collection, as most values are based on multipliers, or outdated.

Similar to the TOTAL case study two significant challenging aspects of the Environmental assessment were the definition of (i) the functional unit and (ii) the system's boundaries of both the baseline and retrofit scenario. Moreover, it was found difficult to gather background inventory data for modelling some processes in both retrofit (e.g., naphtha reforming process) and alternative scenario.

The key findings of the Environmental assessment are summarized as follows:

- The substitution of 5% of LAGO with treated UCO shows positive results towards decreasing the overall GHG emissions.
- The selection of the location of the waste UCO collection centres – in a transport radius of 1500 km – is not an important factor from an environmental perspective.
- The fuel use stage is responsible for significant GHG emissions (>69% of the total life cycle emissions). It is imperative, therefore, to investigate the whole life cycle of vehicle fuels in order to quantify their actual environmental performance.
- High emissions savings (about 86%) are associated with the construction of a newly refining unit using 100% UCO as feedstock; thus, further research is required related to the application of clean fuel production processes. However, due to max cap on UCO usage imposed by RED II legislation, alternative sources of biogenic feedstock will have to be considered.

3.7 Case study 7 and 9: EPBiH in Tuzla and Kakanj (fossil firing power, CHP)

Two case studies were located in Bosnia and Herzegovina. The two plants to be retrofitted belong to the same company (Elektroprivreda BiH).

- 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, with 223 MWe, currently upgraded to 226.5 MWe / 220 MWth for the local DH system), therefore biomass will be combusted in the same furnace as coal. A new biomass feeding / milling system, connected with dedicated biomass burners is foreseen as an option for higher biomass co-firing rate. A wide range of local biomass (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 % (mass basis) of the brown coal currently used as fuel in this power plant.
- In the Kakanj thermal power plant, the full biomass repowering of Unit 5 (currently 118 MWe) was investigated. 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 (e.g.

sawdust, forest residues, etc.) with minimal pre-processing; some small quantities of RDF could also be considered as a co-firing fuel. A boiler derating is expected and the maximum electrical output of the unit would fall to around 69 MWe (net).

Based on results of the performed cost benefit analysis and environmental impact assessment, the Case study company has declared the BIOFIT projects to be promising opportunities for sustainable operation of their CHP plants in long-term view and particularly during the transition period, contributing to the carbon emission cut significantly.

The Case study company stated that the strict criteria of the RED II will be a real challenge for the investigated conversion projects. National derogations related to RED II implementation in BiH (referred to the required net electrical efficiency of biomass power plants) have been proposed in order to be able to implement solutions that are expected to have a positive impact related to reduction of GHG emissions, while increasing renewable energy production.

The Case study team leader reported that the heat supply component of such plants provides a very important local service, even if it is not high efficiency CHP generation. The fact that this case is not considered by RED II is a complication that puts additional requirements on the operators. It was initially surprising that the full conversion case Kakanj was more economically promising compared to co-firing at Tuzla, but eventually this was attributed to the effects of the carbon pricing scheme. The big difference between CAPEX required for conversion and CAPEX required for a green field biomass option is surprising and highlight the value of a retrofit. Most challenging are the biomass market developments and the policy side. For the technical problems, solutions can be found.

In the Supply chain assessment, the lack of data and the discrepancies between sources were challenging. It was good to get assumptions from the case study company and the Bosnian national biomass association to realistically assess the Bosnian biomass market. Theoretical biomass potential in Bosnia and Herzegovina is really high and if the framework conditions would become more supportive (supportive legal framework, improved forest management practice etc.), the biomass markets could grow substantially.

Regarding the Techno-economic assessment, both cases were evaluated with the assumption that the electricity production will be compensated with market prices. The economic feasibility is sensitive to the number of operating hours of the units, meaning that a lack of biomass for operating them has a big impact. However, the low-cost difference between the fuels and the current trends in the electricity prices make the Kakanj conversion case an attractive option.

For Tuzla, it is perhaps surprising that the co-firing operation does not lead to very promising results, but this is due to two main reasons. The first is that a quite elaborate, high CAPEX solution for co-firing is implemented. It is suggested that the possibilities of implementing co-firing with simpler technical arrangements is verified through a series of co-firing trial at the plant. The second and main reason is that carbon pricing for coal is only gradually implemented by EPBiH. Therefore, even if small, the expected cost difference between coal and biomass, is not sufficiently covered by the cost savings achieved through the reduction of CO_2 emissions. Otherwise, further optimization of the biomass co-firing rate and accompanied CAPEX requirements might bring the project to positive economic parameters.

Concerning the Sustainability assessment, there were no significant challenges. The key aspect of the environmental assessment was the heating value of the biomass and its effect on the biomass demand and diesel consumption required for the road transport of biomass. Due to the local biomass sourcing, the short distances of the supply chains and the minimal pre-processing, the GHG savings for both cases were calculated to be very high and well above the RED II threshold. The key issue is that both units do not meet the requirements of RED II regarding electricity production from biomass at that scale of fuel thermal input: neither can be considered as a high efficiency CHP unit while the net electrical efficiency is below 36 %. In addition, for Tuzla 6, coal will continue to be the main fuel input, which is a scenario not supported by RED II.

3.8 Case study 8: EP Produzione (fossil firing power)

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 (white) wood pellets, supplemented by small shares of locally sourced wood chips.

The case study company highlighted that the conversion is heavily dependent on the overall policy developments on the EU level, as well as on the support of the Italian government. The current proposal for RED III excludes power-only plants using forest biomass from receiving support (with a few exceptions, not applicable for Fiume Santo). Unless the situation is clarified, it is highly unlikely that the conversion will be implemented.

The case study team leader indicates that the biomass conversion is a technically feasible option. A converted Fiume Santo could play an important role in the support of the Sardinian electricity grid in the years between the coal phase-out in Italy and the development of stronger interconnections with the mainland and wider deployment of renewable energy production and storage systems on Sardinia. In the short term, the alternative to the dispatchable, renewable electricity provided by a converted Fiume Santo could only come from a new natural gas power plant, which is still a fossil-based solution.

When conducting the supply chain assessment, future sustainable biomass availability was considered as main uncertainty considering a great industrial biomass uptake. However, growing pellets production capacities and currently unused biomass potentials indicate that the biomass availability will continue to be high in the future. Generally, it seems that the policy framework and the support schemes are key limiting factors rather than an expected future lack of wood pellets in the industrial market. Even though current market conditions might make power generation from wood pellets more competitive compared to natural gas or coal, a viable biomass conversion of the Fiume Santo power plan would require a stable policy support mechanism, such as a Feed-in Tariff (FIT) scheme.

Regarding the techno-economic assessment, the economic calculations for the Fiume Santo case study were rather straightforward. The cashflow was based on cash in- and outflow of the retrofit whereby it was not necessary to compare the economic performance with the current coal-fired operations. The retrofit can be economically feasible when a bio-power premium is applied and provided that a minimum level of operating hours every year are met. However, the retrofit is sensitive to variations in pellet prices and cannot be economically implemented if the premium is set at low levels. Renumeration from the capacity market is expected to have a smaller, but important role in making the conversion project profitable.

The challenges regarding the sustainability assessment were the definition of different wood pellet sourcing options from different exporting countries. The key aspect of the environmental assessment was the fact that the unit operation of the Fiume Santo plant is in line with the RED II requirements about the minimum net electrical efficiency level of 36%; therefore, the GHG emissions calculated compared to RED II comparator. The key export result was the fact that the overall GHG emission savings from most of the cases investigated in the retrofit scenario were above the current RED II threshold (70 %) about the electricity generation from biomass feedstock and even above the threshold currently included in the proposal for RED III (80 %) under the Fit-for-55 package.

The main barrier for implementing the Fiume Santo biomass conversion is the uncertainty regarding policy developments. The proposal for the amendment of REDII published in June 2021[1] states that from 2026 on Member States should discontinue support for electricity-only plants, 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. Since the local area has not been included in the list of "Just Transition" regions and plans for BECSS (bioenergy carbon capture and storage) are not mature enough, the conversion project has effectively "frozen". In order to proceed, the planned amendment of REDII should introduce other exceptions, e.g. cases for which there is no commercial demand for heat, extension of support to non-cohesion regions.

3.9 Case Study 10: Sölvesborg Energi och Vatten (CHP)

In this case study the utilization of bio-oil in the existing central heating boilers of Sölvesborgs Energi och Vatten in Sölvesborg, 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 converting from fossil oil to light or heavy bio-oil.

The Case study team leader stated that, since this case study is quite uncomplicated, it would have been possible to be quicker and finish the assessments within about 6 months. It would have been more fruitful for the case study company, if the results would have been ready earlier.

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52021PC0557&from=EN

A surprise was that PM emissions could be a problem for retrofits such this in Sweden. The local politicians are scared in order to exceed PM emission limits, since the facility is placed at a school. It should be checked if retrofitting to biofuels is generally threatening for local politicians, or if it is just in this case.

The Case study company reported some lessons learned about the project management. It was essential to have a national partner (ESS), otherwise the Case study company wouldn´t have taken part in this project. The time between first meeting and final meeting took longer than expected and If a consultant would have been hired, the results would have been ready much faster. However, results wouldn´t have included the assessments from three different research companies, which was very appreciated.

For the Case study company, some uncertainties are still a concern for this investment: Currently, biofuels for heating have no tax in Sweden, but this could change and would therefore change the overall financial framework.

The key aspects of the Techno-economic assessment were the four different fuels, which all have a lower OPEX than the current (fossil) scenario. Due to that, there were only positive economic cases. The low retrofit costs for bio-oil were surprising.

A great advantage for the Supply chain assessment was the availability of national partners for the case study company, especially in order to get data regarding logistics and suppliers.

Regarding the Sustainability assessment, the great decrease of GHG emissions due to the retrofit was surprising. There were no major difficulties in this case study. The only challenges were to find relative data about the process, which is in line with literature, as to provide comparable data with the RED II and the investigated scenarios.

4 Summary of lessons learned from all case studies

Key issues to consider in a retrofit

Where does the biomass come from?

- Even if theoretical biomass potentials are known, the already existing use is difficult to estimate
- Detailed assessment of availability by contacting suppliers is necessary
- Increasing demand for certain waste streams and by-products will increase the price – long-term contracts can stabilize biomass prices
- Decentralized plants in rural areas provide easier access to (solid) biomass
- Liquid biomass (oils) is more efficient to transport than solid biomass

Will the retrofit gain profits?

- Retrofitting often results in lower capital expenditure (CAPEX), shorter lead times, faster implementation, lower production time losses and risks than setting up an entirely new facility
- New products may be difficult to sell
- A new product might not outweigh possibly reduced production of by-products
- If a plant is already quite optimized in using by-products, a retrofit may not be economic
- The price of biofuels is not competitive to fossil fuel prices – support mechanisms are needed to fill this gap

When is a retrofit technically feasible?

- Integration into existing plants requires thought-out plant integration– the complexity should not be underestimated
- Production of the main product should not be changed and thus sets boundaries for amount and quality of side-streams used for the new product

What about the legal framework?

- Scale of planned production compared to regulated market has to be considered (upper limit for use of Annex IX part B feedstocks, targets for advanced biofuels)

- National legislations across member states vary significantly despite being governed by RED II and can lead to different business opportunities

Does the retrofit contribute to GHG emission reduction?

- Using process CO2 or by-products enables high GHG emission savings
- Production of energy intensive products can lead to increased GHG emissions. To avoid this effect, process energy, especially for energy intensive production pathways, should be provided from renewable sources.

What else to consider?

- Local stakeholders should be involved from the beginning – transparent communication is key
- A detailed analysis of all aspects is worthwhile

In a nutshell

Retrofitting is a great chance to optimize existing plants instead of building entire new ones. However, a successful retrofit requires thought-out planning and consideration of several key issues.

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