MUSIC

Market Uptake Support for Intermediate Bioenergy Carriers

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CONTEXT AND OBJECTIVES

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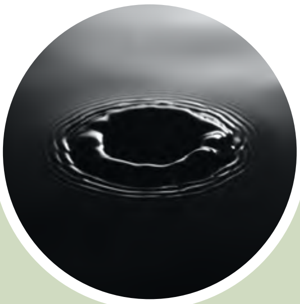
In the last decades, it has become increasingly clear that fossil fuel resources are scarce, finite and their use can harm the environment and our climate. The latest report of the IPCC highlighted once more the unprecedented rate of global warming driven by anthropogenic greenhouse gas (GHG) emissions.1 Limiting global warming to 1.5-2°C at the end of the 21st century requires deep GHG emissions reduction. Increasing the share of renewable energy in the current energy mix will, besides reducing our GHG emissions according to the Paris Agreement (2015), ensure enhanced security of supply, stimulate innovation, create new jobs, and contribute to economic development.

Bioenergy is an essential form of renewable energy and is currently the largest contributor to the renewable energy mix, providing an estimated 57% of EU's renewable energy production in 2021.[2] Bioenergy solutions are manifold, with each of them having an important role in the decarbonization of our economies.

With bioenergy on a sustainable resource base in the European energy mix, **Intermediate Bioenergy Carriers (IBCs)** become of growing importance, as they can ensure a more efficient utilization of biomass feedstocks from agricultural and forest residues. IBCs are formed when biomass is processed to energetically denser, storable, and transportable intermediary products analogous to coal, oil, and gaseous fossil energy carriers. The main advantages to the use of IBCs as compared to raw biomass are the reduced cost of logistics, easy storage and conversion, and the ability to homogenise different biomass types into a single product with uniform characteristics. These IBCs can be used directly for heat and power generation or further refined to higher value-added bio-based products.

MUSIC was a Horizon 2020 project co-financed by the European Commission from 2019 to 2023, which had as central aim to facilitate market uptake of three Intermediate Bioenergy Carriers:



PYROLYSIS OIL

Obtained by fast heating of biomass in the absence of oxygen.

TORREFIED BIOMASS

Obtained by slow heating of biomass in the absence of oxygen.

MICROBIAL OIL

Obtained through bioconversion of lignocellulosic-biomass derived sugars.

Core action of the MUSIC project were two-fold: bottom-up, starting from specific case studies that helped building a consolidated production and consumption base for IBCs. And top-down, targeting industrial sector and policy makers, aiming to make a difference in the market perception of IBCs.

https://www.ipcc.ch/report/ar6/wg1/
https://europeanbioenergyday.eu/

A FIVE-STEP APPROACH TO FACILITATE THE MARKET UPTAKE OF INTERMEDIATE BIOENERGY CARRIERS

IBC implementation is hampered by various market uptake barriers. Currently, IBC technology is facing first-of-a-kind issues where the consumer has to rely on one single deliverer of IBC having no back-up options, and conversely, the IBC supplier has to rely on the consumer, requiring a long-term take-off guarantee for the construction of new plants. Furthermore, high logistics costs prevent take-off of new technologies that use biomass as resource, and the lack of feedstock supply chains causes various technical and non-technical problems. To facilitate the market uptake of IBCs, MUSIC implemented a five-step approach:

Mapping of national and EU frameworks and state-of-the-art to identify barriers and enablers, as well as best practices of IBC deployment and logistics.

Assessment of 8 case studies for different regions and IBC combinations. Specifically, 4 advanced case studies were performed on value chain assessment and 4 strategic case studies on expansion strategies and market uptake.

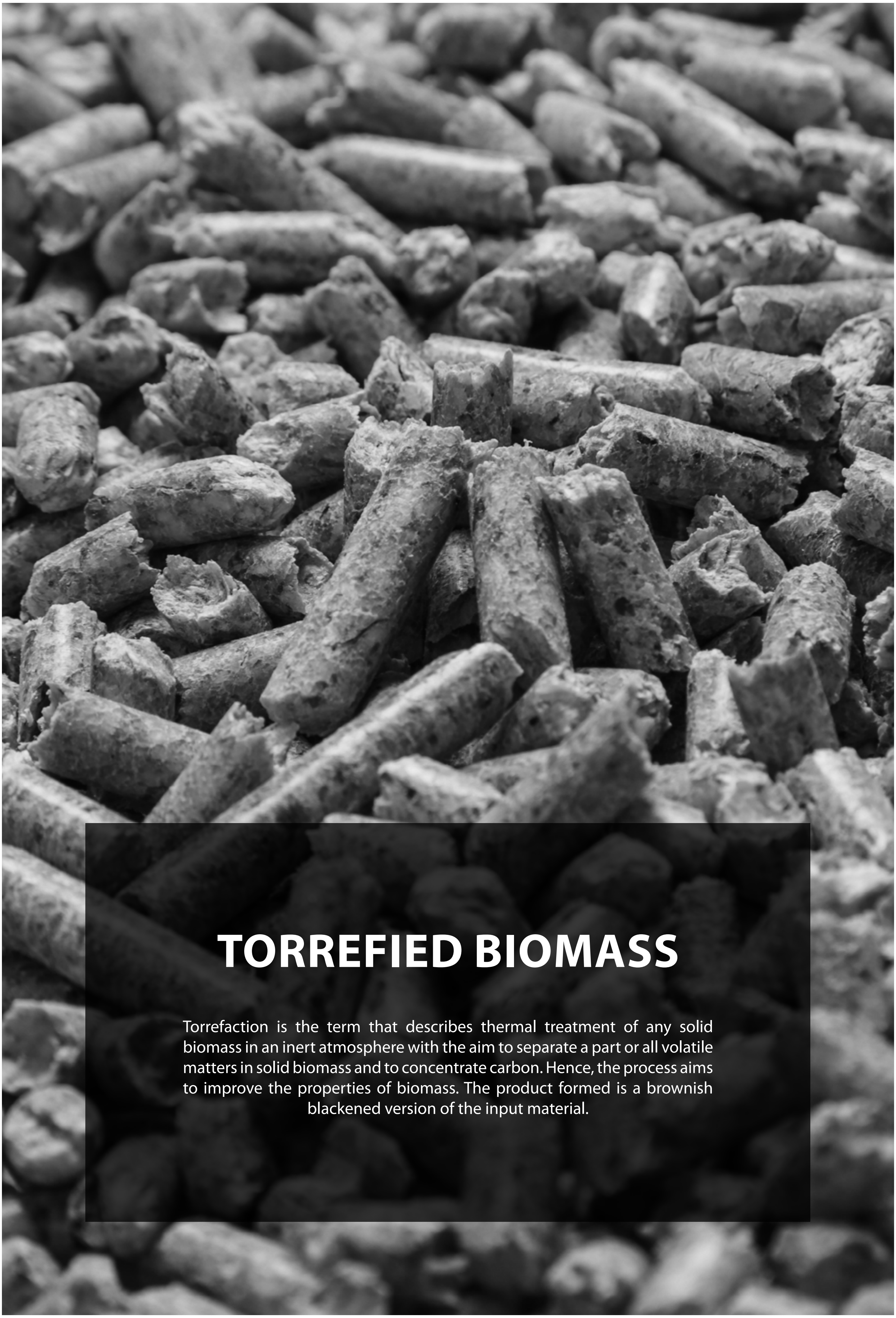
Engaging with case-study-relevant stakeholders to assess their views on IBC supply chains. Regional discourse was initiated to develop specific and strategic recommendations on supply chain development.

Development of biomass mobilization and chain optimization software tools to assess regional biomass flows and facilitate regional biomass trade towards IBCs in case study regions.

Providing advice to policy makers by drafting a multi-disciplinary policy recommendations report regarding preferable conditions for the deployment of IBC technologies.

OPPORTUNITIES, BARRIERS AND CHALLENGES FOR THE MARKET UPTAKE OF INTERMEDIATE BIOENERGY CARRIERS

MUSIC identified best-in-class examples of IBC deployment and associated logistics for each of the IBCs by mapping the European and national project landscape. Furthermore, through a combined assessment of national and European framework analysis with forward and backward casting, the opportunities as well as barriers and challenges for the market uptake of the three IBCs were determined.



TORREFIED BIOMASS

Torrefaction is the term that describes thermal treatment of any solid biomass in an inert atmosphere with the aim to separate a part or all volatile matters in solid biomass and to concentrate carbon. Hence, the process aims to improve the properties of biomass. The product formed is a brownish blackened version of the input material.

BIOMASS MOBILISATION AND LOGISTICS

The torrefaction of biomass is a promising and much discussed pre-treatment method to reduce the costs of bioenergy chains, in particular logistics costs and emissions caused by logistics. When considering the transport of torrefied biomass pellets (TBP) and wood pellets (WP) from Portugal to North-western European countries by sea and comparing their costs, the total costs of one delivered shipload with TBP is slightly lower than for WP due to the higher energy content of TBP. Unloading and conveying of torrefied biomass is possible using the existing systems in coal power plants. Only minor adaptions in dust suppression systems and in the underloader grabs are required. Achieved improvements in densification of torrefied biomass did confirm the expected behaviour in logistics and storage even though large volume shipment and storage experience is yet to be gained.

MARKET OVERVIEW AND MARKET POTENTIAL

It is estimated that about 50 companies in Europe and North America are involved in the development of torrefaction technologies. To date, total cumulative production figures are estimated at 70-120 ktons of torrefied product per year. The product has been used in coal plants, gasifiers and non-industrial facilities.

Torrefaction technologies are capable of converting low-quality biomass, coming from forestry, agricultural or industrial activities, into biomass-derived fuels which can directly replace coal in electricity generation. Torrefaction can also serve as a basis for the development of other technologies whether for energy production or for biorefineries for green chemicals and bio-based materials. Beyond its use for power generation, torrefied biomass can find applications as substitute for fossil fuels in heat production, whether standalone plants for district heating or as a support of industrial processes, and as substitution of coal or heating oil in the production processes of some industries. It is anticipated that torrefied biomass has high potential due to commitments of the steelmaking industry to reach carbon neutrality by 2050, existing funding opportunities for the coal and steel industry, and the framework of the European Green Deal.

MARKET UPTAKE BARRIERS AND CHALLENGES

The current market uptake of torrefied biomass is still limited due to the lack of established full value chains, difficulties to ensure financing as well as the presently higher costs compared to fossil fuels. The bankability of new torrefaction projects is often limited by the lack of long-term offtake contracts and the low number of existing reference projects. Today, torrefaction must be regarded as a technology that can and will further improve, meaning that ongoing funding of research and development is needed.

MICROBIAL OIL

One of the main advantages of microbial lipids or microbial oils is that they are independent from seasonality and climate. Moreover, they can be obtained from a wide range of carbon sources, including renewable ones and organic wastes. The bioconversion of lignocellulose to microbial lipids includes pre-treatment of lignocellulosic biomass, the hydrolysis of structural carbohydrates to fermentable sugars, conversion of hydrolysed sugars into lipids, and the isolation and purification of the product.

BIOMASS MOBILISATION AND LOGISTICS

Biomass mobilisation and logistics for microbial oil production shows strong similarities with the lignocellulosic ethanol chain. In fact, agricultural residues such as wheat straw and corn stover may be used as feedstock, as well as forestry residues and energy crops. The high energy density of microbial oil compared to raw biomass suggests a logistics system where the IBC plant is placed closer to the feedstock production areas than to the bio-refinery where the HVO diesel or jet fuel is produced. This helps to reduce the overall transportation costs of the raw, low-value materials. Multiple feedstock suppliers and/or multiple storage facilities are beneficial to secure operational flexibility and to reduce feedstock supply risks.

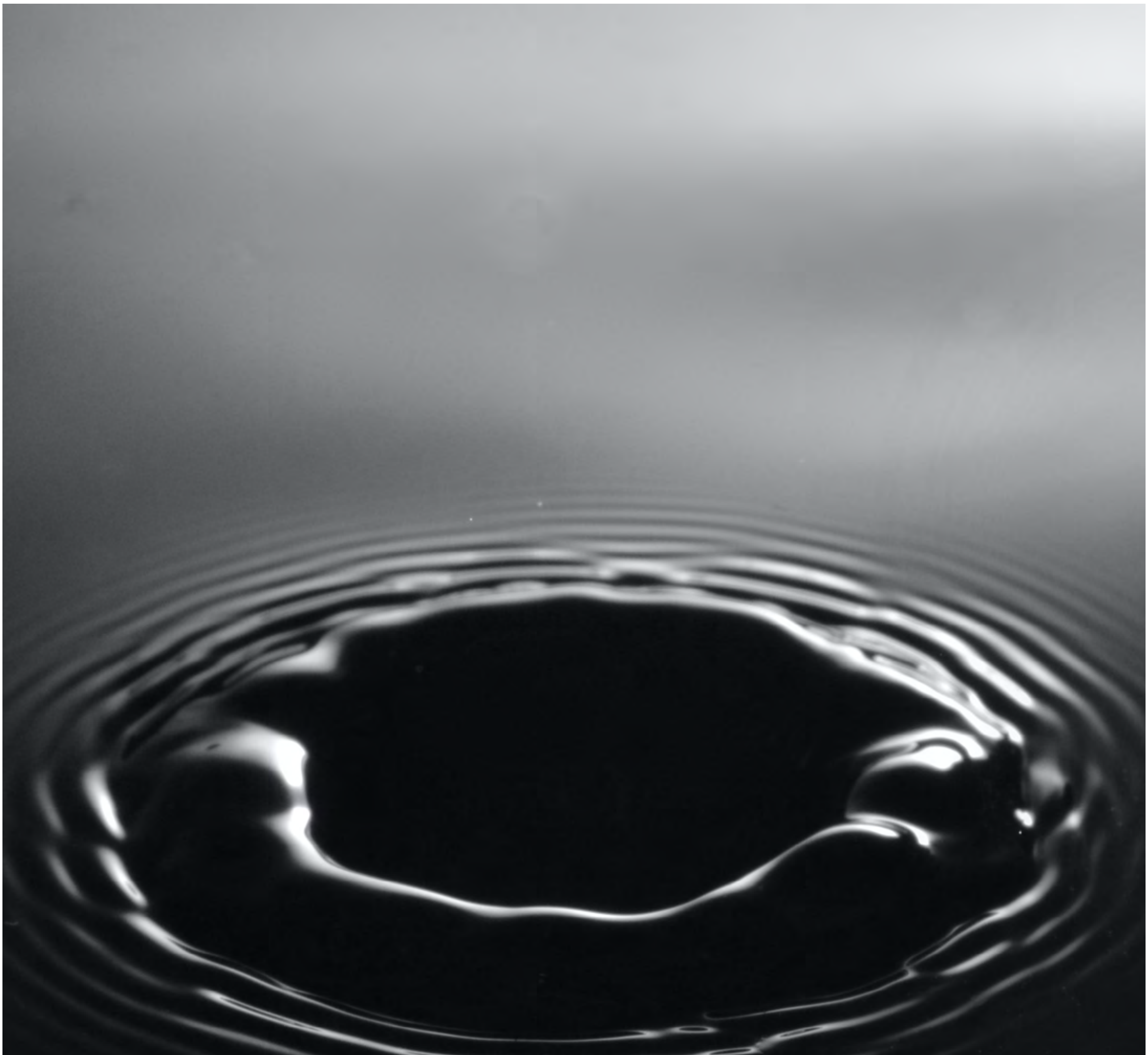
MARKET OVERVIEW AND MARKET POTENTIAL

Today, the main feedstock for the production of biodiesel for the European market are vegetable oils. Lipids are a consolidated feedstock for commercial HVO biorefineries, with palm oil considered one of the best feeds, due to its lower costs and related lower hydrogen consumption. The RED II directive sets a cap for such food- and feed-based biofuels that could contribute for a maximum of a 7% share to the total final energy consumption of EU road and rail transport sectors. RED II also defined targets to reduce the consumption of high ILUC-risk feedstock -such as palm oil - to produce biofuels, starting in 2023 and reaching a complete phase out by 2030. Some HVO producers, however, either already cut the use of palm oil, or have announced to do this by 2023.

Microbial oil production, integrated in existing large scale HVO installations, has a very large potential as a substitute for vegetable oils and food-related lipids. Thus, microbial oils are attracting growing interest as this process could largely benefit from synergies with two major advanced biofuels commercial technologies, namely HVO and lignocellulosic ethanol.

MARKET UPTAKE BARRIERS AND CHALLENGES

Microbial oil still needs high levels of investment in R&D due to its current low TRL of 4-5 and may suffer from the so-called "chicken and egg" situation, in the sense that an operational reference plant is important to persuade reluctant investors, but at the same time such a reference plant is quite unlikely to be funded since investment security is not granted. In order to exploit the potential of microbial oil, upstream supply logistics need to be further developed. Several small- and medium-sized producers would have to be gathered together in order to reach the critical mass of feedstock needed by the IBC plant.



PYROLYSIS OIL

Fast pyrolysis is a process in which organic materials are rapidly heated to 450 – 600°C in the absence of air. Under these conditions, the structure is broken down and organic vapours, non-condensable gases and charcoal are produced. In a next step, the vapours are condensed, and fast pyrolysis bio-oil (FPBO) is formed. FPBO is a dark brown, acidic liquid and may have a similar appearance as fossil oil, but the chemical/physical properties are quite different.

BIOMASS MOBILISATION AND LOGISTICS

Biomass mobilisation and pyrolysis oil logistics highly depends on the local conditions. When operating biomass pyrolysis plants, to secure operational flexibility and to reduce feedstock supply risks, it can be beneficial to have multiple feedstock suppliers and/or multiple storage facilities. In general, a pyrolysis oil project will be more financially viable when build as near as possible to the feedstock to avoid costly transportation of low value material. Either way the transport modality should be chosen according to the amount of biomass, the distance and the resulting transport costs.

MARKET OVERVIEW AND MARKET POTENTIAL

Already today, pyrolysis oil can be considered as an economic solution to replace oil or natural gas. Ensyn (Canada) supplies heat to hospitals, whereby fossil oil is replaced, Twence (Netherlands) sells pyrolysis oil to replace natural gas to produce high-pressure steam at a dairy plant, and Fortum replaces heavy fuel oil with pyrolysis oil in its CHP plant in Joensuu, Finland. In addition, Preem's refinery in Lysekil, Sweden co-feeds pyrolysis oil that is processed into renewable diesel and petrol, and as a result, partly substitutes fossil oil.

Pyrolysis of biomass can create an economic boost to rural areas, whereby locations with an existing forest industry have a high potential. This makes the technology also attractive for new markets in e.g., Asia, Africa, and South America that have an increased interest in using local resources. Even though power production is the main application today, agricultural uses, conversion to biofuels, and chemical production are growing in importance. Furthermore, pyrolysis oil will play a crucial role as (co-)feed in (bio-)refineries for the production of transport fuels.

MARKET UPTAKE BARRIERS AND CHALLENGES

Pyrolysis technology is already proven on a commercial scale. However, similar to torrefied biomass the current market uptake of pyrolysis oil is still limited due to the lack of established full value chains, difficulties to ensure financing as well as the presently higher costs compared to fossil-fuels.

Therefore, increased market uptake of pyrolysis oil will require further research and innovation on advanced technological equipment and processes to increase carbon yields and reduce production costs. In addition, future large-scale market uptake will benefit from a conducive policy and regulatory framework as well as dedicated support activities and schemes on European level.

WHITE PAPER: TORREFIED BIOMASS

The MUSIC partner Bioenergy Europe has provided a concise and accessible overview of the main torrefaction technologies, its main principle, the economic benefits, as well as its current applications and experiences in the industry in the form of a White Paper. The White Paper can be accessed by clicking on this box.

WHITE PAPER: MICROBIAL OIL

The MUSIC partner RE-CORD has provided a concise and accessible overview of the microbial oil production processes and the corresponding technologies, examples of applications, and the utilization of microbial oil co-products in the form of White Paper. The White Paper can be accessed by clicking on this box.

WHITE PAPER: FAST PYROLYSIS BIO-OIL

The MUSIC partner BTG has provided a concise and accessible overview of the pyrolysis oil production process, its implementation status, examples of energy applications, and its potential to convert pyrolysis oil to higher valued products in the form of a White Paper. The White Paper can be accessed by clicking on this box.

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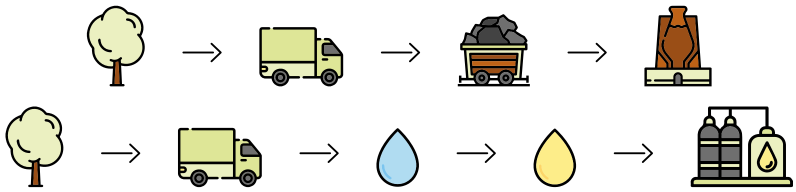
CASE STUDY SELECTION AND HIGHLIGHTS

Within the MUSIC project, eight specific case studies were developed for different regions and IBC combinations. Four case studies focussed on both the take-off users and on the short term, while the other four case studies explored the potential and the logistical implications of significant scale-up in the medium term. These considered additional IBC users and/or a broadened biomass feedstock base.

CASE STUDY HIGHLIGHTS

TORREFIED BIOMASS FOR STEEL PRODUCTION AND MICROBIAL OIL FOR TRANSPORT FUEL PRODUCTION



The case study in Italy focussed on two different value chains. One value chain concerned the production of biochar/pyrogas from regional lignocellulosic biomass residues for use in the Arcelor Mittal steel mill in Taranto. The pyrogas co-product could be used for internal energy use of the plant.

The other value chain concerned the large-scale production of microbial oil for use at the ENI existing biorefineries in Porto Marghera (Veneto) and Gela (Sicily). Lignocellulosic biomass residues were considered as feedstock for oleaginous yeasts to produce lipids.

BIOCHAR FOR USE IN THE ARCELOR MITTAL STEEL MILL

The case study showed financially favourable results with a Net Present Value (NPV) of 39M Euros, a 15-year payback time and an Internal Rate of Return (IRR) of 11.1%. About 60% of the income is generated by the EU carbon allowance prices that are earned due to reduction in CO_2 emissions and a Green Steel premium that is to be paid by the customers of the steel mill. The Green Steel premium accounts for 15% of the revenues. The environmental performance of the IBC value chain can be described as particularly good, showing a 90% GHG emissions savings in the case of direct physical substitution of coal and 88% GHG emissions savings for the replacement of natural gas for process heat needs.

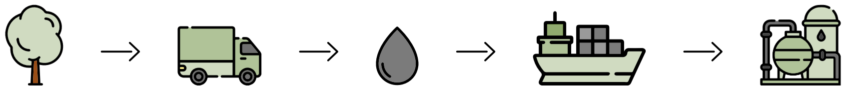
Essential for the business case is the timely securing of low-cost biomass and the amount of pyrogas used to power the slow pyrolysis process. This means in practice that the IBC plant needs to be centralized at the steelmaking site to ensure full usage of the pyrogas.

LARGE-SCALE PRODUCTION OF MICROBIAL OIL FOR USE AT THE PORTO MARGHERA AND GELA BIOREFINERIES

The second case study showed that biomass availability was year-round sufficient, having a 50% biomass surplus. The average total price of dry biomass for the IBC plant has been assessed per crop type. Values ranged from 87 €/t to 105 €/t. Variability is mostly related to the transport costs, which in turn is affected by the existing transport infrastructure. The costs for Microbial Oil were determined to lie between 1127 €/t and 1363 €/t. Cost variability depends mostly on whether the Microbial Oil is produced centralized or decentralized, and whether lignin is valorized or not. Sale of the surplus lignin is considered economically advantageous for the case.

CASE STUDY HIGHLIGHTS

PYROLYSIS OIL UPGRADING TO ADVANCED TRANSPORTATION FUELS



The case study in Sweden and Finland concerned the production of pyrolysis oil in several plants in Sweden and Finland, followed by sea transport to the Netherlands, where it is upgraded to a drop-in advanced marine biofuel.

The purpose of this case study was to assess the logistics and feasibility of a long-distance value chain producing pyrolysis oil at various sites in Sweden and Finland and subsequent upgrading in the Netherlands, and to investigate the expansion of such value chain at multiple sites in the same countries.

VALUE CHAIN IMPLEMENTATION

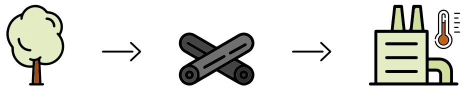
The minimum quantity of pyrolysis oil that could realistically be upgraded in an upgrading plant was determined to be 72,000 tonne/year, which is the equivalent of the yearly production of 3 standard-sized biomass pyrolysis plants. Minimum costs for pyrolysis oil at the factory gate was determined to lie between 300 and 350 Euro/tonne. International transport can take place in various ways and volumes. An option involving monthly transport is considered technically feasible. Total costs for international transport were calculated at about 61-62 Euro/tonne. Upgrading of the pyrolysis oil requires substantial amounts of hydrogen. To ensure that the GHG emission reduction of the entire value chain is above 80% (to comply with REDII requirements), hydrogen production should be combined with carbon capture and storage (CCS), or hydrogen should be produced from renewable sources. A pyrolysis upgrading plant situated in the Netherlands will only be economically viable if current support levels for advanced transportation fuels are increased.

VALUE CHAIN EXPANSION

An expansion of this case study to 192.000 tonnes/year of pyrolysis oil was considered. This is the equivalent of the yearly production of 8 standard-sized biomass pyrolysis plants. Minimum costs for pyrolysis oil at the factory gate was determined to lie between 312 and 430 Euro/tonne. An option involving monthly transport by sea to Rotterdam is considered technically feasible. Total costs for international transport were calculated at about 58-91 Euro/tonne, dependent on the transport frequency. Also here, hydrogen is required which means substantial costs. It should also be combined with CCS. Production costs for the pyrolysis-based transport fuels would amount to about 1750 Euro/tonne, which is roughly twice as much as the 2021 price of a fossil alternative. The minimum costs for pyrolysis oil at the factory gate are higher when 8 standard-sized biomass pyrolysis plants are considered instead of 3. This is partly due to the new market reality of higher costs for biomass, logistics and materials.

CASE STUDY HIGHLIGHTS

TORREFIED BIOMASS FOR DISTRICT HEATING IN GREECE



The case study in Greece concerned the conversion of agricultural residues, such as straw and tree prunings, to torrefied materials and, subsequently, utilize them in district heating plants and district heating networks.

The purpose of this case study was to assess the logistics and feasibility of a torrefied biomass value chain supplying a 30 MW_{th} biomass combustion plant of DETEPA, and to investigate large-scale implementation at multiple regional (district) heating plants and relevant industries in the region.

VALUE CHAIN IMPLEMENTATION

The case study has shown that enough biomass is available in the vicinity of the torrefaction unit. Investment costs are primarily linked to the torrefaction reactor size (70% of the CAPEX). Torrefaction doubles the operational costs in comparison with the utilization of the energy-equivalent raw biomass. In the short term the currently used fuel mix of lignite and wood chips is financially the most attractive option, as long as lignite can be procured at a price not exceeding 46 €/tonne. It is realistic to assume that the lignite price will increase because of the Greek coal phase-out that is to be completed by 2028. DETEPA should anticipate significant increases in energy production costs because of this coal-phase out, even when it offers substantial environmental benefits.

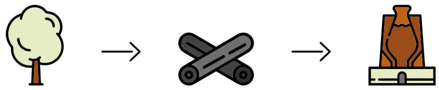
VALUE CHAIN EXPANSION

The total production costs for torrefied biomass were calculated at between 24 and 39 €/MWh. This is higher than the price for wood chips and for pet-coke (a fossil alternative to lignite). To break-even with wood chips price, one torrefaction unit with a capacity of 140,000 tonnes/year located not further than 115 km from the conversion location is required. In the case of pet-coke, a torrefaction unit of 60,000 tonnes/year would be sufficient. Factors affecting the total IBC value chain costs are torrefaction unit capacity, biomass price, biomass location and demand fluctuations.

There are a lot of enabling factors regarding biomass utilization in Greece. The Greek National Energy and Climate Plan (NECP) emphasizes on biomass and wastes, and on sustainability certification schemes for biofuels, bioliquids and solids. However, the legal framework and the lack of large-scale pilot plants are major hindrances.

CASE STUDY HIGHLIGHTS

TORREFIED BIOMASS IN ARCELORMITTAL'S STEEL PLANTS



The International case study concerned the use of torrefied biomass at ArcelorMittal sites across Europe.

The purpose of this case study was to assess the feasibility of broadening the range of biomass feedstocks to be torrefied at ArcelorMittal's Ghent (Belgium) facility, including Solid Recovered Fuel (SRF), Refuse-Derived Fuel (RDF), and waste wood, and to investigate the logistics and feasibility of expanding the value chain to various other ArcelorMittal steel mills, including facilities in North/South France, North Spain, North Germany, Poland, and Italy.

VALUE CHAIN IMPLEMENTATION

In terms of availability, price and torrefaction product yield, shredded used treaded wood (B-wood) and SRF, or blends thereof, are the most promising feedstock. However, the content of ash, chlorine and sulphur and the presence of toxic heavy metals requires proper attention and consideration, having an impact on the possible applications of the torrefied product. Due to the higher chlorine and sulphur content in the feedstock the torrefaction process needs to be equipped with a flue gas cleaning system to limit the emission of HCl and SO_2. The rather high ash content in the torrefied product can lead to customer problems, like an unacceptable ash melting and ash drain behaviour. The presence of heavy metals may lead to soil, water, and air pollution.

VALUE CHAIN EXPANSION

ArcelorMittal has assessed the potential contribution of implementing Torero-type torrefaction technology at its European production facilities, taking into account local feedstock conditions. Assuming an average replacement rate of 60% of waste wood versus Pulverized Coal Injection (PCI) and a threshold of 15% of PCI being replaced by waste wood, a potential demand of 1.6 Mton of waste wood per year was estimated for ArcelorMittal.

Extrapolating to the overall EU steel production (via BF-route), the total waste wood demand would be 5.8 Mton. A total volume of waste wood treated in Europe is estimated at 50 Mton, and therefore, sufficient volume is available to supply the steel section in Europe.

Scaling up will require continued public funding, given the billions of euros needed to achieve large-scale carbon-neutral steelmaking.

3

AN INTERACTIVE PLATFORM FOR FEEDSTOCK MOBILISATION

AN INTERACTIVE PLATFORM FOR FEEDSTOCK MOBILISATION

A platform for mobilising biomass resources has been developed to facilitate local and regional biomass trade in Western Macedonia (Greece). The platform, called Binter, is hosted on a smartphone app which main purpose is to foster market development of IBCs through feedstock mobilisation. The platform offers the ability for farmers or bio-feedstock producers to advertise their available biomass by uploading it in the database. Information such as the location, quantity of the respective biomass types and photographs can be presented. Based on that information, IBC producers can organise their collection more efficiently. The Binter application also include a simplified CO_2 emissions calculator which can give an estimation of CO_2 eq. emitted during the lifecycle of biomass fuels, based on the principles and methodology given in Annex VI of the REDII.

Ultimately, the Binter app helps to mobilise the unexploited quantities of biomass for conversion and improves the financial support eligibility of IBC production schemes by indicating the conformity with the requirements of RED II. The Binter application can be found in the Google Play Store and can be downloaded on Android supported smartphones free of charge.

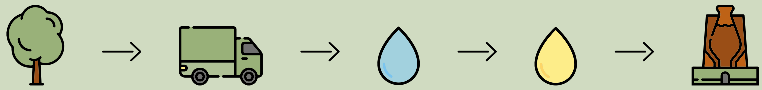
SCAN TO DOWNLOAD

4

ENGAGEMENT WITH CASE-STUDY-RELEVANT STAKEHOLDERS

ENGAGEMENT WITH CASE-STUDY-RELEVANT STAKEHOLDERS

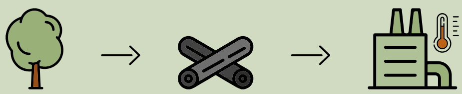
To facilitate IBC market uptake, it is fundamental to engage different groups of stakeholders and to analyze the macro-environment of IBC supply chains. The MUSIC project facilitated dialogue with case-study-relevant stakeholders to identify enablers and hindrances, forming the basis for the development of strategic recommendations with the main aim of establishing a positive environment for IBCs. As the macro-environment differs across case study regions, tailor-made recommendations were proposed for each case study region. In addition, strategies and recommendations are proposed that may apply to many EU countries.



ITALY

A concept for collection, storage, and transport of very heterogeneous agricultural biomass residues as feedstocks is not yet put into practice in the Veneto region. One problem especially in the south part of Italy are the many small and scattered farms, like olive plantations. **Support by agricultural associations could be very helpful for the initiation of innovative hubs and biomass trade centres.**

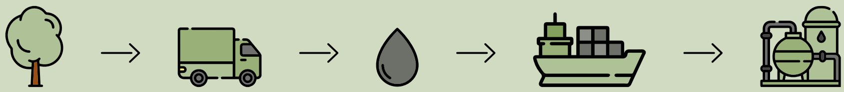
At the moment, technological challenges are persistent in the conversion process to Microbial Oil and further research activities are needed to increase the TRL level and process efficiency. **Therefore, market uptake of Microbial Oil for upgrading to HVO biofuel may require more time** and is not foreseen for the near future. Alternatively, there could be other higher value applications for the IBC as an intermediate carbon carrier in material-based applications.



GREECE

Stakeholders were interested in the approach but currently no industrial scale torrefaction plant is located in the region. Similar to the Italian case study, the large number of small and scattered farms makes it difficult to implement a concept for collection and storage of residual biomasses which are available in abundance. **Associations and contracts between groups of farmers and industry could be a solution.**

Another hindrance is the almost sole focus of the government on support of wind and solar as renewable energy sources. Biomass applications for energetic use are not prioritised in the Greek government policy. **A first real pilot project in synergy with other renewable project should be implemented to convince investors of the usefulness of the concept in specific economic and regional contexts.**

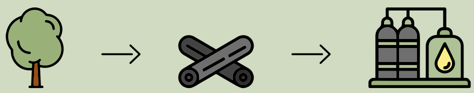


SWEDEN & FINLAND

FPBO made from residues of sustainably managed forests represents a promising regionally available resource for advanced biofuels. Therefore, **associations and joint ventures between international stakeholders and industry should further promote forest residues use for advanced biofuel production and promote communication between different industrial sectors.**

Currently, there is a decreasing trend in public appreciation of using woody feedstocks for biofuels, especially in The Netherlands. Social acceptance issues can be avoided by **accelerating information campaigns, by following guidelines to use certified feedstocks from sustainable managed forests, and by applying life cycle assessment.**

Technology development should be aligned to use **synergies** (e.g., plant construction near green hydrogen production sites and other industrial installations, such as pulp mills and/or refineries) **and best-for-value applications must be investigated** (e.g., lower quality FPBO could serve as fuel for CHP plants in Sweden).



EUROPE

Currently, there are vast amounts of unused waste feedstocks on the market, such as waste wood type B and C. However, their use is limited as specific applications in steelmaking require high quality torrefied biomass, which requires high quality feedstocks. **Quality issues with SRF and RDF exist as there is insufficient waste separation at waste treatment sites, resulting in heterogeneous waste mixtures. Quality issues may be addressed by torrefaction technology development and by improving the waste separation process**, which as a result increases the proportion of torrefied biomass for replacement of coal coke in blast furnaces.

The availability of large amounts of biomass and hybrid waste feedstocks may be limited in proximity of large steel mills. There is a high discrepancy between theoretical, technical and mobilizable potential of all considered feedstock types. In addition, also other industries are increasingly demanding waste feedstocks for their processes in the course of implementation of circular economy concepts, thereby increasing competition, and hence, feedstock costs. **There is a need for an exact definition of biomass potentials and determination of mobilizable technical biomass potential.**

Related to that, the frequently changing regulatory framework in Europe (e.g., REDII, Waste Framework Directive) hampers long-term off-take agreements between the steel industry and feedstock providers. **Such agreements can be pushed by the Fit-for-55 package, while uniform legislation on waste wood categorisation should facilitate re-integration of large volumes of waste feedstock in the circular economy.**

As the potential of torrefied biomass to replace all fossil carbon in steel production is limited, **further innovative concepts for torrefied biomass in steelmaking such as use as carbon source in steel material or use of syngas in DRI-EAF processes should be explored in the future.**

The uncertain and constantly changing policy framework at the EU level, combined with the lack of implementation at the national level, is hindering the development and innovation of IBCs. As a result, there is a lack of investment and contractual security for the industry.

The challenge is to consider regionally varying economic, societal and environmental conditions across the EU when implementing IBC value chains. **National targets for related IBCs and advanced biofuels** have to be adapted and adjusted accordingly. **Cross-sectoral concepts for IBCs market uptake must be developed**, especially in synergy with other renewable energy sources and also by the integration of the cascading principle for specific types of biomass and waste in a circular bio-economy. **The cascading use should not be mandatory but may be applied if there is a demand under specific circumstances in regional markets.**

Associations of feedstock providers and industry must be created to support IBCs business cooperation and create biomass trade centres and regional innovation hubs. Further research and innovation activities as well as standardisation/certification activities can be supported and financed by members of the formed associations coming from all stakeholder groups. Finally, the associations can also push politics to create financial and regulatory incentives for stakeholders in the IBC value chain.

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INDUSTRY PLATFORM

To foster market uptake of IBC 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 MUSIC project. Four EU wide outreach activities have been organized as part of the MUSIC Industry Platform 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 recommendation papers and policy recommendation papers.

BUSINESS MISSIONS

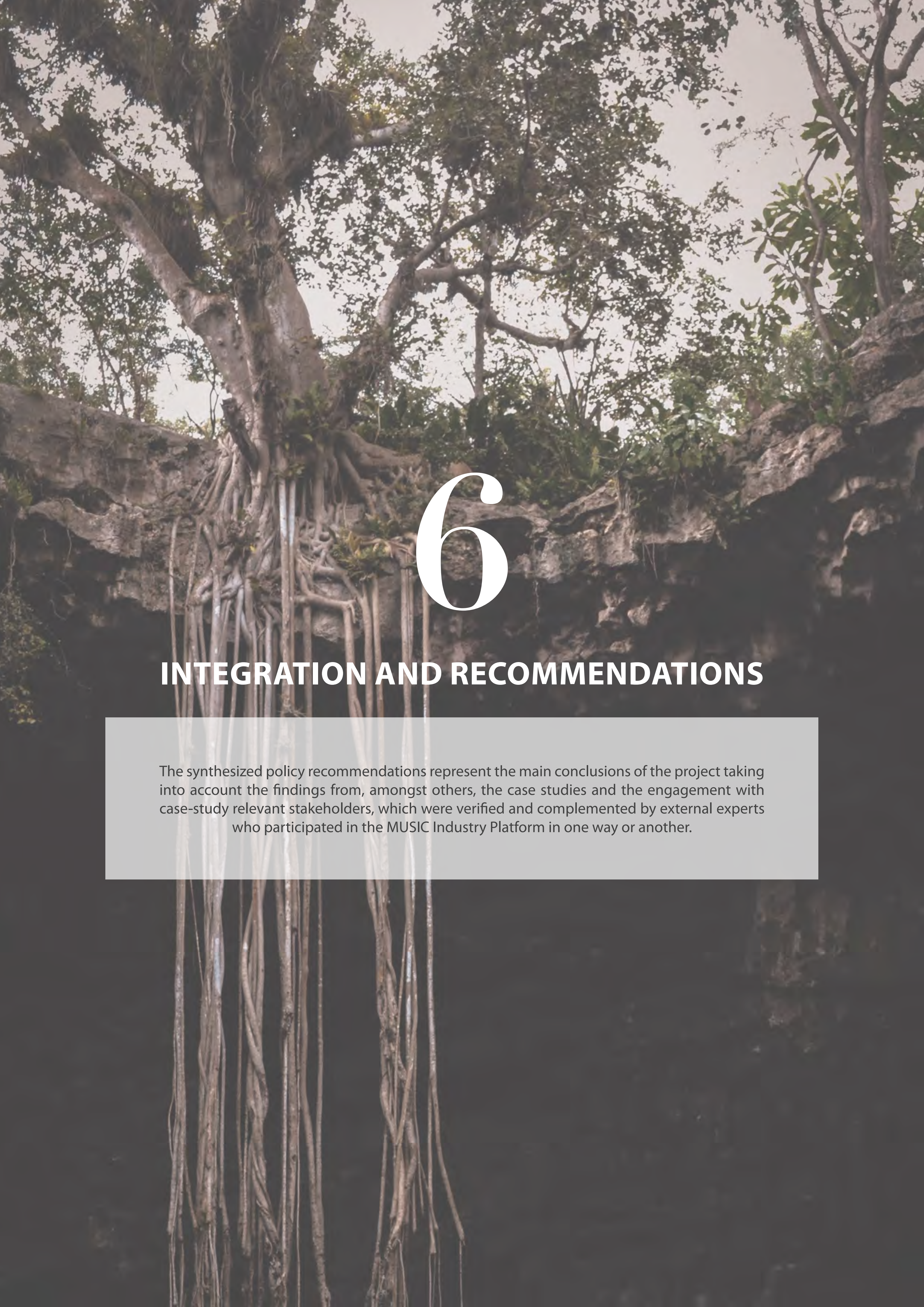
MUSIC organized two business missions, one focusing on FPBO and another focusing on torrefied biomass for the metallurgical industry. The former took place on 14 – 15 September 2022 in the framework of the Advanced Biofuels Conference in Stockholm. Participation in the conference allowed the project beneficiaries to present their technology to a wider audience, while also allowing them to develop a better understanding of market and policy framework conditions, especially in Nordic countries. The second mission featured a visit to the ArcelorMittal Ghent steel mill on the 16th of February 2023, having a special focus on the Torero and Steelanol innovative pilots. This business mission enabled the participants to develop a high understanding of the prospects and challenges of using torrefied biomass in the metallurgical industry. Combined, the business missions reached approximately 220 individuals.

INDUSTRIAL WORKING GROUPS (IWG)

MUSIC established a series of Industrial Working Groups (IWGs), the aim of which was to involve relevant industrial stakeholders in the project activities and to obtain their views and opinions regarding the market uptake prospects of IBCs. Six IWG meetings took place within the project duration, each focusing on either a specific type of IBC and/or a specific sector of application. Through the IWGs, the MUSIC project managed to reach to a professional community of more than 300 individuals, while also inviting more than 10 organizations (technology providers, end-users, trade associations, research institutes, policy makers and others) to share relevant presentations and actions in the field of IBCs.

FINAL INTERNATIONAL DISSEMINATION WORKSHOP

The final dissemination workshop took place on 23 November 2022 in cooperation with the European Bioenergy Future (EBF) conference. The workshop included presentations about the use of torrefied biomass in the steel industry, market updates on FPBO, and prospects of using biomass in hard to abate sectors. A panel discussion explored additional experiences and provided insights on technical, regulatory and market aspects of IBC market uptake.



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INTEGRATION AND RECOMMENDATIONS

The synthesized policy recommendations represent the main conclusions of the project taking into account the findings from, amongst others, the case studies and the engagement with case-study relevant stakeholders, which were verified and complemented by external experts who participated in the MUSIC Industry Platform in one way or another.

THE ROOTS FOR IBC MARKET UPTAKE

ADOPT A CONSTANT POLICY FRAMEWORK FOR BIOMASS SUSTAINABILITY CRITERIA

The recast Renewable Energy Directive (the so-called "REDII") was the first EU-wide legislation for establishing mandatory sustainability criteria for solid biomass used for bioenergy. This framework enabled the bioenergy sector to have a specific reference point for sustainability requirements in biomass sourcing and logistics. However, as of the time of writing, REDII has not been implemented in all countries, and hence, not yet fully evaluated. Still, negotiations on the upcoming REDIII are in full swing and hint at the adoption of much stricter impositions. The unstable policy framework can be a deterrent to investments in IBCs.

ADOPT A "SOFT" CASCADING PRINCIPLE

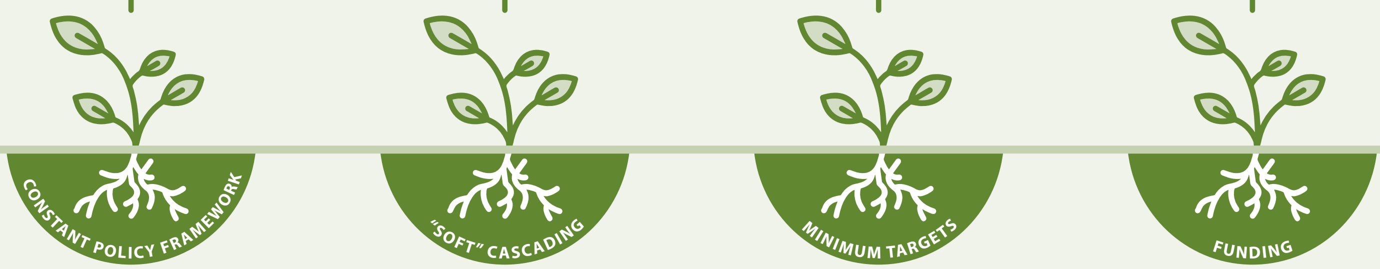
Historically, the development of IBCs started with applications in the energy markets which are typically at the low priority end for the cascading principle. However, mandatory, and strict cascading criteria would most likely fail in biomass markets, as was the case in a few previous attempts. IBC producers should still have the flexibility to explore opportunities in both the established energy markets, as well as into new applications, such as materials. IBCs also provide interesting opportunities for integrating biomass streams into biorefining concepts.

ESTABLISH MINIMUM TARGETS FOR IBCS RATHER THAN QUOTAS

Up to now, IBCs have not received dedicated recognition from policy makers regarding their potential to decarbonize the sector. For other energy carriers, such as biomethane and green hydrogen, the EU has adopted specific targets for 2030 and beyond, providing confidence for investors embarking on new projects. Adopting similar targets for IBCs in relevant sectors, for instance, 1 million tons of biocoal for substitution of coal in metallurgical application by 2030, would provide a strong policy message.

PROMOTE AND PROVIDE FUNDING FOR INNOVATIVE APPLICATIONS

Although torrefied biomass and FPBO have reached Technology Readiness Level (TRL) 9, the number of commercial applications is still very small compared to other established biomass conversion technologies. In addition, novel applications of IBCs in other sectors may still emerge, while further demonstration is needed to take advantage of the possibilities of IBCs in sectors already investigated by MUSIC deployment (e.g., steel, maritime transport). Access to funding for innovation (e.g., first-of-a-kind projects, demonstration projects), such as the Innovation Fund and Horizon Europe, can help unlock the potential.



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