BioMates

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Report on Risks of Social Acceptance of BioMates

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1. Preface

1.1. Introducing BioMates

The BioMates project combines novel technologies for the cost-effective conversion of residues and second-generation biomass (wheat and barley straw, Miscanthus and forestry residues) into high-quality bio-based intermediates (BioMates) that can be co-processed with petroleum streams to produce a hybrid fuel ready for use as transportation fuel (Figure 1). BioMates thus comprise renewable and reliable co-feedstocks. BioMates main conversion processes are AFP and single-stage mild catalytic hydro-processing (mild-HDT). Whist AFP is expected to take place next to feedstock production, the mild-HDT would take place within or next to the refinery to make efficient use of excess energy and energy carriers (such as hydrogen). The BioMates concept will help minimize demand for fossil energy, as well as capital and operational costs, since it will partially rely on underlying refinery conversion capacity, to increase the bio-content in final transportation fuels. Broadly, then, the BioMates concept will contribute to the wider agenda for making transportation systems sustainable through use of fuels with biogenic content that help reduce GHG emissions (Holder and Gilpin, 2013; Tsita and Pilavach, 2013). BioMates will also help to achieve the aims of increasing energy security and promoting economic development in rural areas through enhanced economic activity and job expansion (Gracia et al., 2020; Panoutsou et al., 2021).

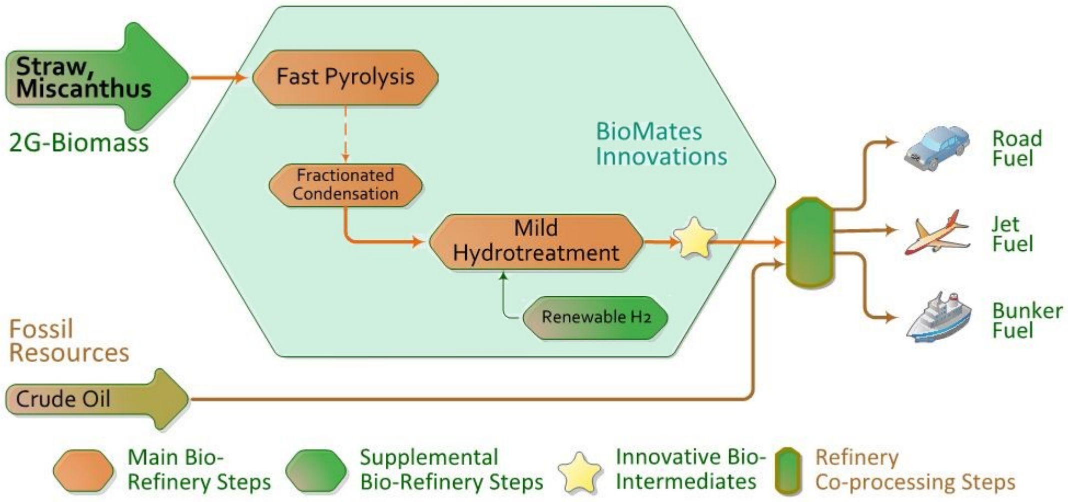


Figure 1: The BioMates concept - Process Flow

1.2. European Commission support

The current framework strategy for a Resilient Energy European Union demands energy security and solidarity, a decarbonized economy and a fully-integrated and competitive pan-European energy market, intending to meet the ambitious 2020 and 2030 energy and climate targets (EC-2014a, EC-2014b). Towards this goal, the European Commission is supporting the BioMates project for validating the proposed innovative technological pathway, in line with the objectives of the LCE-08-2016-2017 call (EC-2015). This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727463.

1.3. The BioMates team

The BioMates team comprises nine partners from industry, academia and research centres:

- Centre for Research & Technology Hellas / CERTH - Chemical Process & Energy Resources Institute / CPERI, Greece - *http://www.cperi.certh.gr/*
- Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, Germany (Project Coordination) - *www.umsicht.fraunhofer.de*
- University of Chemistry and Technology Prague UCTP, Czech Republic - *http://www.vscht.cz*
- Imperial College London ICL, United Kingdom - *www.imperial.ac.uk*
- Institut für Energie und Umweltforschung Heidelberg gGmbH / ifeu, Germany - *www.ifeu.de*
- HyET Hydrogen B.V. / HyET, Netherlands - www.hyet.nl
- RANIDO, s.r.o., Czech Republic - *http://www.ranido.cz/*
- BP Europa SE, Germany - www.bp.com/en/bp-europa-se.html
- RISE Research Institutes of Sweden - www.ri.se

For additional information and contact details, please visit *www.biomates.eu*.

2. Risks of Social Acceptance of BioMates and Mitigation

2.1. Social Acceptance

The social acceptance of novel technologies, applications, and products has been increasingly acknowledged as essential for their successful development and take up, including those for the renewable energy sector (Wüstenhagen et al., 2007; Upham, Oltra, and Boso, 2015; Hyacynth, 2018). Social acceptance refers to 'a favourable or positive response (including attitude, intention, behaviour and – where appropriate – use) relating to a proposed or in situ technology or socio-technical system, by members of a given social unit (country or region, community or town and household, organization)' (Upham, Oltra, and Boso, 2015:103), whilst more broadly it entails societal embedding and adoption (Hyacynth, 2018). A growing body of research testifies to the increased attention being paid to the social acceptance of biofuels, looking at the social, economic, and political factors that condition social acceptance, and how social acceptance, in turn, impacts on the development of biofuels projects, infrastructure, chains, and policies (Delshad et al., 2010; Savvanidou et al., 2010; Zhang et al., 2011; Cacciatore, et al., 2012; Fung et al., 2014; Dragojlovic and Einsiedel, 2015; Moula, Nya´ri and Bartel, 2017; Gaede and Rowlands, 2018; Kim, Lee, and Jaemyung, 2019; Leibensperger et al., 2021; Bach et al., 2021; Løkke, Aramendia and Malskær, 2021).

Social acceptance plays a very important role in advancing or constraining the development and implementation of novel biofuel technologies and attendant policies, and that social acceptance is, in turn, influenced by a range of factors. The focus here is on perceptions of risks to the BioMates concept as identified by stakeholders and the public, which can then be taken as a proxy of risks to social acceptance of specific aspects of the concept (Fung et al., 2014; Løkke, Aramendia and Malskær, 2021). Yet, perceptions of risk are themselves informed by awareness, knowledge, attitudes, beliefs, and perspectives on biofuels and hybrid fuels, and so these too need to be ascertained, acknowledged and incorporated into discussions of proposed projects for biofuels and hybrid fuels development. These are the issues addressed this report. The next section introduces the methodology employed to identify risks to the social acceptance of BioMates.

2.2. Methodology

The methodology used for identifying risks to the social acceptance of BioMates comprised three elements. Firstly, a literature review was carried out to identify the key issues related to social acceptance of feedstocks, processes and end-products associated with the production of biofuels and hybrid fuels. These issues were then used to orient discussions about risks to the BioMates concept by stakeholders, who participated at an online workshop convened in April 2021 to help gauge social acceptance of BioMates (reported fully in D39). A total of 18 stakeholders participated, alongside eight project partners, including those who joined the session to provide extra support to the partners who introduced the project to the audience and those who facilitated the interactive sessions. The stakeholders were mostly based in Europe, representing diverse sectors of interest or activity, although academics and researchers predominated (Figure 2).

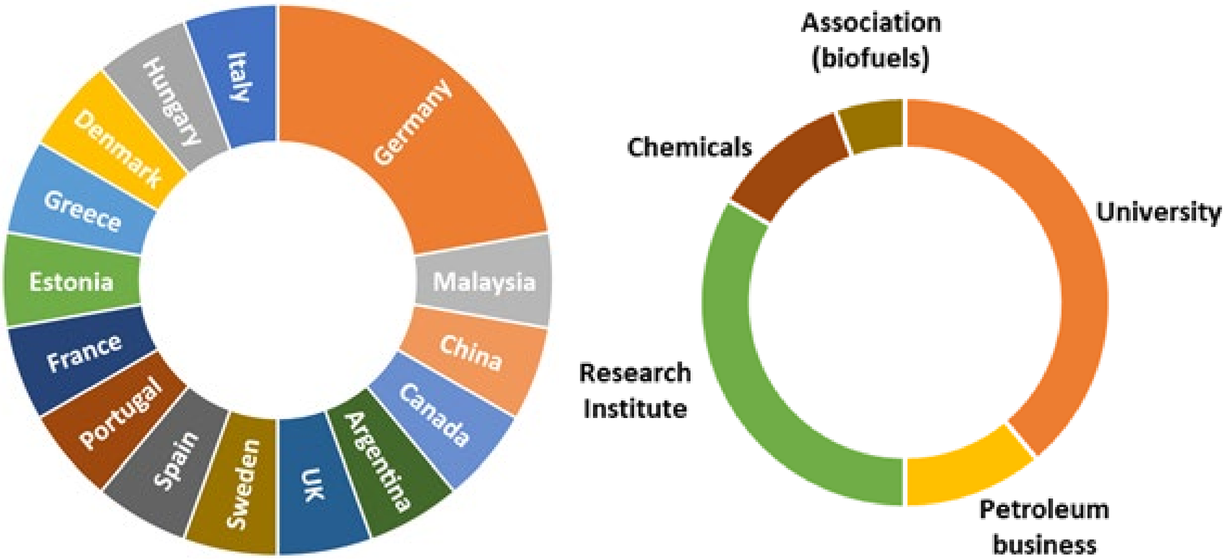


Figure 2: Workshop Participants' Base Country and Sector (Source: BioMates, D39).

These issues identified in the literature review were elaborated further and incorporated into an online questionnaire survey that ran between April and May 2021. A total of 104 people participated in the survey, giving their views, perspectives and expectations on a range of issues relating to biofuels and hybrid fuels, providing another means to gauge the social acceptance of BioMates. Stakeholders made up 91% of the sample, whilst the remainder 8% comprised respondents self-identified as a member of the public. Also, respondents based in the EU made up 65% of the total sample, as shown in Figure 3. Key respondents' characteristics are show in Figure 4.

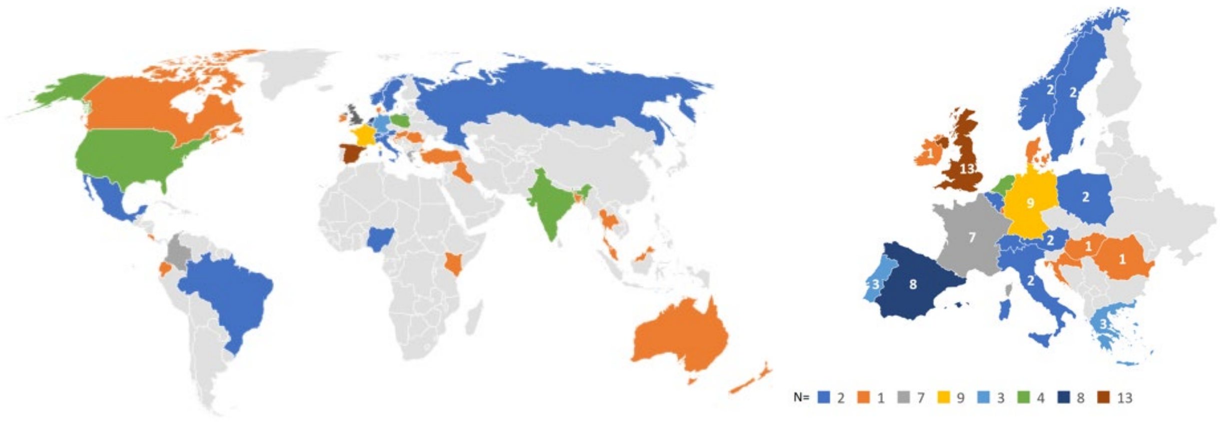
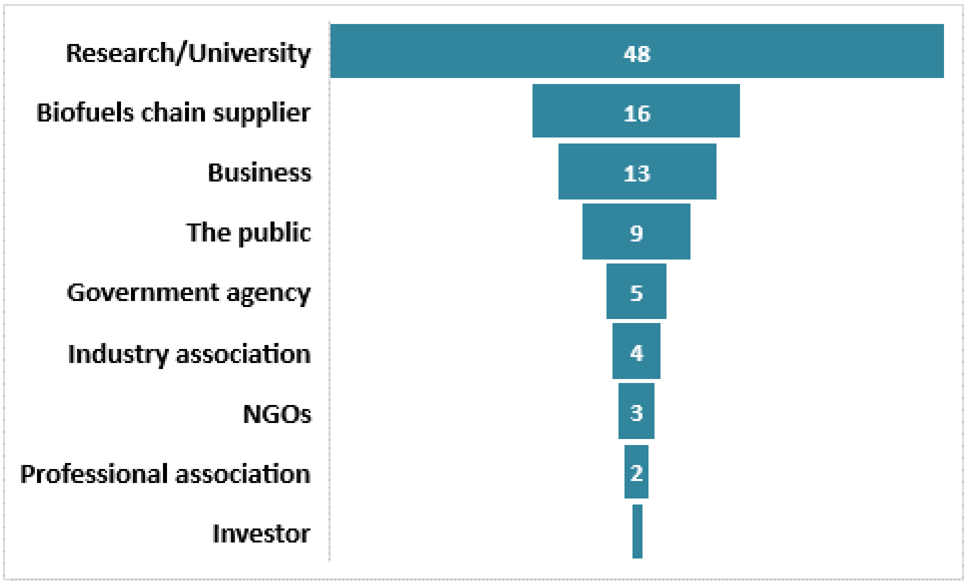
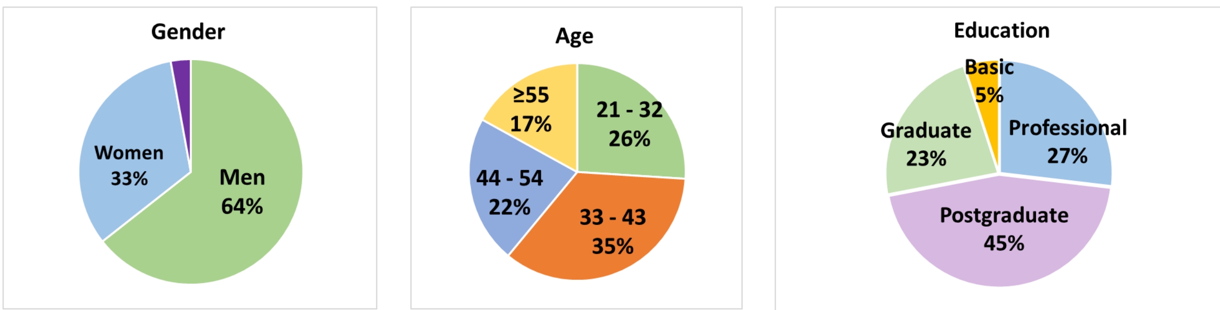


Figure 3: Survey respondents' base country and EU countries





The survey asked respondents to state their level of familiarity with biofuels/hybrid fuels. Figure 5 shows the level of familiarity across the sample, whilst Figure 6 shows level of familiarity according to type of respondent.

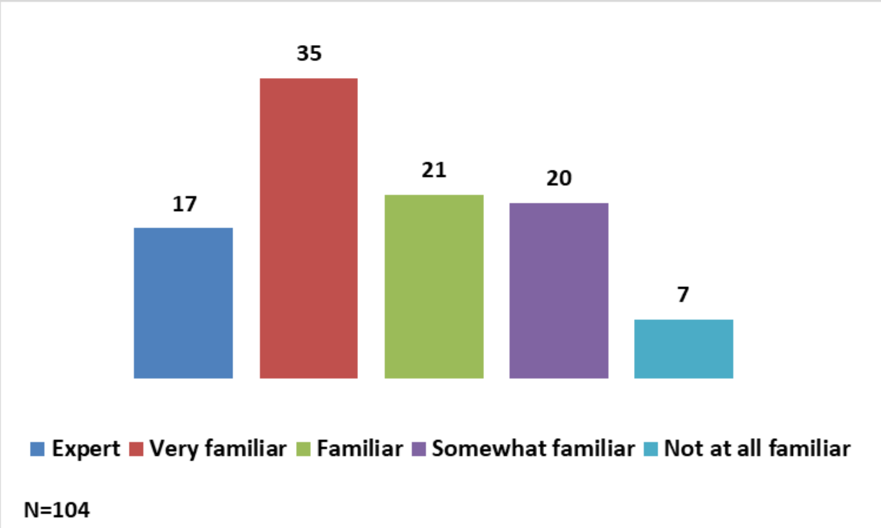


Figure 5: Survey respondents' level of familiarity with biofuels/hybrid fuels

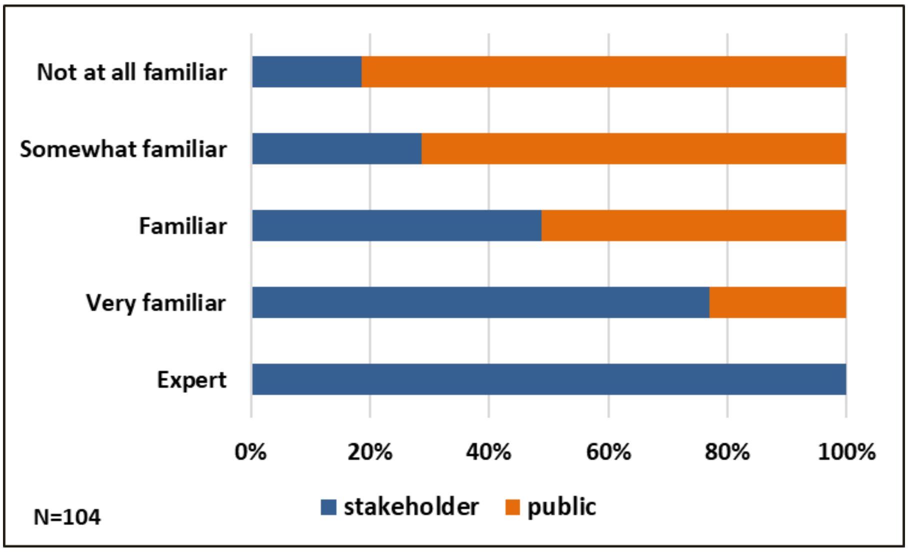


Figure 6: Survey respondents' level of knowledge about biofuels/hybrid fuels

The results obtained from the workshop and the survey specific issues specific to feedstocks, technological processes and products are introduced and discussed in turn in the next sections.

2.3. Risks to Social Acceptance of Feedstocks

The BioMates project envisages the use of two main advanced, lignocellulosic biomass feedstocks, namely straw (from wheat and barley), and the perennial grass Miscanthus, although forestry residues may also be considered. Stakeholders identified various risks relating to the biomass feedstocks, proposing mitigating measures for some of them, whilst others are proposed to fill the gaps, although not all measures fall within the scope of the BioMates concept implementer. They are summarised in Table 1.

Table 1 Risks and Mitigation: BioMates feedstocks

Biomass Feedstocks Risks	**Mitigating measures (by stakeholders; *or in the literature*)**
Availability (volume, seasonality, competition)	• Provide incentives to farmers • Use multi-annual contracts
Price (stability)	• Provide incentives to farmers • Use multi-annual contracts • Keep all processes costs as low as possible • Legislation to regulate prices
Suitability of Miscanthus (dedicated crop that may cause ILUC and high water consumption)	• Consider alternative feedstock
Composition (size; density; yield)	• Carry out analysis of ash content/melting point
Logistics (collection points; preservation; storage; transportation)	• Set up appropriate collection and storage system • System specified in contractual arrangement
Origin (provenance)	• *Source feedstocks in a sustainable manner*
Social acceptance	• *Assured by use of advanced biomass (non-food/non-feed)*
CO_2 emissions cost	• *Offset by curbing emissions from conversion processes*
Crude Oil Risks	**Mitigating measures (by Stakeholders)**
Price (levels; fluctuation; volatility)	• Uncertain whether realistic measures are feasible
Quality (miscibility, for co-processing)	• Ensure appropriate quality to produce hybrid fuel

As seen in Table 1, most risks identified by stakeholders are for the biomass feedstocks. Biomass availability was identified as a risk, linked to volume, seasonality (i.e., whether available year-round), and competition with other uses (e.g., straw left on the ground post-harvest as soil cover for replenishment) and processes (e.g., other biorefinery uses). Indeed, biomass availability was identified by 39% of survey respondents as one of the key factors hindering the market expansion of biofuels. Agricultural residues in particular are set to play an important role in biomass provision to biorefineries, and even though availability from current farming practices may be regionally and seasonally limited, the supply chain for cereal straw is well established (Star-COLIBRI, 2011). Nevertheless, a recent forecast of feedstock potential availability based on rates of growth of cultivated areas in the EU up until 2030 suggests that wheat and barley straw (the preferred BioMates feedstocks) will increase only marginally (Wietschel, Thorenz, and Tuma, 2019), so availability may remain a concern. Moreover, feedstock availability is a key determinant of the viability of a biorefinery, with feedstocks typically accounting for 40-60% of the operating costs, and so, biorefineries are only likely to attract investment when sustainable provision of affordable feedstock can be assured (Caputo, 2005; Star-COLIBRI, 2011; Hennig, Brosowski, and Majer, 2016). A mitigating measure proposed by stakeholders was the provision of state incentives to farmers, which is supported by the survey findings, as most survey respondents (76%) thought that state should provide incentives to crop growers. But whilst just under one half (46%) thought that the state should actually subsidise the cultivation of biofuel crops, two fifths (41%) thought it should not. But as a survey respondent noted, 'EU countries do not have the same obligation on the EU-level of providing subsidies to the farmers, for growing non-food crops for biofuels', which is thus seen to require making government incentives mandatory. A further measure proposed by the stakeholders to address the risk of biomass feedstock availability was engaging farmers through long-term contracts, although a variety of types of contract should also be considered that meets the needs of both crop growers and biofuel producers (see Leibensperger et al., 2021).

On the risk of competition for biomass feedstock, BioMates may face some competition with established uses for straw. Currently these include animal bedding and fodder, heat and power, horticulture, mushroom production, frost protection and natural fertilizer. BioMates may also use forestry residues for conversion into the bio-oil. Forestry residues are mostly left on site following forest management operations but can be collected for many uses (e.g., heat and power, wood pulp, panel board production, mulch, animal bedding, and landscaping), with large potential for extracting them without generating negative impacts (e.g., wood chips, saw dust and shavings, paper crumb; GOVUK, 2016). Hence, whilst straw and wood that are diverted from animal bedding may entail depending on replenishment from other sustainable sources, diversion of animal feed may entail greater need for roughage or carbohydrate crops, with potential ILUC risk (Arup-Urs, 2014). Dedicated feedstocks for biofuels currently face little competing uses, such as Miscanthus, which is used only in small volumes for animal bedding, and biomaterials, but if it is to be grown as a dedicated biofuel crop on arable land without mitigating measures it will likely cause ILUC (Arup-Urs, 2014; GOVUK, 2016).

Price of biomass feedstocks was seen by stakeholders as a risk due to likely fluctuations that will impact along the chain. Again, state provision of incentives (including subsidies) and locking farmers and buyers into long-term (multi-annual) contracts were proposed to ensure continuous supply. A further measure proposed was to keep costs in all other areas (i.e., processes) as low as possible. But regulation was also called for to help keep biomass prices stable.

The suitability of Miscanthus was questioned due to being a dedicated bioenergy crop that may potentially cause ILUC, and because this crop requires large volumes of water for growing and processing, which, in turn links to the risk of water availability. It was suggested that it be replaced by an alternative feedstock. Production volumes for Miscanthus grown commercially in the EU remain limited (around 20,000 ha, in Lewandowski et al., 2016), which may signal low competition for BioMates. Miscanthus is also seen as being best suited for cultivation on marginal land (i.e., land less suitable for conventional crop production). But there is debate about what constitutes marginal land (Raman et al., 2015; Elbersen et al., 2019), since at least two meanings can be identified, one that refers to land that is unsuited for food production, whilst the other refers to land whose economic value is marginal (Shortall, 2013). But lack of knowledge, technical equipment and integration into a structured biomass market may discourage farmers from cultivating this perennial bioenergy crop (Ben Fradj et al., 2020).

More generally, the composition of the proposed biomass feedstocks raised risks relating to size (i.e., volumes required for conversion), consistency and density (i.e., whether reliable for processing) and yield (i.e., volumes obtained), which technical procedures can help address (e.g., analysis of ash content and melting points).

Concerns were also raised about potential geographical dispersal of collection points away from refineries or refinery processes, which raise issues about transportation costs, and about storage conditions and measures to ensure preservation given that straw decays rapidly. These could be mitigated by design and implementation of appropriate collection and storage systems along with their specification in contractual agreements.

A further risk noted was the origin of the biomass, linked to concerns about whether it will entail importation (i.e., cross-boundary movement) and associated costs (e.g., financial, environmental, social) and whether it might displace other activities and the implications of that (i.e., ILUC). The type and origin of biomass, in turn, are linked to a social acceptance risk, although the fact that they are second generation (i.e., not edible crops nor animal feed) already addresses that. Indeed, the survey results show that over one half of respondents (56%) thought only non-food crops should be used to produce biofuels, but a large majority (86%) thought that it was also important to increase the range of crops. In terms of biomass sourcing, about one third (34%) thought that such crops should be grown within their own country, but another third (34%) disagreed, and the remainder (33%) had no opinion on this.

Biomass feedstocks were also seen to be at risk of imposing a CO_2 emission 'cost' which could mitigated by curbing emissions from processes.

Regarding the fossil feedstock, the quality of the crude oil used for co-processing was identified as a risk since it will determine the refinery entry point for co-processing. This will require ensuring appropriate quality to mitigate against miscibility issues that may jeopardise the quality of the final hybrid product. Risks to crude oil prices were also identified (e.g., levels; fluctuation; volatility) but this issue is clearly outside the remit of BioMates concept implementers as such, being determined largely by macro-factors (e.g., market forces and state policy).

2.4. Risks to Social Acceptance of Process Technologies

The main processes employed by BioMates are the AFP and single-stage mild catalytic hydro-processing (mild-HDT), which are complemented by fractional condensation, electrochemical hydrogen compression with state-of-the-art renewable hydrogen production, fine tuning of BioMates properties and optimal energy integration. The risks identified with them as identified by stakeholders are shown in Table 2, along with mitigating measures.

Table 2: Risks and Mitigation - BioMates processes

Process risks	**Mitigating measures (by stakeholders; *or in the literature*)**
Biomass type/composition	• Biomass pre-treatment
Process contaminants (sulphur/ash content)	• Analysis of contaminants
Efficiency • feeding system • catalyst • hydrogen electrolyser • equipment • conversion route	• Ensure maximum efficiency of • equipment • processes
Cost of new technologies	• *Keep all processes costs as low as possible*
Renewable hydrogen • high cost • may compete with electricity	• Reduce costs of renewable hydrogen by using 'blue' or 'green' hydrogen) • *BioMates envisages the use of a PPPV power plant to produce its own hydrogen through water electrolysis, electro-chemical compression and purification*
Biomass cannot be wholly converted into bio-oil	• *Biochar fraction can be commercialised as fertiliser*
Co-processing entry points affected by bio-oil composition	• *Diverse entry points into refinery streams are being examined for the BioMates intermediate bio-oil*
Technological issues • TLR • Type of refinery • Process complexity	• Demonstration
CO_2 emissions from processes	• *Curb emissions from processes as much as possible*

As stakeholders noted, the characteristics of the biomass feedstock are seen to pose risks to techno-processes as contaminants (i.e., sulphur and ash content) which in turn bear on the composition of the bio-oil obtained. But this can be addressed by treatment of the biomass prior to conversion and analysis of contaminants.

Risks were also identified to the efficiency of equipment and processes (i.e., catalyst, feeding system, conversion route, co-processing entry point, hydrogen electrolyser). The way to address these is by seeking maximum efficiency in their use, which is in inherent to the BioMates concept.

The cost of novel technologies was noted as a risk, which is to be addressed by improving processes and technology, reduce capital and operational costs and keep prices in check. The high cost of renewable hydrogen was also seen as a risk, along with the potential competition for electricity which. According to stakeholders, this can be addressed by using ‘green’ hydrogen (i.e., from electrolysis powered by renewable electricity), or even ‘blue’ hydrogen (i.e., from fossil sources). However, BioMates proposes to produce its own ‘green hydrogen’ (i.e., zero-emission) from an own-design solar power system for use in the mild-HDT stage. Hydrogen is needed for upgrading high-oxygen content biomass feedstocks into ‘drop-in’ biofuels for co-processing in petroleum refineries. A key challenge remains finding cheap and renewable sources of hydrogen, with global hydrogen demand expected to increase, adding pressure on existing refinery capacity for hydrogen (van Dyk et al., 2019). Hence, by supplying its own renewable hydrogen, BioMates can avoid competition for this input with other sectors.

It was also observed that biomass cannot be wholly converted into bio-oil, which may raise issues about efficiency (i.e., high volumes of biomass needed) and costs. But one of the scenarios envisaged for BioMates proposes the commercialisation of biochar as fertiliser, which can help offset some costs.

Bio-oil composition was also noted as risk since it affects co-processing entry points, but again, this issue is part and parcel of the BioMates concept design.

Further technological risks were identified, relating to the type of refinery, complexity of processes, and maturity (i.e., technological readiness level) which was also seen by some as an opportunity as they offer more options (i.e., different types of biomass, more conversion routes), although some also thought that high complexity means that technical malfunction or failure may impact on more processes. Clearly, though, these issues have already largely been addressed in BioMates concept design itself, whilst risks identified throughout the execution phase have been duly monitored, addressed and reported (i.e., Task 5.1 and the periodical reports on technical risks management). A final risk raised were CO_2 emissions from the chemical transformations of biomass, which will need to be curbed as much as possible.

2.5. Risks to acceptance of Intermediate and Final Products

BioMates refers to the intermediate product obtained from the conversion of the biomass feedstocks, which will then be co-processed with crude oil to obtain the final product, a hybrid fuel that is ready for use as a transportation fuel on road, air and water vehicles. The risks identified by stakeholders associated with bio-oil and final hybrid fuel and proposed mitigating measures are shown in Table 3.

Table 3: Risks and Mitigation - BioMates products

Product risks	Mitigating measures (by stakeholders; *or in the literature*)
Bio-oil is difficult to convert	• Technological solutions
Pyrolysis does not produce pure biofuel	
Whether co-processing works	
Miscibility of fuels	
Expected fuel may not be obtained	• Change proportion of biofuel in the mix
Desired fractions may not be obtained	
Uncertainty as to how hybrid fuel will be used	• Apply standards
Safety concerns (jet fuel/querosene)	
Whether the hybrid fuel is adequate to aviation	• Strong collaboration with industry to demonstrate bio-oil uses in the transportation sector
Co-processing not envisaged in regulations	• Appropriate and stable regulation regime

As can be seen, some of the risks identified relate to the actual characteristics of the bio-oil (i.e., difficult to convert further, may have impurities not eliminated by AFP), which, in turn, link to other risks. These relate the characteristics of the hybrid fuel, to miscibility and the proportion of fuels obtained in the final product, and, ultimately, to the effectiveness of co-processing of these two types of fuel (i.e., whether it works). Changing the proportion of biofuels in the mix and generally adapting technological processes are proposed as mitigating measures. Clearly, again, some of these issues are inherent to the BioMates concept design, which will have been anticipated, but others will have emerged, addressed and reported during the process of execution of the project itself.

One risk that was not identified by stakeholders but is highly important is the competition that the BioMates bio-oil and the final hybrid fuel may face from a range of other renewable transportation fuels and other applications. The BioMates bio-oil may compete to some extent, with a gamut of bio-oils that have been used for producing chemicals for several years now, as well as applications as fuels in boilers, engines, and turbines for heat and power generation, or still bio-oils upgraded to high-quality hydrocarbon fuels (Czernik and Bridgwater, 2004). The upgraded hybrid fuel may also face some competition from other transport renewable fuels, namely biodiesel and bioethanol which can be similarly used without engine modification. In addition, a range of advanced biofuels are under development (e.g., lignocellulosic ethanol, fuel from algae, biohydrogen, biomethanol, Fischer-Tropsch diesel, biohydrogen diesel), whilst biomethane may also offer competition (IEA-BIOENERGY, 2019). Indeed, about one fifth (19%) of survey respondents thought that competition from other renewable fuels is a potential barrier to the market expansion of BioMates hybrid fuels. Stakeholders also wondered whether the hybrid fuel is suitable for use in air transportation, indicating that this could be addressed through demonstration to the transportation sector in general, in collaboration with industry, to underscore the value and benefits of co-processing BioMates with fossil fuel for transportation and help ensure the viability of the proposed hybrid fuel. But it is very likely that it will face some competition from biodiesel production for aviation and maritime transportation (Panoutsou et al., 2021).

Still on the topic of competition, the BioMates bio-oil may also compete unfavourably with oil prices, especially in the context of low oil prices that prevailed since the mid-2010’s up until recently in the context of the Covid-19 pandemic, although oil prices have begun to rise again in the last few months.

Indeed, stakeholders noted that competition with crude oil prices, along with the volatility of fossil fuel prices may discourage the market expansion of BioMates, as well as constraining the consumption of the hybrid fuel by end-users, not least because final prices to consumers may be higher than those for fossil fuels, which result from compounding costs along the chain. The competition between biofuels and fossil fuels is a perennial challenge to the development of the biofuels sector has been extensively documented. But as Reboredo, Ramalho and Pessoa (2017) have argued, no effort to reduce biofuels production costs through technological breakthrough can compete with cheap oil, and to address this, they have called for the abolition of fossil fuels subsides, along with scrutiny of subsidies for advanced biofuels to prevent distortions through unfair competition in the energy market. In this respect, it is apposite to note the comment of a survey respondent, who stated that 'all externalities should be reflected in the price of fossil fuels and only then these should be compared to hybrid and biofuels', whilst another noted the need to address 'sustainability aspects of fossil fuels' in discussions of biofuels.

Stakeholders also raised concerns about the safety of the hybrid fuel, particularly as an aviation fuel, as well as concern about potential misuse, and proposed the adoption of standards and certification as a mitigating measure.

A final risk identified by stakeholders relating to BioMates products was the lack of provisions for co-processing in existing EU regulations, which has implications for accounting for contribution of the biogenic content in the hybrid fuel to carbon reducing emission targets, amongst other issues. Such provisions need to be incorporated into appropriate and long-term regulatory regimes to ensure that the hybrid fuel plays its part in the decarbonisation of the transportation sector.

2.6. Further Risks to Social Acceptance of BioMates

Besides the risks to the BioMates concept identified previously for inputs, processes and products, stakeholders and survey respondents also discussed other, issues that may also be treated as risks to the social acceptance of BioMates. One such issue is knowledge of biofuels, which can be pivotal to conditioning social acceptance. Stakeholders at the workshop, for instance, thought society lacks understanding and knowledge of biofuels and hybrid fuels, a perception that the survey data seems to corroborate (Figure 6) and also resonates with the findings of research on social acceptance of biofuels reported earlier, which is generally low or limited (section 3.1). However, the results of the survey show that levels of understanding of biofuel issues vary not only between stakeholders and the public, but also amongst stakeholders. For instance, survey respondents were asked to decide whether some statements were generally true or false. Their responses are shown in Figure 7.

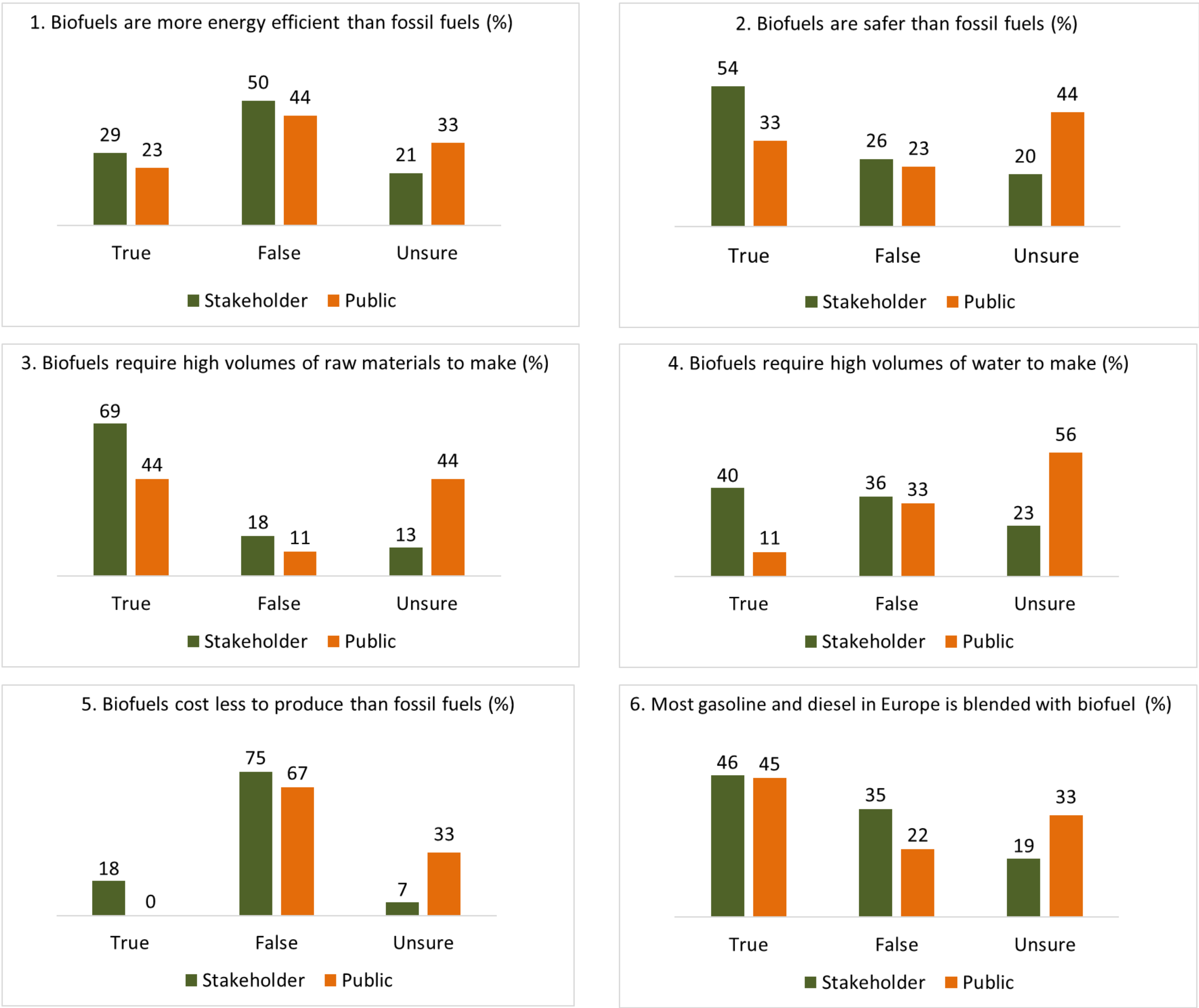


Figure 7: Survey respondents' knowledge of biofuels

As can be seen, regardless of whether the statements hold true (and acknowledging that some may be disputable), the public in the sample are in general more unsure about their veracity than stakeholders. However, there is also divergence of opinion amongst the stakeholders, since some thought the statements true, when the expected answer might be false, and vice-versa. These results are useful in that they help glimpse the potential role of opinion and knowledge in influencing social acceptance.

Survey respondents were also asked to state whether they agreed with further set of statements about positive and negative impacts of biofuels. Their responses are shown in Figure 8.

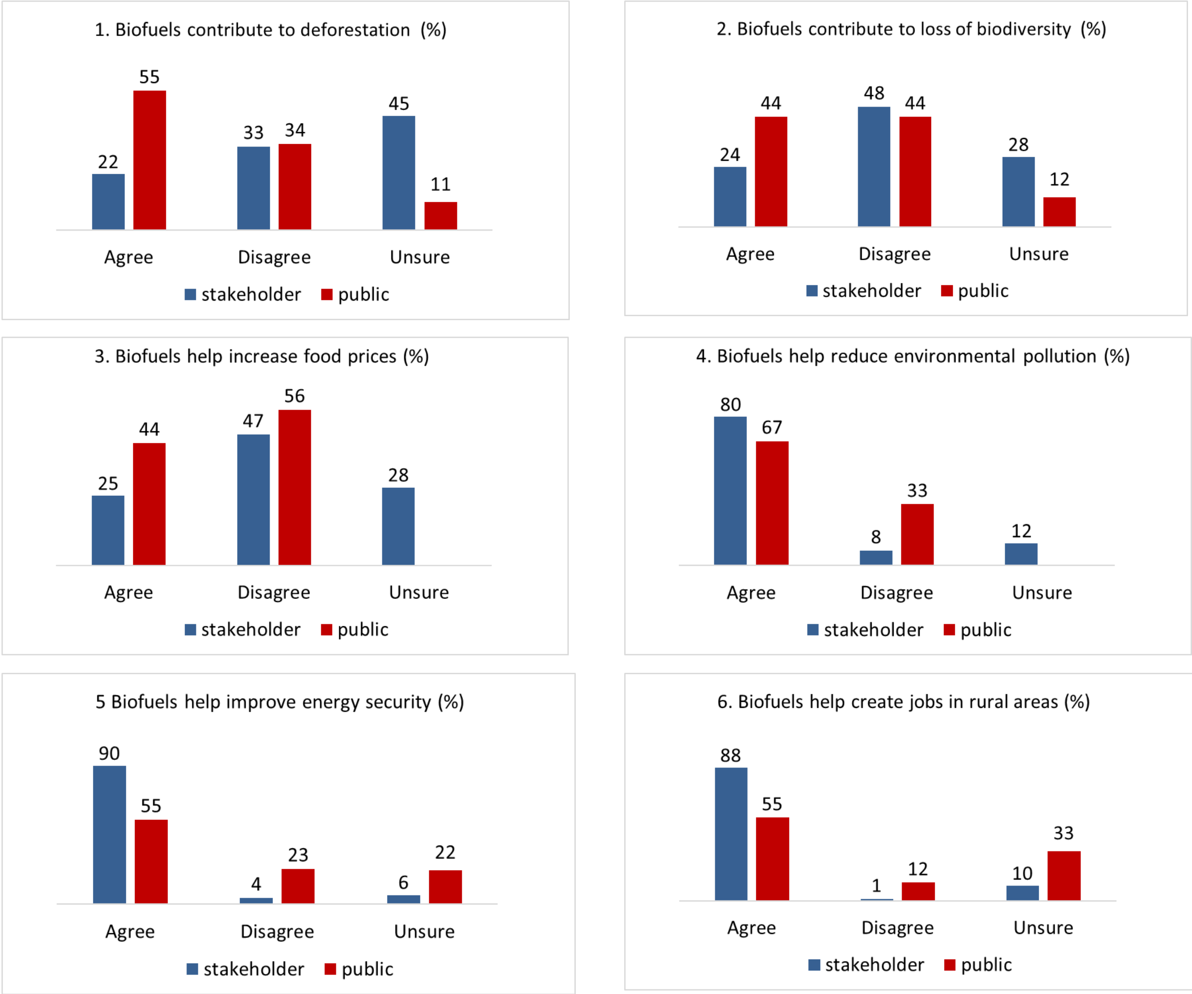


Figure 8: Survey respondents' opinions on Biofuels

As can be seen, stakeholders were more unsure about the negative impacts than members of the public (statements 1-3) suggesting a more guarded approach to the issues, whereas more members of the public agreed with statements about the negative impacts of biofuels than stakeholders (statements 1-3). Conversely, more stakeholders also agreed with statements about the positive effects of biofuels than members of the public (statements 4-6). Thus, again, these results help envisage the links between opinion and social acceptance.

Importantly too, knowledge and opinion about biofuels will themselves influence perceptions about the sustainability of biofuel chains, and these also influence social acceptance. For instance, the statements in Figures 6 are about energy efficiency, product safety, use of natural resources, and cost, whilst those in Figure 7 raise issues about environmental, climate, social and economic impacts, and energy security, all of which relate to sustainability.

A further issue that may be also treated as a risk to the social acceptance of BioMates is that of perceptions about government support to the development of the biofuels supply chain. Figure 9 shows the responses of stakeholders and the public regarding the type and extent of support.

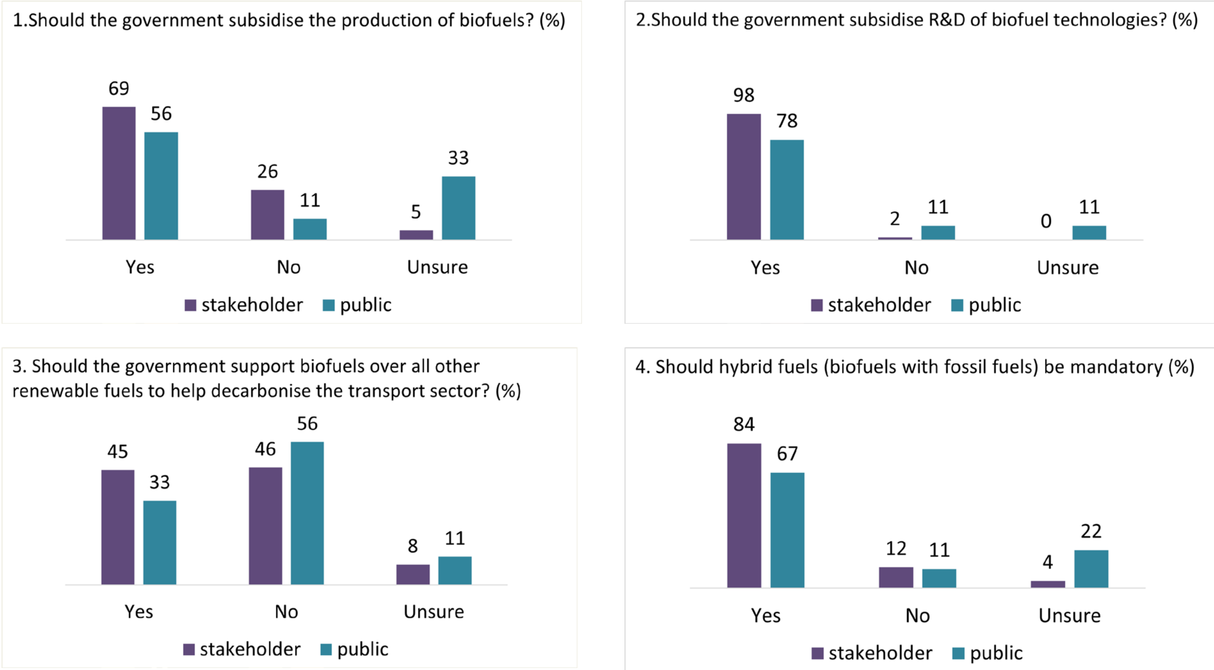


Figure 9: State support to biofuels/hybrid fuels

As the data show, stakeholders and the public largely agreed on the provision of subsidies to biofuels production (Figure. 9.1), but more stakeholders opposed such intervention than the public, whilst the public were more unsure as to whether such support should be provided than stakeholders.

Regarding government subsidy of Research and Development of biofuel technologies (Figure 9.2), the vast majority of stakeholders agreed with such policy, and the majority of the public did too, but one in ten in the public opposed it, and also one in ten were unsure about such intervention.

On the issue of whether the government should support to biofuels over other renewable fuels (Figure 9.3), the public mostly opposed it (56%), but amongst stakeholders virtually the same proportion opposed it (46%) or backed it (45%), whilst only a small and proximate share of the public (11%) and stakeholders (8%) were unsure about it.

As to whether hybrid fuels should be made mandatory (Figure 9.4), both stakeholders and the public in their majority thought they should, a much higher proportion of stakeholders did so (84%) than did the public (67%), whereas over one fifth (22%) of the public were unsure about it, in contrast to only a very small minority of stakeholders (4%). But one in ten of stakeholders (12%) and of the public (11%) opposed such intervention. This is an interesting finding, since fuel sellers, at least in the European Union, have been obligated to supply fossil fuels containing a minimum proportion of biofuels, for well over a decade now in order to contribute to the overall target of renewable fuels in the transport sector, with such targets being increasingly raised in the last few years alone to enable the EU to honour its commitments to the Paris Agreement, and most recently in the 'Fitfor55 Package' (EC/CEU, 2021). But a further examination of the data, focusing on respondents based in the EU, shows differences between stakeholders and the public regarding knowledge about biofuels, and even amongst those who are drivers. Figure 10 shows the results about knowledge of the use of biofuels in the EU. As can be seen in Figure 10.1, the large majority of stakeholders thought that fossil fuels in the EU contain biofuels, whereas the public in their majority could not tell. Both groups thought that the statement is false, although a much higher proportion of the public thought so (12%) than did stakeholders (%%). Amongst those who are drivers in the EU (who form an important subgroup of stakeholders as consumers), the vast majority of stakeholders know that the fuels they use contain biofuels, in contrast to a majority of the public who did not know.

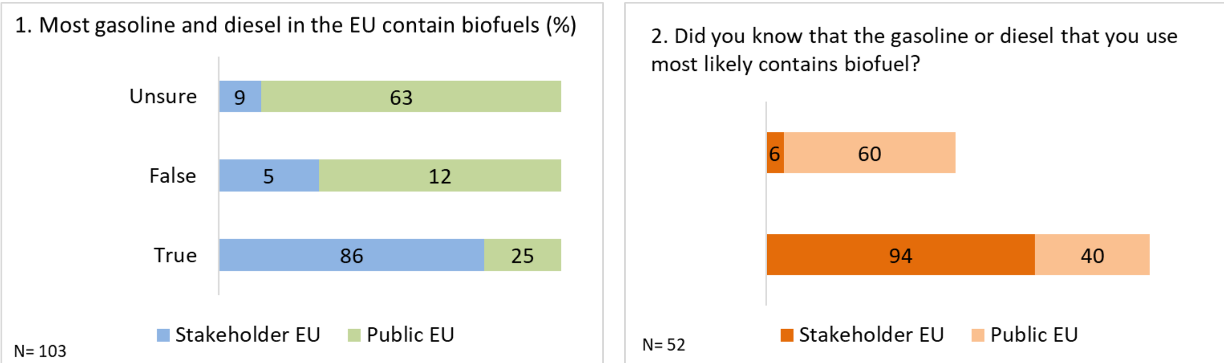


Figure 10: Knowledge about biofuels amongst EU survey participants

In aggregate, then, the results of survey show that stakeholders in general tend to be more knowledgeable about biofuels than the public, and that the public understanding of biofuels and their impacts is limited, as widely reported in the literature (see Løkke, Aramendia and Malskær, 2021 for a full review). Clearly, though, even amongst stakeholders there is disparity regarding knowledge and opinion about the impacts of biofuels, government support to biofuels and the use of biofuels (and these can be further examined according to different groups of stakeholders).

As argued before, knowledge and opinion will play an important role in conditioning social acceptance of biofuels and of hybrid fuels obtained with them. Given that the blending of fossil fuels with biofuels is already mandatory in the EU, it can be argued that social acceptance by consumers, at least, is largely assured (that is, by default). Yet, there might be room for exercising choice at the pumps if more than one brand is offered, and ascertaining Willingness-To-Pay, a further indicator of social acceptance (this topic will be discussed fully in D6.3). However, social acceptance of BioMates will be crucial among all other stakeholders along the chain, from biomass suppliers, investors, biofuel producers through to fuel distributors. This will require mitigating against the risks identified previously for specific stages of the chain, as well as wide-ranging and long-term measures to enhance understanding about biofuels by both stakeholders and the public and their meaningful engagement in biofuel projects, ventures and initiatives. For instance, the siting of any BioMates biorefinery of or biorefinery processes can lead to local impacts that may generate opposition by local people (e.g., increased road traffic; increased noise from the processing plant; increased air pollution; water issues). Addressing their concerns and proposing mitigating actions to minimise or do away with such impacts should increase social acceptance and are also key requirements for social sustainability.

3. Conclusions and Recommendations

This report discussed a range of risks to social acceptance of the BioMates concept. Key issues related to social acceptance were identified through a literature review, including specific issues to social acceptance of the biofuels chain (e.g., inputs, technologies and products). These were subsequently reworked to orient discussions about risks as perceived by stakeholders convened at a workshop, whilst a separate questionnaire survey with conducted with stakeholders and the public provided additional data on a range of topics to gauge their understanding of biofuels. In the approach adopted in the analysis, the risks identified are taken as proxy for risks to social acceptance more widely.

A range of interrelated risks were identified for feedstocks (e.g., availability; price; logistics; sourcing), for conversion technologies (e.g., biomass type and composition; process efficiency and complexity; costs) and for products (e.g., fuel fractions and quality; safety; lack of regulation for co-processing). Besides these, knowledge and opinion of biofuels by stakeholders and the public and their perceptions about government support to the development of the biofuels supply chain were identified as pivotal to social acceptance, thereby configuring potential risks. A variety of measures were also put forward to mitigate the risks identified at each stage of the chain, mostly by stakeholders, whilst others followed from analysis of the survey data. Whilst many measures are incumbent on those who will actually implement the BioMates concept on the ground, others fall outside their direct remit, being contingent on policy frameworks and instruments.

Stakeholders broadly accepted the BioMates concept, acknowledging that synthetic fuels have a role to play in the decarbonisation of the transportation sector in the immediate future, and that use of hybrid fuels may become a standard practice in the sector. The BioMates bio-oil offers clear advantages over extant renewable fuel alternatives since it is converted from advanced, second-generation biomass feedstocks, which averts the 'fossil versus fuel' dilemma, and complies with the EU's regulations. BioMates is also being developed at a time when internal combustion engines in the EU are set to remain the main technology in road transport into the next decade, comprising around ¾ of the total light vehicle fleet, hence biofuels remain the most realistic renewable option for most transport vehicles up to 2030, and thus a key component in technology mix to address GHG emissions from transport. The hybrid fuels derived from BioMates can be used directly in these conventional engines, without modification, and be supplied through existing fuelling stations (Chin et al., 2014). The hybrid fuels derived from BioMates will also contribute to the portfolio of fuels that incorporate biofuels being developed for shipping (Bach et al., 2020) and aviation (Filimonau, Miroslaw and Pawlusińsky, 2018; Kim, Lee and Jaemyung, 2019). Indeed, as Panoutsou et al (2021) note, advanced biofuels can make a substantive contribution to efforts to decarbonise road, air and water transportation in the short to medium term, so long as the challenges besetting their value chain are addressed to help speed up production and market uptake. Thus, BioMates novel technologies have an important role to play in helping the EU meet its commitments to reducing carbon emissions from transport through increased use of renewable fuels and hybrid fuels with biogenic content.

However, the success and sustainability of BioMates hinge on addressing challenges specific to its concept (i.e., due to the combination of types of feedstocks used, the conversion processes, and the intermediate and final products obtained) as well as the long-standing challenges contingent on the evolving landscape for sustainable transportation fuels, which all play a part on social acceptance of diverse stakeholders along the chain. For instance, stakeholders at the BioMates workshop noted that current policies in the EU to offer no real incentives for the market take-up of either bio-oils or hybrid fuels. Policies that ban the use of particular types of crops or biomass, policy focus on quotas (rather than on quality) and the enforcement of quality regulations and standards were all seen as barriers to market expansion. In particular, the uneven implementation of regulations for renewable energy across the EU region was seen as key issue. Stakeholders called for a variety of measures, including:

- regulation of prices of biomass feedstocks
- provision of subsidies to help policy targets
- parity in the provision of incentives to different renewable fuels
- accounting for bio-content in all energy products
- making hybrid fuels eligible for discounting

- policies to encourage the demand for hybrid fuels
- greater support to investment in production and commercialisation of hybrid fuels
- more investment to help overcome technological 'bottlenecks' and "the valley of death" (i.e., the non-realisation of the potential of novel technologies through lack of scaling-up).

Overall, the prospects for the BioMates concept are promising, as it is seen to offer a suitable interim solution to the seemingly intractable challenge of achieving zero carbon emissions through the phasing out of fossil fuels from the transportation sector. However, the evolving landscape for sustainable transportation fuels face long-standing challenges that need to be overcome through better articulation among all stakeholders, greater commitment to decarbonisation of the transport sector by business and government, effective state support, and stable and coherent policy frameworks. In addition, more wide-ranging and long-term measures are needed to help improve broader social acceptance of BioMates, targeted at enhancing knowledge of biofuels. Awareness-raising and public education campaigns were proposed by stakeholders and by survey respondents, reiterating recommendations in the literature that also call for public engagement strategies (Hyacynth, 2018) and programs and activities to increase people's knowledge about biofuels benefits and impacts (Baral, 2018), which academia and Non-Governmental Organisations may be best placed to lead for being perceived as trustworthy and reliable (Leinspenberger et al, 2021). As Løkke, Aramendia and Malskær (2021:8) contend, 'the future of biofuels may very well depend on the increased likelihood of support from an informed and educated public, not only towards technologies as such, but also towards policies for biofuel implementation, and envisioned futures'.

4. Disclaimer

This report reflects only the authors' view. Neither the European Commission nor its executive agency, CINEA, are responsible for any use made of the information it contains.

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5.1. General

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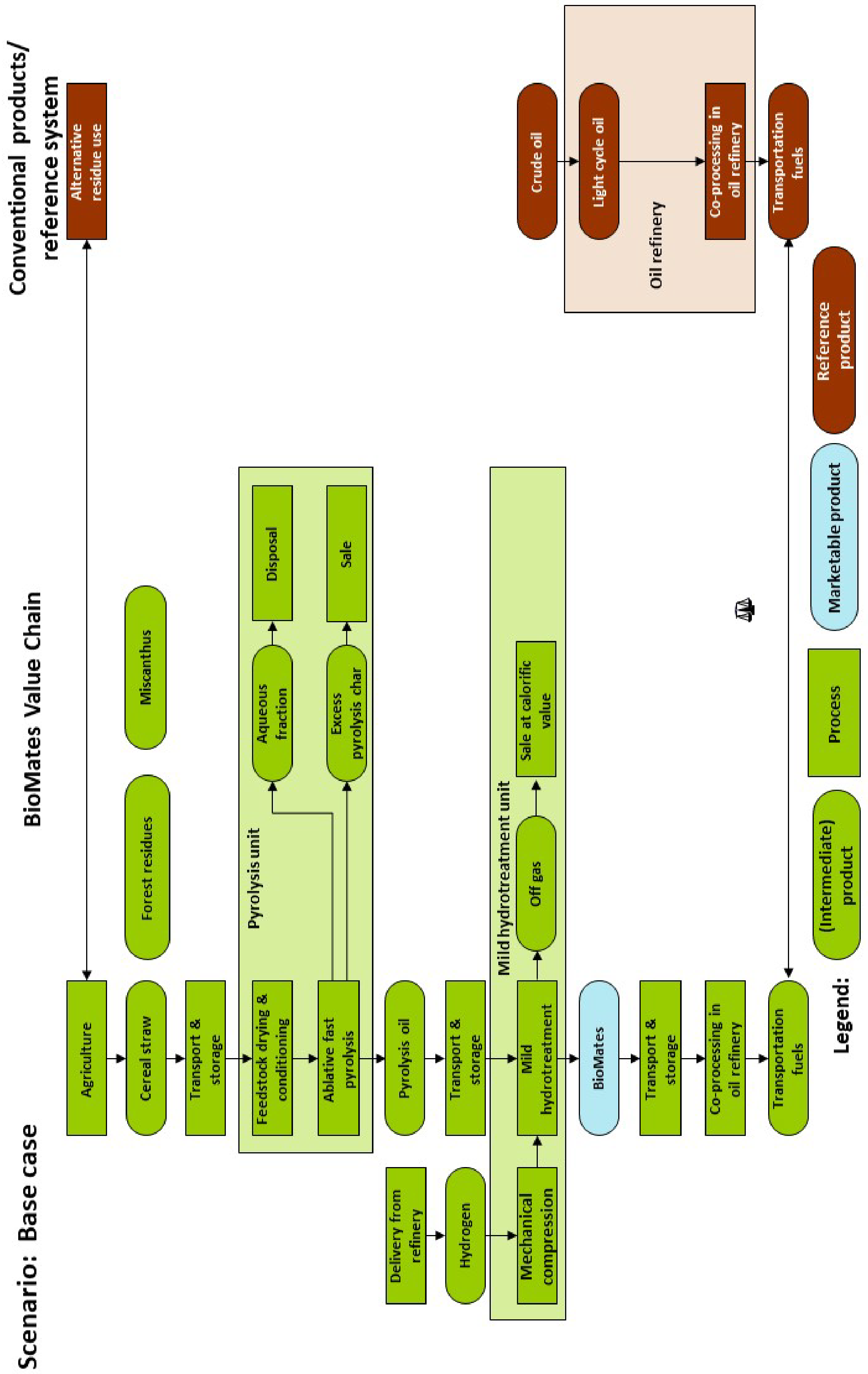
5.2. BioMates Deliverables

For public deliverables and public summaries of confidential deliverables, please see http://www.biomates.eu/results/approved-deliverables, https://s.fhg.de/openaire-biomates or https://s.fhg.de/Cordis-BioMates

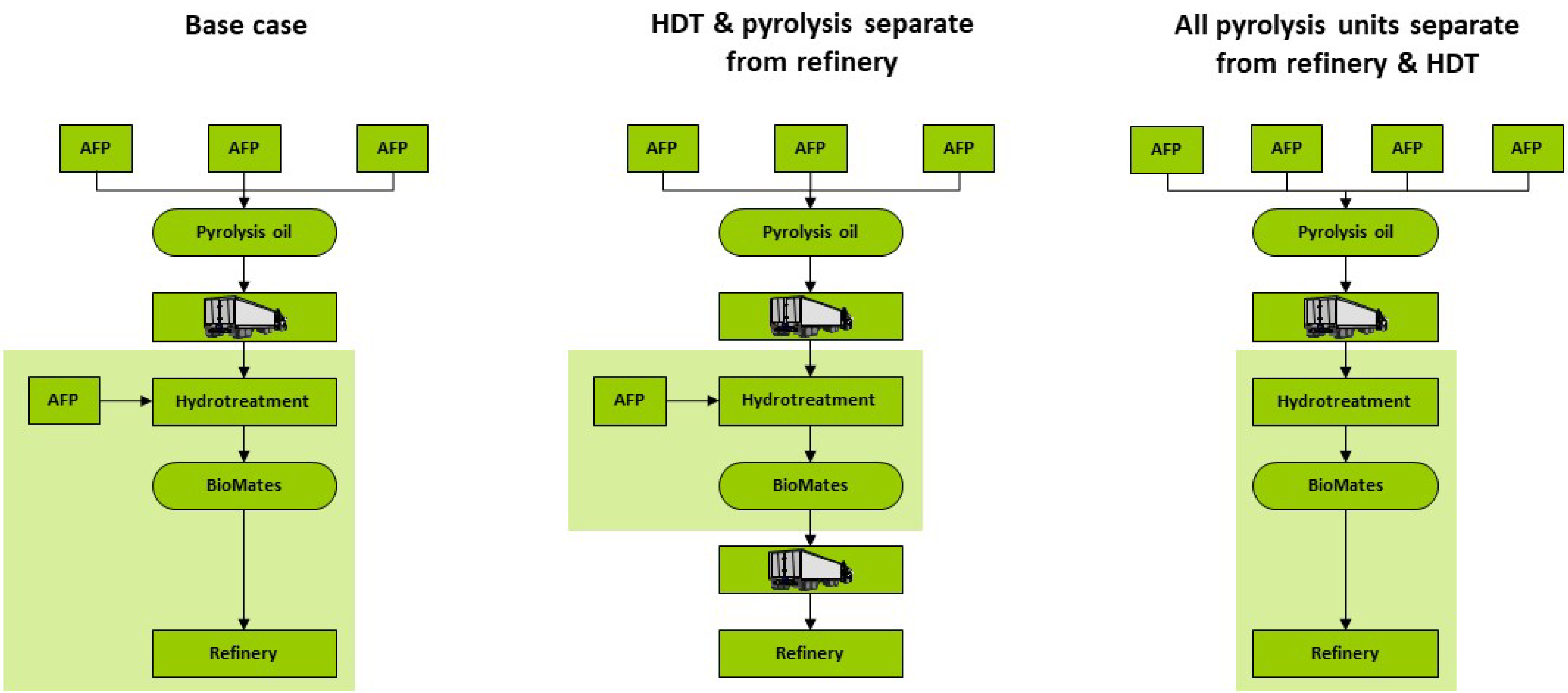
D6.3/D53 Report on public perception and market/regulatory barriers – public report

D4.2/D39 Report on Workshop conducted with stakeholders – public report

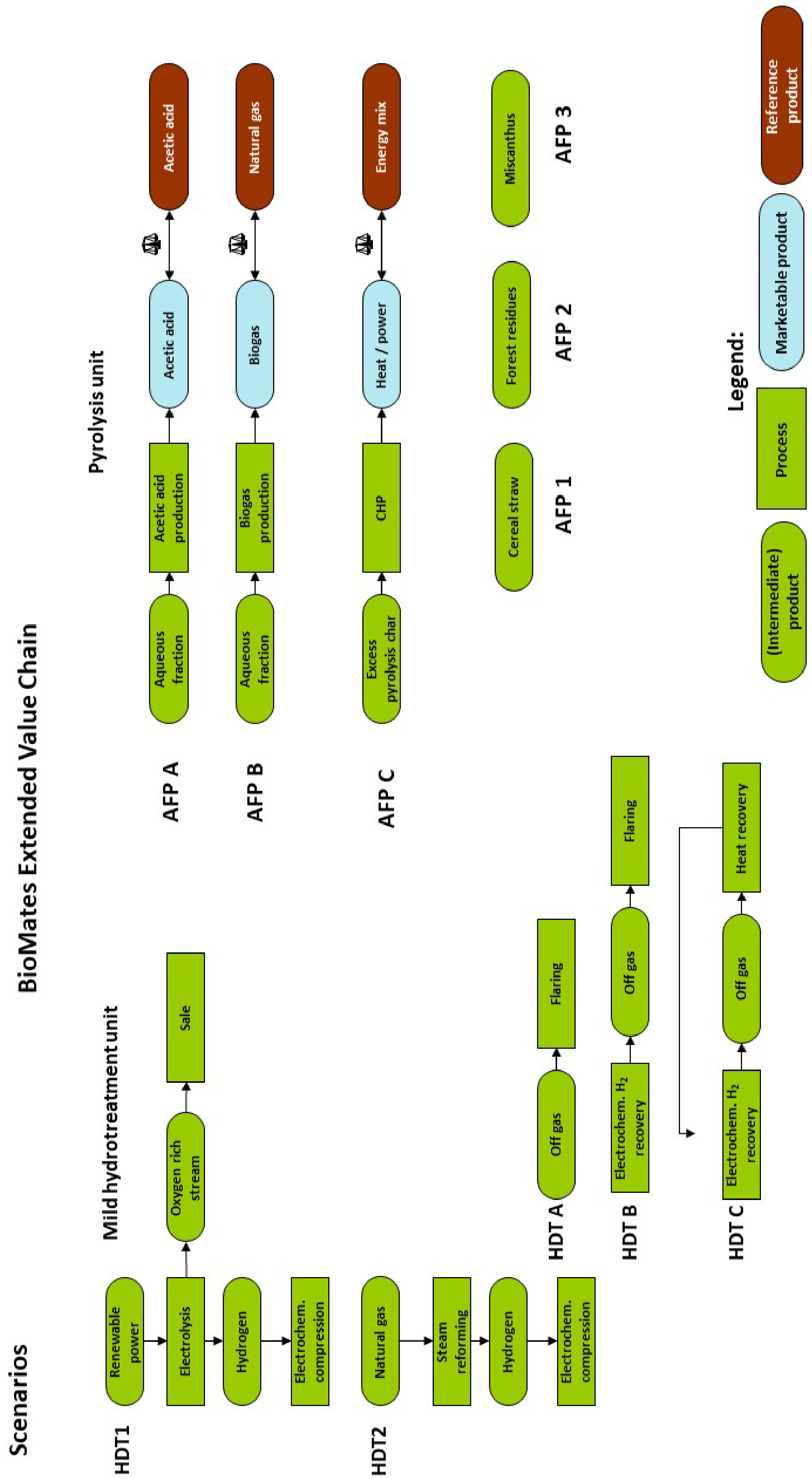
ANNEX I – BioMates Scenarios and Pathways



BioMates: Logistics and integration in scenarios



Light green box indicates co-located and, where applicable, integrated processes


BioMates Extended Value Chain
Scenarios
Pyrolysis unit
Mild hydrotreatment unit
AFP A
Aqueous fraction
Acetic acid production
Acetic acid
Acetic acid
AFP B
Aqueous fraction
Biogas production
Biogas
Natural gas
AFP C
Excess pyrolysis char
CHP
Heat / power
Energy mix
Cereal straw
Forest residues
Miscanthus
AFP 1
AFP 2
AFP 3
HDT1
Renewable power
Electrolysis
Hydrogen
Electrochem. compression
Oxygen rich stream
Sale
HDT2
Natural gas
Steam reforming
Hydrogen
Electrochem. compression
HDT A
Off gas
Flaring
HDT B
Electrochem. H2 recovery
Off gas
Flaring
HDT C
Electrochem. H2 recovery
Off gas
Heat recovery
Legend:
(Intermediate) product
Process
Marketable product
Reference product