BioMates

Deliverable D6.3 - Report on Public Perception,
Market and Regulatory Barriers to BioMates

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1. Introduction

This report examines barriers to the market diffusion of BioMates that need to be addressed to help enhance the business case for BioMates. Key barriers discussed are public perception of innovative technologies and products, market-based issues, as well as policy-based issues. The report also discusses measures to address these barriers and enable the implementation of BioMates as a viable and sustainable commercial venture for energy production for the transportation sector.

BioMates aims to help reduce dependence on fossil fuels by providing a bio-oil intermediate that can be co-processed with oil derivates to produce an alternative hybrid fuel ready for use as fuel for road, water and air transportation. Expectations are high for the development and commercialisation of advanced biofuels that will help meet policy targets for renewable fuels for transport in a sustainable manner (Raman et al., 2015; Goetz, German and Weigelt, 2017; Panoutsou et al., 2021). BioMates meets the aspirations of the European Commission (EC) regarding the use of renewable fuels in transport. These aim to contribute to the cost-effective defossilisation of the transportation sector in the European Union (EU) through energy diversification whilst also promoting innovation, generating employment and growth in the EU economy, and reducing reliance on energy imports (EC/CEU, 2021).

2. BioMates

2.1. The BioMates Project

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 Ablative Fast Pyrolysis (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. BioMates will also help achieve the aims of increasing energy security and promoting economic development in rural areas through enhanced economic activity and job expansion (Tsita and Pilavachi, 2013; Gracia, Barreiro-Hurlé and Pérez, 2020; Panoutsou et al., 2021).

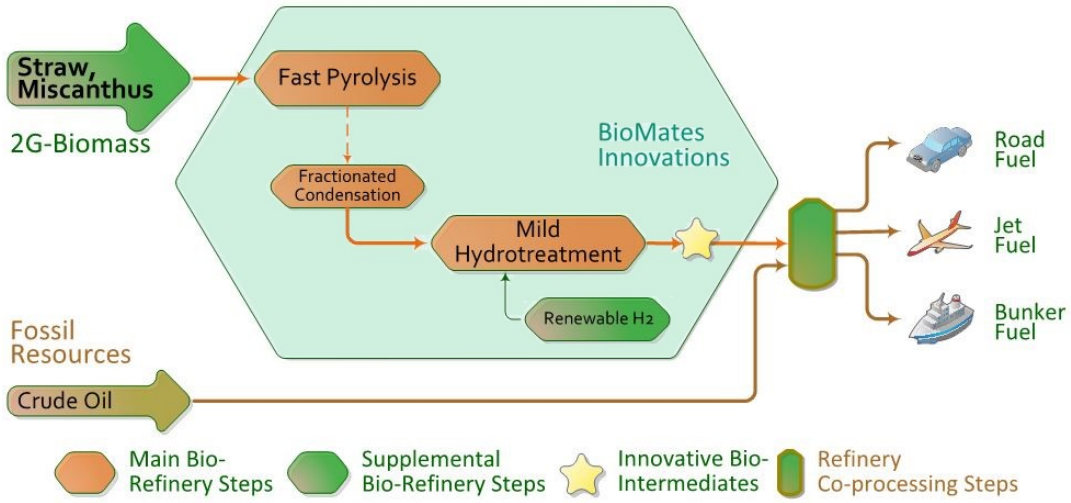


Figure 1: The BioMates concept - Process Flow

2.2. The BioMates Team

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

http://www.cperi.certh.gr

- Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, Germany – www.umsicht.fraunhofer.de
- University of Chemistry and Technology Prague, Czech Republic - http://www.vscht.cz
- Imperial College London, United Kingdom - www.imperial.ac.uk
- Institut für Energie und Umweltforschung Heidelberg gGmbH / ifeu, Germany - www.ifeu.de
- HyET Hydrogen B.V. / HyET, The 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
- Research Institutes of Sweden / RISE, Sweden - https://www.ri.se/en

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

3. Public Perception, Market and Regulatory Issues for BioMates

This report focuses on three key types of barriers to the market diffusion of BioMates. Public perception is an important element of social acceptance of innovative technologies and products (such as the BioMates concept and its hybrid fuel) that impacts on market expansion. Similarly, market-based issues, such as, for instance, competition, and policy-based issues, such as regulations for using biomass feedstocks and blended fuels, all have implications for the market expansion of BioMates. These barriers are examined in turn in this report. The first topic introduced is public perception of biofuels and BioMates which incorporates primary data obtained through a workshop with stakeholders and a survey of the public. The discussion focuses on views, opinions and knowledge of various issues related to biofuels. The report then moves on to discuss key market-based barriers

for BioMates, including those identified by stakeholders and the public. The section after focuses on key policy-based barriers to BioMates and incorporates inputs from workshop and survey participants. The last section sums up the key barriers and proposes measures to address them and concludes by making the case for the market diffusion of BioMates as a successful and sustainable commercial venture.

4. Public Perception Issues

4.1. Public Perception

Public perception in the context of diffusion of innovation can be said to refer to social understandings based on views, opinions, perspectives, values, and attitudes. Public perception has often been used interchangeably with public or social acceptance, which refers to positive responses to proposed technologies or socio-technical systems by members of any given social unity (Upham, Oltra, and Boso, 2015). Public perception can be seen as the most general aspect of acceptance and can be gauged for society as a whole rather than for specific groups (Chin et al., 2014). Social acceptance, in turn, results from the interactions between diverse societal groups, most notably, stakeholders, consumers, and the wider public (Wüstenhagen et al., 2007; Upham, Oltra, and Boso, 2015; Hyacynth, 2018). Social acceptance can also be active or passive (Sauter and Watson, 2007, in Chin et al., 2014). Willingness-to-Pay (WTP) to use any specific type of renewable energy, for instance, represents active social acceptance as through voluntary consumption of it the public actively support its development. By contrast, passive social acceptance entails fostering public acceptance through government policies, (as in the case of biofuels), where commonly incremental usage is backed by government mandatory blending policy rather than public voluntary support (Chin et al., 2014). Still, as van De Velde et al. (2009) argue, even where consumers have no choice regarding the level or types of blended fuels they use, insights about the factors conditioning acceptance of such blends can be valuable for informing energy policy and fuel marketing.

Social acceptance is now seen as essential for the successful development and market take up of novel technologies, applications and products, including those for the renewable energy sector (Wüstenhagen et al., 2007). 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 it, in turn, social acceptance impacts on the development of biofuels projects, infrastructure, chains, and policies (Savvanidou, Zervas, and Tsagarakis, 2010; Zhang et al., 2011; Cacciatore, et al., 2012; Fung et al., 2014; Dragojlovic and Einsiedel, 2015; Moula, Nyári,and Bartel, 2017; Gaede and Rowlands, 2018; Kim, Lee, and Jaemyung, 2019; Zhao et al., 2020; Leibensperger et al., 2021; Bach et al., 2021; Løkke, Aramendia and Malskær, 2021). Empirical research has shown that the public generally have low levels of knowledge about biofuels (Baral, 2018), and that people often express neutral attitudes to biofuels due to lack of opinion or awareness about them (Filimonau, Mirosław and Pawlusiński, 2018). It has also been argued that the public is generally supportive of biofuels despite its limited knowledge of them (Løkke, Aramendia and Malskær, 2021), although earlier research has shown that such support will vary according to the type of biomass feedstocks and biofuels involved (Delshad et al., 2010). Empirical research has also been growing on

WTP for biofuels consumption as an important indicator of social acceptance (Giraldo, Gracia, and Amaral, 2010; Savvanidou, Zervas, and Tsagarakis, 2010; Lanzini, Testa, and Iraldo, 2016; Moula, Nyári and Bartel, 2017; Tongzhe and McCluskey, 2017; Gracia, Barreiro-Hurlé and Pérez, 2020).

Drawing on these issues, the remainder of the section examines public perception of the BioMates concept, an important element of social acceptance[1] that can play a critical role in its market diffusion.

4.2. Methodology

The methodology used for examining public perception of BioMates comprised three elements. Firstly, a literature review was carried out to identify the key issues related to public perception of feedstocks, processes and end-products associated with the production of biofuels and hybrid fuels. These issues were then used to guide discussions about stakeholders' perceptions of barriers to the implementation of the BioMates concept along with enabling factors, during a workshop held online in April 2021 (reported fully in D.39). In total, 18 stakeholders participated, alongside eight project partners, including those who joined two interactive sessions 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).

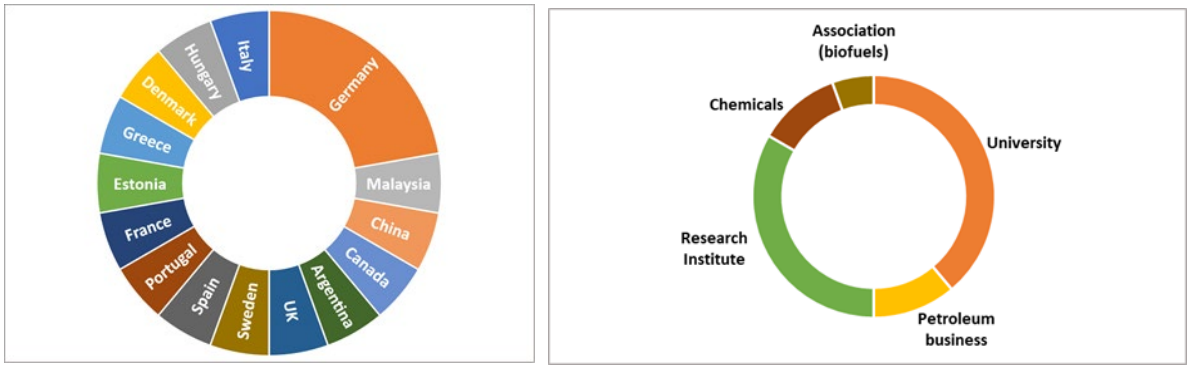


Figure 2: Workshop Participants' Base Country and Sector.

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, giving their opinion on a range of issues relating to biofuels and hybrid fuels, thus providing a means to gauge public perception of biofuels and BioMates. The majority of participant were stakeholders (91% of the sample), whilst the remainder comprised members of the public (8%). 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, whilst their level of familiarity with biofuels and hybrid fuels are shown in Figure 5.

[1]Perceptions of risks and social acceptance are examined fully in D5.8.

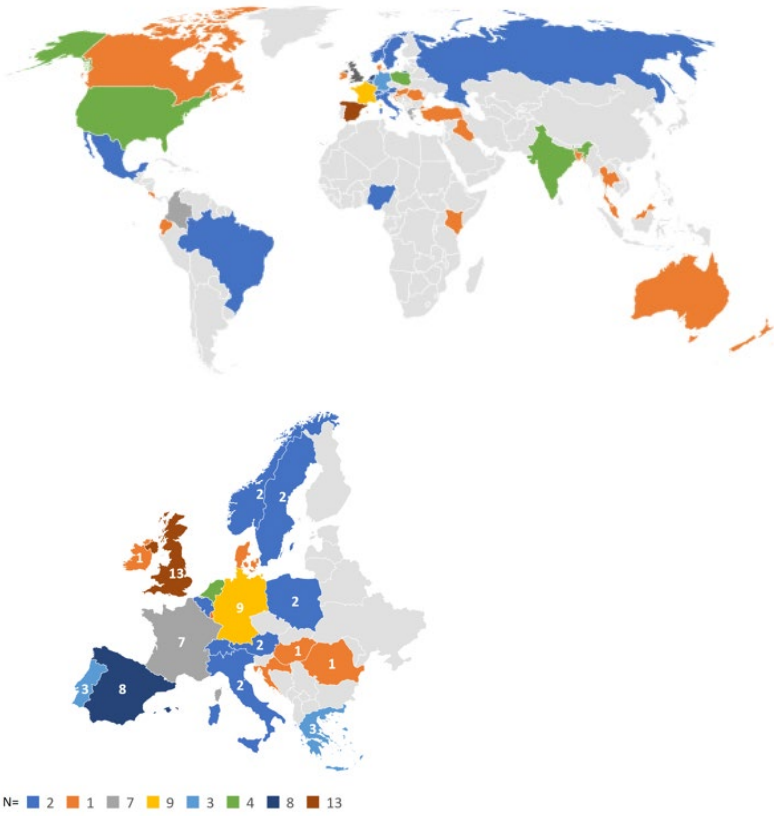


Figure 3: Survey respondents' base country and EU countries

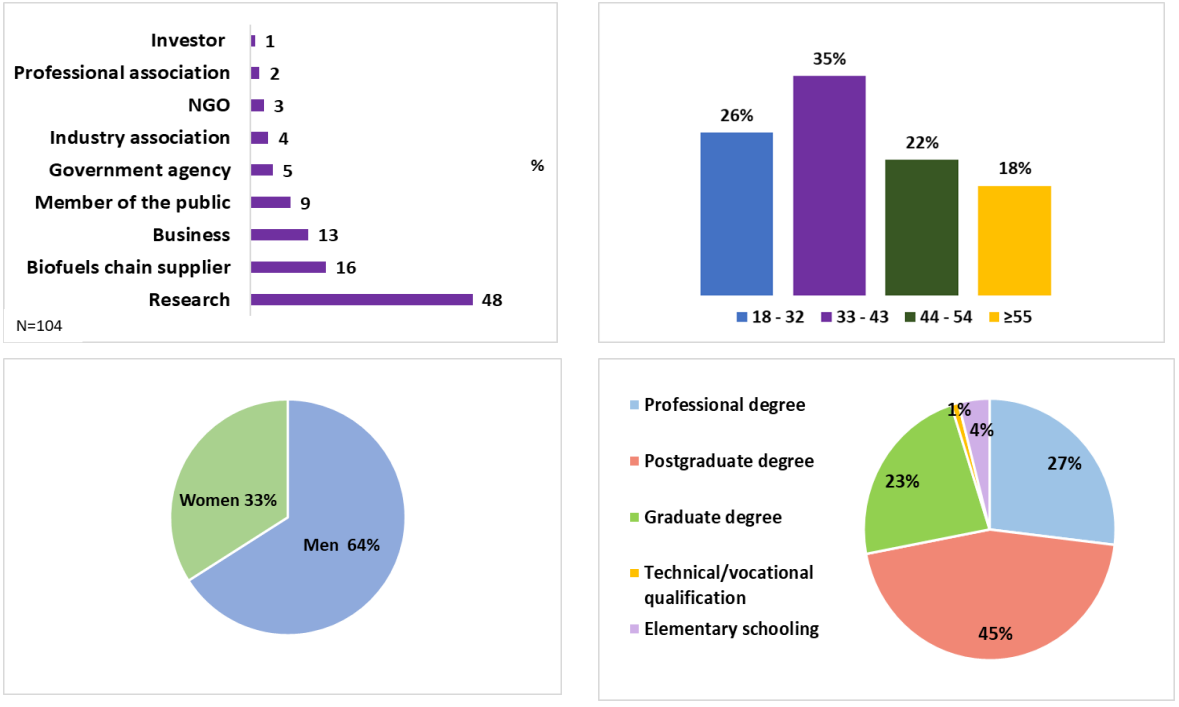


Figure 4: Survey respondents' key demographics

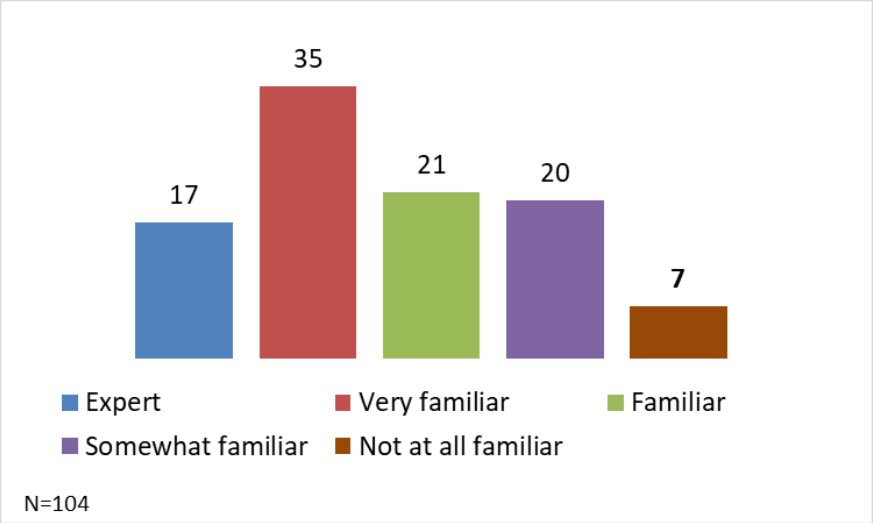
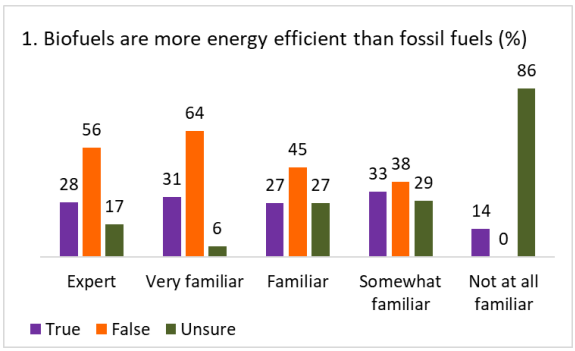


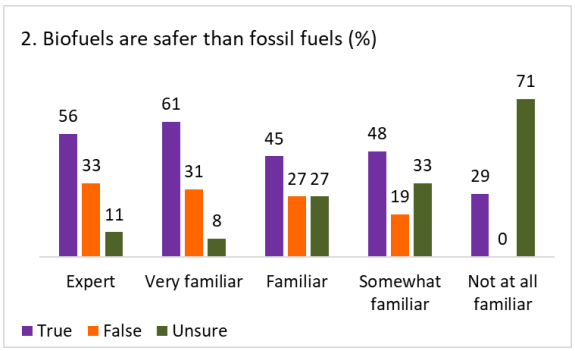
Figure 5: Level of familiarity with biofuels/hybrid fuels

As can be seen, two-thirds of respondents were men (66%), and whilst women made up one third. Respondents were highly educated, three-fifths were young (18-43 years of age), and nearly one half had a background in research. Just over one half (52%) were either experts or very familiar with the topic of biofuels, whilst two fifths had some familiarity with the topic.

4.3.Public Perception of BioMates

The contributions of participants in the workshop and survey respondents were used to help gauge their perception of biofuels and BioMates and understand its role and scope in hindering or enabling the market expansion of BioMates. Amongst the various barriers identified by workshop participants, society's general lack of understanding and knowledge of biofuels was noted as an important societal barrier. This issue was explored in the survey through a series of statements about biofuels features and impacts vis a vis fossil fuels (see similar studies by van de Velde et al., 2009; Delshad et al., 2010; Giraldo, Gracia, and Amaral, 2010; Savvanidou et al., 2010; Moula, Nyári and Bartel, 2017; Filimonau, Mirosław and Pawlusiński, 2018). Respondents were asked to decide whether they are generally true or false. Figure 6 shows the statements and the responses given participants grouped according to their self-identified level of familiarity with the topic of biofuels.





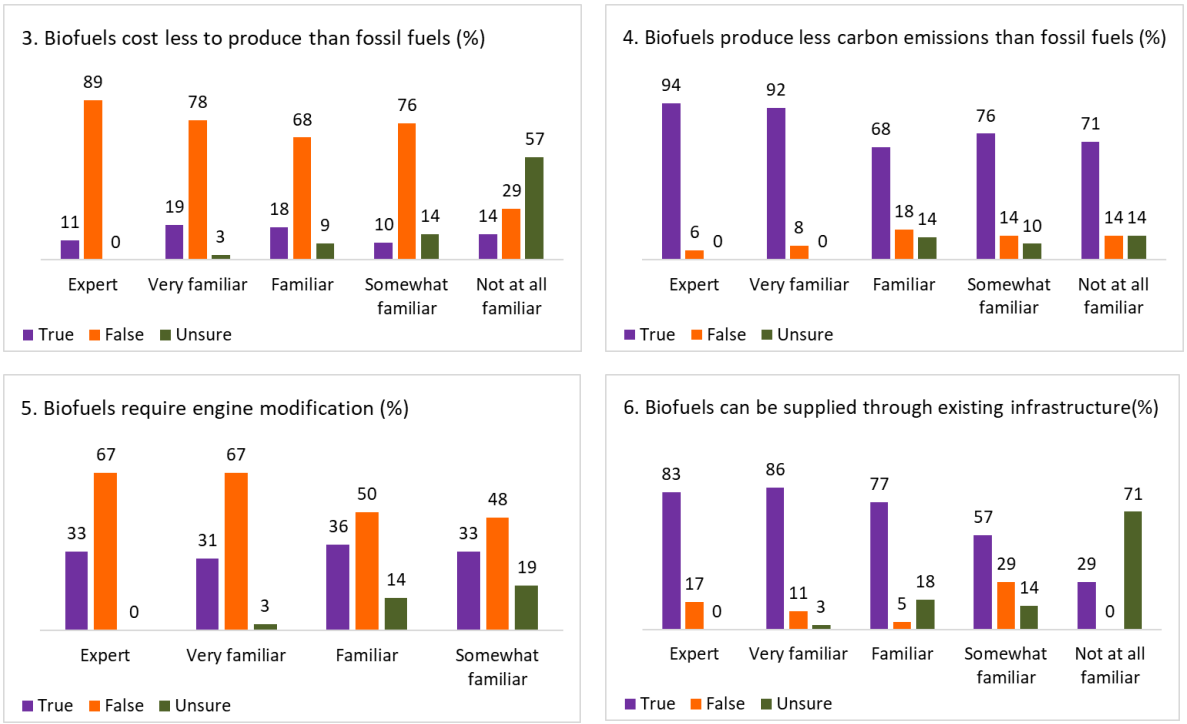


Figure 6: Knowledge of biofuels

As can be seen, even though some of the statements may be moot, the results show a convergence of responses across the groups for most statements. Thus, for instance, a majority of respondents in most groups think that biofuels are less energy efficient than fossil fuels (Figure 6.1), whilst the vast majority of those unfamiliar with it (86%) were unsure. A broadly similar picture emerged for responses regarding the safety of biofuels (Figure 6.2), with the highest share of respondents across the groups supporting the notion that biofuels are safer than fossil fuels, whilst those unfamiliar with biofuels were again the most unsure about it. The convergence was even more striking for responses to the next two statements. Thus, the highest shares of respondents across the groups (bar those unfamiliar with biofuels) refuted the statement that biofuels cost less to produce than fossil fuels (Figure 6.3). The majority of respondents across all groups, including those unfamiliar with biofuels, thought that biofuels produce less carbon emissions than fossil fuels (Figure 6.4). Responses also converged on refuting the notion that engines require modification to take biofuels (Figure 6.5), and on supporting the statement that biofuels can be supplied through existing infrastructure (Figure 6.6). In broad terms, the results show that most groups disputed statements 1, 3 and 5, but supported statements 2,4 and 6, as might be expected. Thus, on the one hand, the results point to a relatively knowledgeable sample as a whole. Yet, on the other hand, it is interesting to verify a lack of consensus on responses to every statement amongst those self-identifying as 'experts' on biofuels or 'very familiar' with the topic (particularly statements 1 and 2).

A further survey question asked about knowledge of the biogenic content in fossil fuels in Europe, bearing in mind that transportation fuel suppliers and retailers in member states of the European Union have been mandated 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. Such targets have been raised steadily in last few years to enable the EU to honour its commitments to the Paris Agreement, and most recently in the 'Fitfor55 Package' (EC/CEU, 2021).

Indeed, most EU-based respondents who are also drivers (88%) knew that the fossil fuels they use most likely contain biofuels, whilst the remainder (12%) did not know it. Figure 7 shows the responses by survey respondents based in Europe to a statement and a question about the biogenic content in fossil fuels.

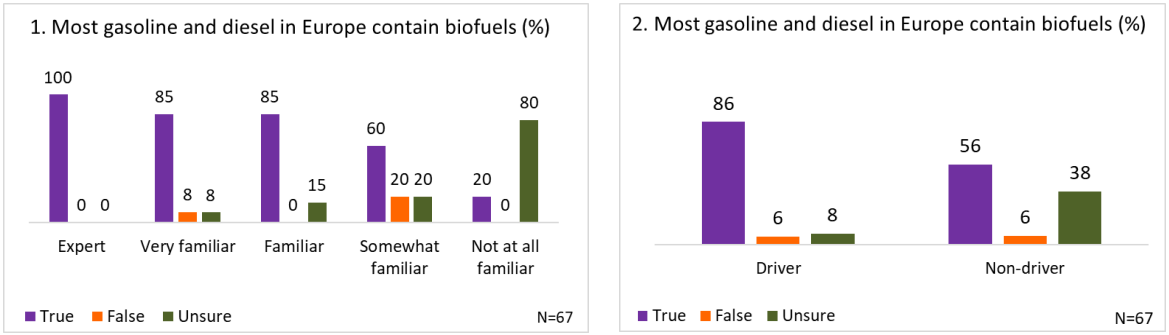
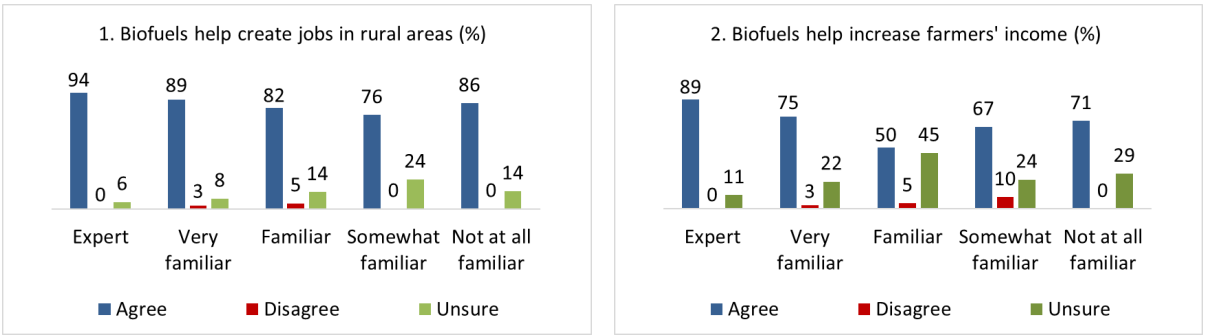


Figure 7: Knowledge of biofuels (EU respondents)

The results show that, for the most part, respondents based in Europe who have some level of familiarity with biofuels thought it is true that fossil fuels in Europe contain biofuels, whereas most of those with no familiarity at all could not tell either way (Figure 7.1). Amongst the drivers and non-drivers in the EU, the majority supported the notion that most fossil fuels in Europe contain biofuels, although just over one-third of non-drivers (38%) were unsure. But, again, it is interesting to note that amongst those who self-identified as being familiar or very familiar with biofuels, and also amongst drivers, there were minorities who thought that the statement was false or could not tell.

4.4. Public Perception of Sustainability Issues

As with knowledge, opinion helps gauge public perception of biofuels that can have important implications for their market development, including sustainability issues. The survey allowed for an examination of perceptions about issues relating to different dimensions of biofuel sustainability (Awudu and Zhang, 2012; Jensen and Andersen, 2013; Arup-URS, 2014; Raman et al., 2015; Hennig, Brosowski, and Majer, 2016; Baudry et al., 2017; Gracia, Barreiro-Hurlé and Pérez, 2020; Bach et al., 2021). Respondents were asked to indicate agreement or disagreement with a series of statements on social, economic and environmental impacts and requirements of biofuels. Figure 8 shows the grouped responses according to familiarity with biofuels to statements relating to socio-economic aspects.



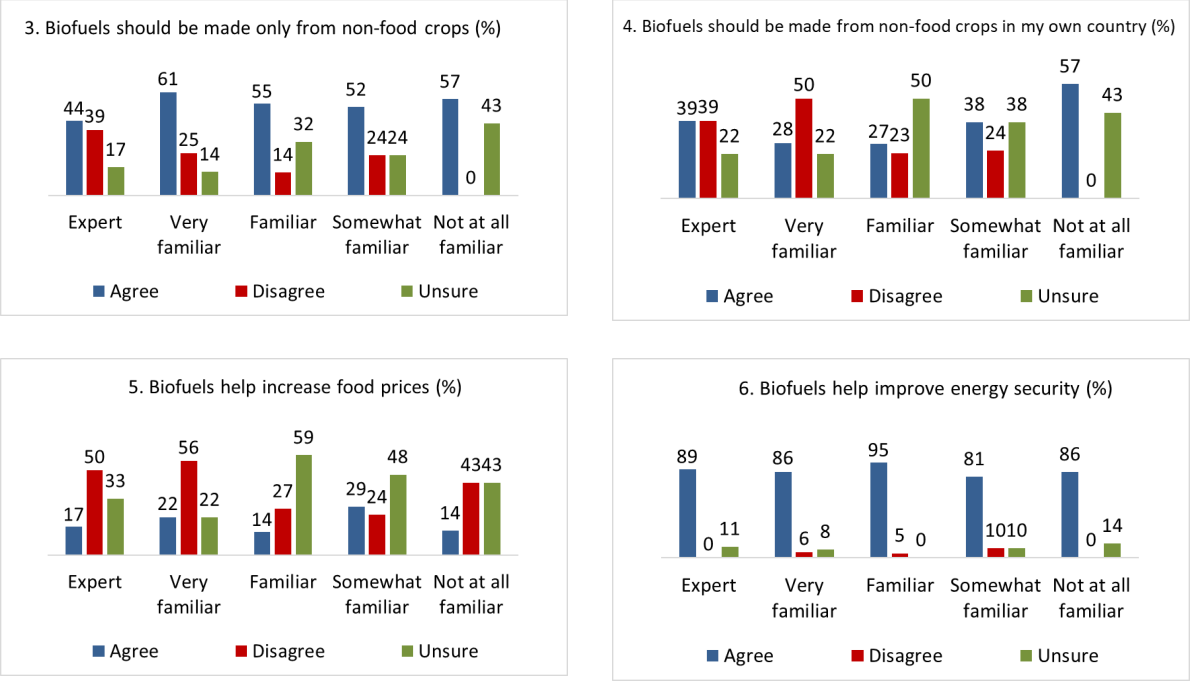


Figure 8: Opinion on biofuels social sustainability

As can be seen, there was clear agreement across all groups that biofuels contribute to rural development through job creation (Figure 8.1) and by raising farmer's income (Figure 8.2), and that they also improve energy security (Figure 8.6). However, the picture was more mixed regarding the responses to the other statements. Thus, although the highest proportions of respondents across the groups agreed that biofuels should only be made from non-food crops, there were also some sizeable minorities who disagreed (including experts) or were unsure (Figure 8.3). This echoes the controversy surrounding the use of food crops to produce biofuels, as well documented in the debate on 'food versus fuel'. Yet, in the context of the EU, BioMates biomass feedstocks fully comply with legislation requirements that favour non-food crops and agricultural residues and so, on this criteria, public acceptance is virtually assured. However, still regarding the sourcing of biomass, the responses were even more mixed regarding the sourcing of non-food crops in their own country (Figure 8.4), with those unfamiliar with biofuels agreeing the most as well as being the most unsure about it, whilst opinion was also divided amongst experts. This finding is interesting too since most respondents agreed that biofuels help improve security, which is usually sought by reducing reliance on imported fossil fuels, and a key stated aim for increasing national targets for blended fuels for transportation. The responses were also mixed regarding the impact of biofuels on food prices, which again, echoes elements of the 'food versus fuel' debate. As can be seen (Figure 8.5), a majority of experts and those very familiar with biofuels disagreed with the notion that biofuels help increase food prices, whilst those familiar or somewhat familiar with the topic were unsure. Those unfamiliar with biofuels either disagreed or were unsure.

Next, survey respondents were asked to choose whether statements about the requirements and impacts of biofuels relating to environmental sustainability were true or false. The statements and responses are shown in Figure 9.

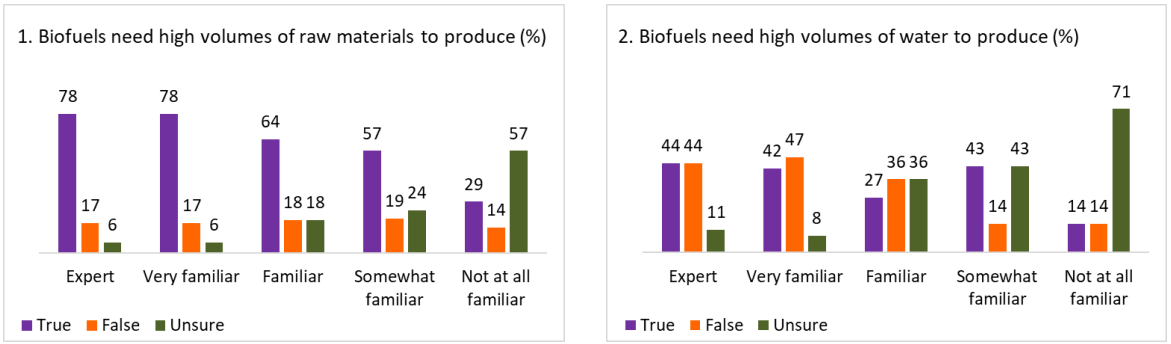


Figure 9: Knowledge of environmental requirements of biofuels

The results in Figure 9 for statement 1 show that across the groups with different levels of familiarity with biofuels, the highest proportions are of respondents who think that biofuels do consume high volumes of raw materials, although those unfamiliar with the topic were the most unsure. But opinion was highly divided across all groups about whether biofuels consume high volumes of water, with those unfamiliar with biofuels accounting for the highest share of uncertainty. The statements on biofuels environmental and climate impacts and effects are shown in Figure 10, along with the responses. As can be seen, opinion about the negative impacts of biofuels is divided across most groups, in contrast with a general agreement across the groups about positive impacts, although amongst those unfamiliar with biofuels were more divided regarding the impact of biofuels on climate change (Figure 10.3).

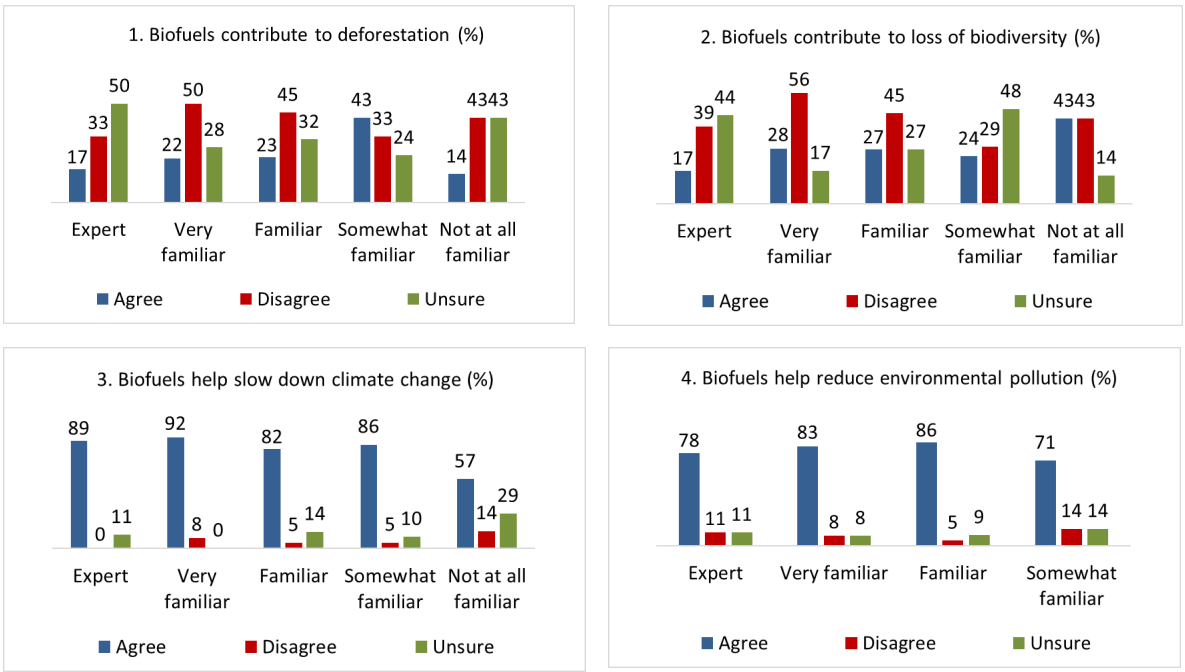


Figure 10: Opinion on environmental impacts of biofuels

4.5. Willingness-to-Pay

As argued previously (4.1), knowledge and opinion can play an important role in conditioning public acceptance of biofuels and, by extension, of hybrid fuels obtained with them. Given that the blending of fossil fuels with biofuels is already mandatory across the EU, it can be argued that social acceptance by drivers is assured by default, since they cannot choose not to use blended fuels in conventional

vehicles. But, as van de Velde et al. (2009) have argued, consumer's lack of choice about level or types of blended fuels to use need not preclude obtaining insights about the factors that condition acceptance of these blends as they can help inform fuel policy and marketing. Indeed, consumers may be able to exercise some choice at the pumps if more than one brand is offered, including those containing biofuels certified with ecolabels to ensure their sustainability (Lanzini, Testa and Iraldo, 2016).

Research has shown the growing interest in WTP as a further indicator of public acceptance of biofuels and blended fuels (e.g., Savvanidou, Zervas and Tsagarakis, 2010; Giraldo, Gracia, and Amaral, 2010; Moula, Nyári and Bartel, 2017; Gracia, Barreiro-Hurlé and Pérez, 2020). The survey explored this topic, asking drivers about their WTP to use the BioMates hybrid fuel. Figure 11 illustrate the results. As can be seen (Figure 11.1), a majority of nearly three fifths (59%) were only willing to pay for BioMates hybrid fuel the same that they pay for conventional fossil fuels.

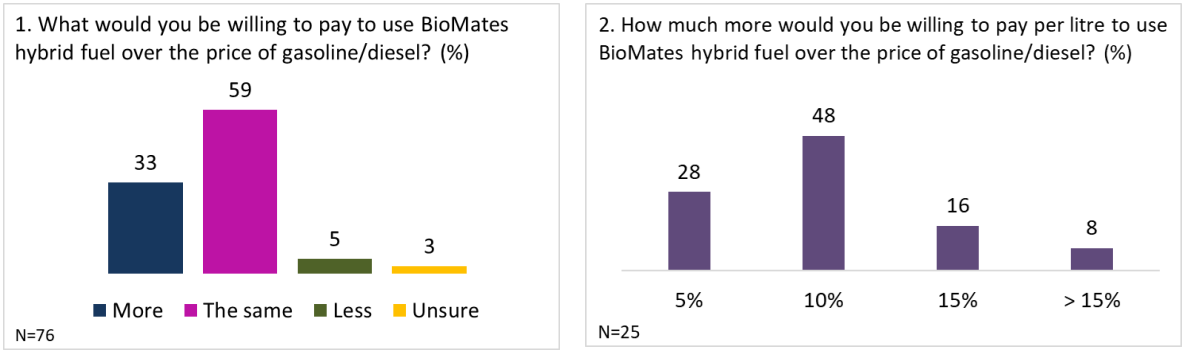


Figure 11: WTP for BioMates for road transportation

However, one third were willing to pay more than the price of conventional fuels. Of these, under one half was willing to pay 10% over the price per litre of conventional fuels, followed by over one quarter who were willing to pay 5% more per litre than conventional fuels. Another quarter were willing to pay 15% or more over the price of fossil fuels per litre. Hence, these results show that social acceptance of BioMates hybrid fuel for road transportation does not translate as WTP more for it compared to fossil fuels.

As the BioMates concept envisages the use of blended fuels in aviation, the survey also asked respondents about their WTP for travelling in aircrafts powered by BioMates hybrid fuel where the cost would be reflected on the air ticket price, so the question was open to the whole sample. Figure 12 shows the results. As can be seen, the results are very similar to WTP for BioMates for road transportation. Thus, one half of respondents were willing to pay only the same price for air travel on BioMates hybrid fuel as they would pay for air travel on conventional fuels, whereas over one third were willing to pay more (Figure 12.1). Of these, over one half were willing to pay 10% for air travel on BioMates hybrid fuel over the price for air travel on fossil fuels. But over one quarter were willing to pay 15% or more for air travel on BioMates hybrid fuel over the price for air travel on fossil fuels. In addition, over one quarter were willing to pay 15% or more for air travel on BioMates hybrid fuel over the price for air travel on fossil fuels. Thus, these results show that public acceptance of BioMates hybrid fuel for air travel does not translate as willingness to pay more for it compared to fossil fuels.

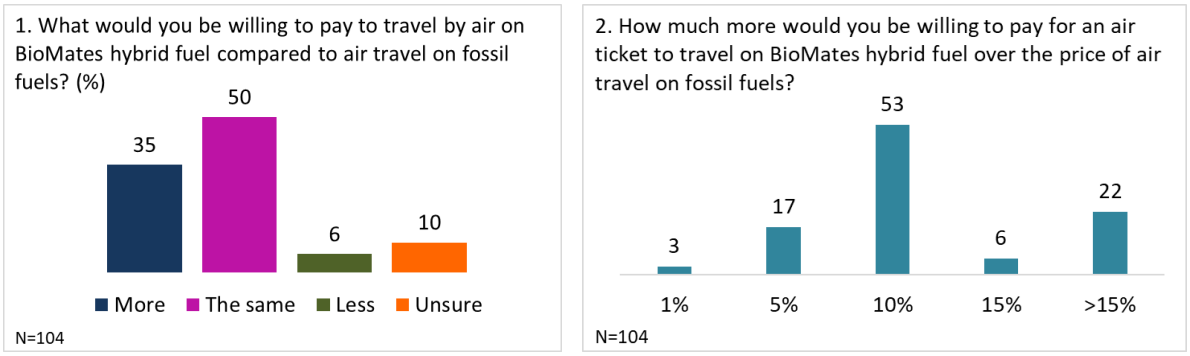


Figure 12: WTP for BioMates for air travel

5. Market Issues

5.1. Public Perception of Market Barriers

The discussions with participants in the workshop and the survey were used to identify further barriers to the market expansion of BioMates. In the survey, respondents were asked to choose from a list of options three key factors that currently hinder greater consumption of biofuels which included market-based factors. The results are shown in Figure 13.

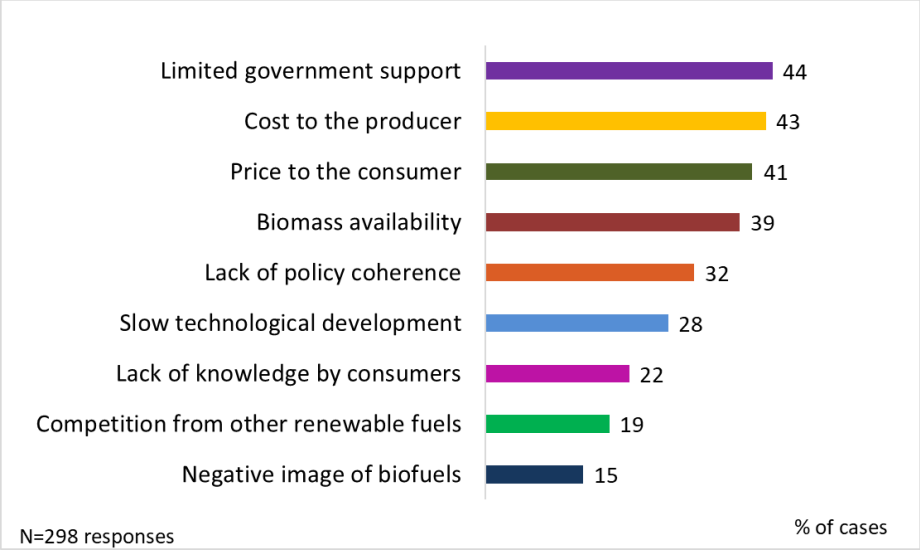


Figure 13: Factors that hinder market expansion of biofuels

Amongst the four top barriers identified in Figure 13, two are patently market-based, that is, cost to the producer (chosen by 43% of the sample), and price to the consumer (selected by 41% of the sample), although biomass availability is also a function a price and so may, indirectly, operate as a market barrier (selected by 39% of the sample). Competition from other renewable fuels is also a market barrier, although it was the second least chosen barrier.

It was possible also to explore the choices of top barriers amongst respondents based in the EU against those outside. The results are shown in Figure 14. In terms of market-based barriers, the most salient difference is about cost to the producer, noted by a higher proportion of non-EU based respondents than by those based in the EU. The gap was smaller regarding price to the consumer and also

competition from other renewable fuels. However, there was a big discrepancy on biomass availability, noted as a barrier by one half of non-EU based respondents, but only by one third of EU-based respondents.

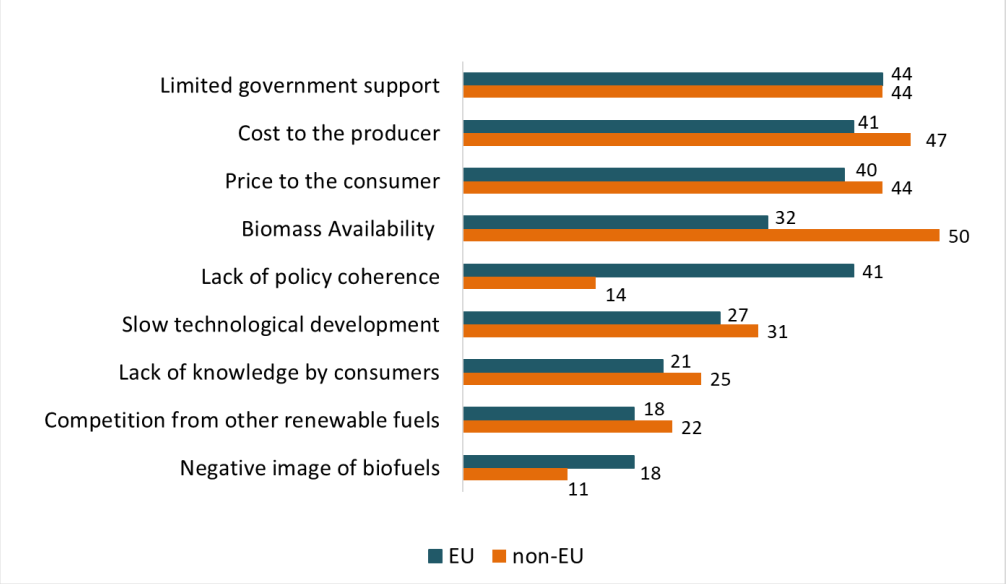


Figure 14: Factors that hinder market expansion of biofuels (EU/non-EU)

At the workshop, participants identified similar and additional market-based barriers to those named in the survey. Regarding price, stakeholders thought that availability of feedstock has a knock-on effect on feedstock price itself and which is likely to impact on the price of the BioMates bio-oil that will be co-processed with petrol streams. Other contingent production factors (e.g., water consumption; weather conditions) may similarly impact on the bio-oil and fuel prices. Further market barriers identified were high capital and operating costs, along with costs arising from technological issues. Competition with crude oil prices along with volatility of fossil fuel prices were also seen to potentially disadvantage BioMates, whilst compounding costs along the biofuels chain could push up the price of the intermediate bio-oil, hindering its take up by refineries or increasing prices to the consumer, thereby making them more expensive than fossil fuels.

5.2. Wider Market Barriers

Beyond public perception, other market issues can also operate as barriers to the market expansion of the BioMates concept. One important issue is competition. The BioMates concept may face different levels of competition with established uses for biomass feedstocks, other biorefinery inputs, and with fossil fuels themselves.

Current main uses for straw are animal bedding and fodder, heat and power, horticulture, mushroom production, frost protection and natural fertilizer, although alternative forest residues may be extracted sustainably (e.g., wood chips, saw dust and shavings, paper crumb). Forest 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 having negative impacts (GOVUK, 2016). As a general rule, feedstocks that are left uncollected can be collected sustainably within limits. 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 mean more 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 miscanthus is grown as a dedicated biofuel crop on arable land without mitigating measures it will likely cause ILUC (Arup-Urs, 2014; GOVUK, 2016; Ben Fradj, 2020).

In terms of other inputs, BioMates proposes to produce its own 'green hydrogen' (i.e., zero-emission) from solar energy 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 will avoid competition for this input with other sectors.

The BioMates bio-oil obtained from the AFP may, in turn, compete to some extent with the 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).

In the context of transportation fuels, the upgraded hybrid fuel obtained from co-processing of the BioMates bio-oil with crude petroleum streams may also face some competition from other transport renewable fuels, namely biodiesel and bioethanol which can be also used without engine modification, and a range of advanced biofuels under development (e.g., lignocellulosic ethanol, fuel from algae, biohydrogen, biomethanol, Fischer-Tropsch diesel, biohydrogen diesel), and biomethane (IEA-BIOENERGY, 2019). There is also likely to be competition with biodiesel production for aviation and maritime transportation (Panoutsou et al., 2021).

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 pandemic, although oil prices have begun to rise again in the last few months. The competition between biofuels and fossil fuels as a perennial challenge to the development of the biofuels sector has been extensively documented. Recently, Reboredo, Ramalho and Pessoa (2017) have argued that no effort to reduce biofuels production costs through technological breakthrough can compete with cheap oil, and call for the abolition of fossil fuels subsides, and scrutiny of subsidies for advanced biofuels to prevent distortions by unfair competition in the energy market. Mitkidis et al. (2018) have similarly noted that cheap oil makes biofuels less competitive with petroleum based fuels.

Besides fossil fuels, there are several biobased competing products that already have an established value chain and can pose an entry barrier to BioMates. Foremost, second-generation ethanol from straw could be one of the key competing products. Hydro-treated vegetable oil (HVO) diesel market. Still under development is the green jet-fuel market, which is a part of the overall diesel market, since HVO can be further converted in a refinery to Hydro-processed Esters and Fatty Acids (HEFA). However, yields for HEFA are lower than for HVO due to the formation of Naphtha. BioMates, on the other hand, can be cost-competitive provided it leverages both the supply-side and the demand-side synergistic potential presented by the size of the European market. On the supply-end, the

decentralised pyrolysis oil production can overcome well-known limitations associated with pyrolysis technologies, in particular regarding low energy density feedstock such as straw. On the demand side, (production and distribution), the qualities of BioMates allow it to be blended with LCO or VGO as co-feed for hydro-processing in a refinery into a mixture of green diesel, gasoline and jet-fuel. If upstream BioMates operations are realisable close to refineries, several CAPEX and OPEX cost elements, such as logistics, storage, hydrogen processing and sharing be considerable economical.

When exploring the capital requirements to enter the market, the economic analysis (in Deliverable 4.5) and the business case for BioMates (in Deliverable 6.2) reveal that the feasibility of the Biomates technology is less sensitive to CAPEX cost but very sensitive to variable costs (e.g., feedstock cost) and fixed costs (e.g., wages). Therefore, setting-up of the pyrolysis unit in the eastern European region could be favourable due to biomass availability, biomass price as well as competitive wages. Country specific variable and fixed cost for labour, engineering, logistics and transport as well as existing infrastructure, such as refineries, along with chemical and fermentation plants next to train and waterways will play a more dominant role in overcoming any market barriers for BioMates. In addition, to be competitive, the scale of future BioMates should be similar to existing biodiesel and HVO plants, which are up to 0.25 million and 1 million tonnes respectively.

6. Policy/Regulatory Barriers to BioMates

6.1.Public Perception of State and Policy Scope

Policy-based barriers comprise the last type of barriers to the market expansion of the BioMates concept. Again, the discussions with participants in the workshop helped identify some of these barriers, whilst the survey probed respondents about actions by the state to support and boost the development of biofuels chains and the biofuels sector more generally.

Stakeholders in the workshop thought that existing policies in the EU offer no real incentives for the market take-up of bio-oils or hybrid fuels. They further noted that policies that restrict or ban the use of particular types of crops or biomass operate as market barriers, as do policies that favour specific hybrid fuels (e. g., petrol and electricity). These perceptions chime with some of survey results. For instance, most respondents thought that it is important the state give incentives to biofuel crop producers (76%), as well as giving tax credits to biofuel producers (83%) and making hybrid fuels (fossil fuels with biofuels) mandatory (86%) - the latter being an established practice in the EU for many years now. Stakeholders also thought that policy focus on biofuel quotas, rather than on quality constrains the market, although some voiced concern that quality regulations and standards add further to costs, thereby also constraining the market. In the context of the European Union, the uneven implementation of regulations for renewable energy across the region was seen as a key hurdle (e.g.., the Renewable Energy Directive; the Fuel Quality Directive).

Regarding state intervention, the survey asked respondents whether the state should subsidise the biofuels chain and infrastructure and prioritise biofuels above all other renewable transportation fuels. The questions and answers are shown in Figure 15. As can be seen, less than one half of the sample thought that the state should subsidise the cultivation of biofuel crops (Figure 15.1), whilst two fifths thought it should not, whilst just over one in ten could were unsure. But a clear majority

(two thirds), thought that the state should subsidise the production of biofuels (Figure 15.2), and a majority (three fifths) also agreed that the state should subsidise the expansion of biofuels infrastructure (Figure 15.3). Most of those surveyed also thought that the state should subsidise Research and Development of biofuel technologies. But opinion was divided as to whether the state should promote biofuels over all other renewable transportation fuels, with only a slight majority disagreeing, over those who agreed (Figure 15.5). The divide was also apparent amongst the respondents based in the EU and those based out it (Figure 15.6). The latter issue was also discussed by stakeholders in the workshop, who pointed out that interventions focused on biofuels would hinder diversification in road transportation, that is, by prioritising private vehicles and combustion engines over public transport and all-electric engines.

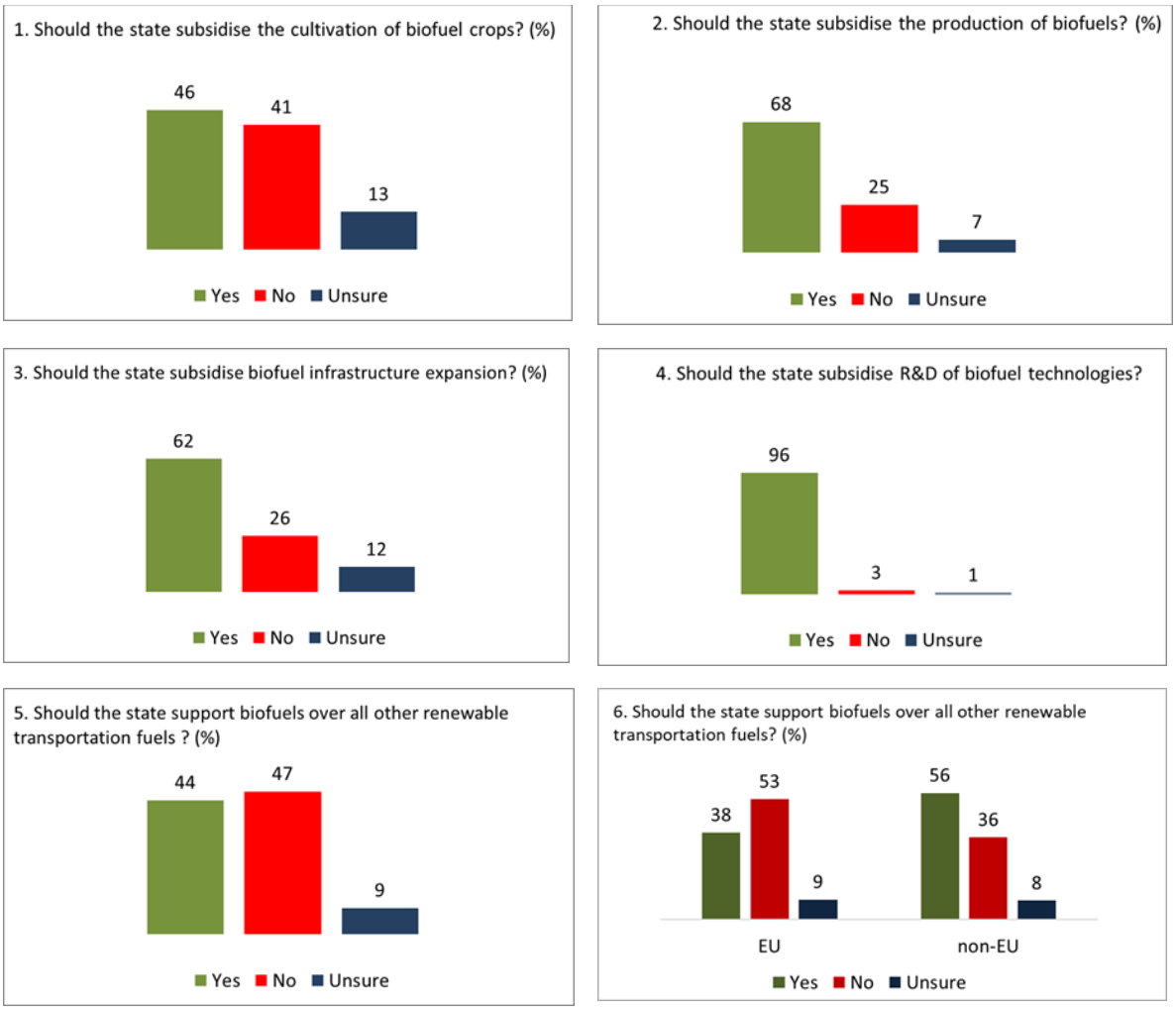


Figure 15: State support to biofuels

6.2.Policy issues in the EU

In December 2019, the EC put forward the European Green Deal, a new overarching strategy aimed at making Europe the first climate-neutral continent by 2050, as part of its commitments to 2015 the Paris Agreement. The European Climate Law, which came into force in July 2021, enshrines in binding legislation the Green Deals' goal to achieve climate neutrality, as well as setting an intermediate target for net GHG emissions by at least 55% by 2030, compared to 1990 levels. Also, in July 2021, the European Commission adopted a package of proposals ('Fitfor55') to overhaul the EU's climate,

energy, land use, transport and taxation policy instruments to achieve this intermediate target. The proposed changes raise some key challenges for the market diffusion of BioMates.

One pressing issue is the lack of specific legislation for the co-processing of biogenic feedstock in conventional petroleum refineries and the allocation of renewable properties for different outputs from coprocessing. Co-processing had been contemplated in previous draft legislation, but it has now been left to the discretion of the European Council through delegated acts and justified on the basis that coprocessing of fossils and renewables is not yet widespread in the EU (EUR-LEX, 2021). Yet, several companies operating in Europe have been carrying out co-processing, a practice that is also expected to continue to grow. But the lack of specific legislation has at least two important implications for the BioMates bio-oil: firstly, in terms of accounting for its contribution to the new mandatory GHG emissions reduction targets and biogenic content as defined in key legislation; and secondly, for limiting the scope of pyrolysis bio-oils for generating substantive economic value. Yet, co-processing helps make more efficient use of refinery capacity and assets as well as helping lower dependence on imported crude oil.

A further issue is the review of the regulation on CO_2 emission standards which now abolishes new passenger and light commercial vehicles with internal combustion engines (ICE) from 2030 onwards (EUR-LEX, 2021b). It also stipulates that all such all new vehicles registered from 2035 are to be zero-emission. The new regulation will certainly limit the scope of BioMates in road transportation beyond 2030. Yet, BioMates is being developed at a time when ICE vehicles in the EU are set to remain the main technology in road transport into the next decade, comprising around some 75% of the total light vehicle fleet (Panoutsou et al., 2021). Biofuels remain the most realistic renewable option for most transport vehicles up to 2030, and thus a key component in technology mix to address raised targets for reducing GHG emissions from the transportation sector (Panoutsou et al., 2021). Indeed, despite ambitious electrification targets in the EU, ICE vehicles will still predominate by far over zero and low-emission vehicles, which are expected to comprise only 10% of vehicles in this segment by 2025, whilst by 2035, some 85% of the vehicle stock will still be powered by ICE vehicles, although by 2050, this would be reversed, with electric vehicles dominating the stock, and ICE comprising only 20% (Michalopoulos, 2019). Clearly, there is a role for BioMates in this segment since the hybrid fuel can be supplied to existing ICE vehicles, and it can also still be supplied to long-distance heavy duty vehicles (i.e., trucks), given that they are not covered by the proposal. Yet, as it stands, the proposal has the potential to deter investment on the BioMates concept, given the tight schedule for setting up and running a BioMates biorefinery before the ban of new ICE vehicles comes into force in 2030.

A further key issue that has been extensively documented is the lack of stability in policy frameworks affecting biofuels that operate to discourage new investment and financial commitment in the sectors affected, thereby jeopardising efforts at market expansion within them. The very increased impetus for decarbonising the transport sector in the EU through the slew of amended or new policies that set targets for GHG reductions may thwart investment in new fuel technologies, thus paradoxically impacting on the ability of member states to meet their legal mandates for reducing GHG emissions. The feedback on the EC's adoption of the new proposals for the Renewable Energy Directive (RED II) reveals various concerns regarding policy change (EC, 2021). This included, for instance, concern that the current review of the RED is the second in just three years and that constantly changing the legal framework undermines investor confidence in the biofuel sector that may lead businesses to pause

investment decisions thus putting the future supply of biofuels in EU at risk. There were also calls for suspending the introduction of the proposed changes until RED II is fully enforced by member states, which for the most part has yet to happen, although the deadline for it lapsed in June 2021, with the transposition marked by policy disarray and quagmire (see Vierhout, 2016). Failure to meet the deadline for transposition was further compounded by the obligation to implement the new changes without first having clarification about delegated acts and specific legislative detail which may take months or years to be disclosed. Concern was also expressed that the directive places a burden on the biofuel sector through the application of its sustainability criteria which, in turn, sets the biofuel sector at a disadvantage to the fossil sector. Similarly, the proposed minimum taxation level for biofuels, which for advanced biofuels would be equivalent to the 98.6% of the fossil fuel taxation base, disproportionately penalises biofuels, which on average save a much higher proportion of GHG than fossil fuels, which is all the more problematic, given the relatively small share of advanced biofuels in overall transport energy (EC, 2021).

Finally, the policy arena in the EU is highly fragmented due to significant variations in the ways member states transpose and implement the RED and compliance mechanisms for control of CO_2 tailpipe emissions, which in turn derive from their own interpretations of policy and legislation that may be marked by ambiguity or lack of clarity. There is a patent lack of harmonisation in the enforcement of control mechanisms, verification and documentation for feedstocks and biofuels (Arup-Urs, 2014; Brown et al., 2020), which jeopardises the effective operation of a single market for biofuels (Vierhout, 2016). Thus, fragmentation, lack of harmonisation, coherence, transparency, and stability of policies and strategies all operate to constrain or stifle investment in biofuel ventures and novel biorefinery technologies, therefore, hindering the development of the biofuels sector, with obvious implications for BioMates.

7. Addressing the barriers: the case for BioMates

The successful market diffusion of BioMates as a sustainable commercial venture hinges on a complex combination of factors, including public perception, market dynamics, and policy determinants. This report has discussed barriers associated with them, incorporating the perspectives of stakeholders and the public. This section highlights the key barriers and measures to address them.

Regarding public perception, the survey data has revealed a sample of participants that is relatively knowledgeable about biofuel topics. This reflects the greater participation of stakeholders in relation to members of the public confirming that stakeholders in general tend to be more knowledgeable about biofuels than the public and that public understanding of biofuels and their impacts is limited (see Løkke, Aramendia and Malskær, 2021 for a full review). Yet, the survey data also revealed a lack of consensus on some key issues even among those who self-identified as highly knowledgeable, and divided opinions on the environmental and socio-economic impacts of biofuels. Further, the survey data showed that social acceptance of the BioMates hybrid fuel for road and air transportation does not necessarily translate as WTP more for it compared to prices paid for fossil fuels. In addition, workshop participants identified society's general lack of understanding and knowledge of biofuels as an important societal barrier to acceptance. These results point to the need for wide-ranging and long-term measures to enhance understanding about biofuels by both stakeholders and the public. In

particular, greater effort should be directed at awareness-raising initiatives and education campaigns focused on new biotechnologies and bioproducts promoted jointly by stakeholder across all relevant sectors, as well as meaningful societal engagement in biofuel projects and, ventures.

In terms of market-based barriers, the primary data (survey and workshop) showed that cost (to the producer) and price (to oil refineries, distributors, and consumer) are key barriers. A crucial measure to the market diffusion of BioMates is to keep production costs down (capital and operational) to help make the intermediate bio-oil and the final hybrid fuel affordable ('right price'). A further, general market barrier to the BioMates concept is potential competition with established uses for some of the biomass feedstocks, other biorefinery inputs, and with fossil fuels themselves (specific measures to address them are discussed in section 4.2).

Among the main policy-based barriers is the lack of incentives for the take-up of bio-oils or hybrid fuels. The survey data shows wide support for provision of state incentives, subsidies and tax credits to biofuel producers, but opinion was divided as to whether the state should promote biofuels over all other renewable transportation fuels. The uneven implementation of regulations for renewable energy across the EU region and recent reviews of key policy instruments cause uncertainty and instability that operate to constrain or stifle investment in biofuel ventures and novel biorefinery technologies. Measures to overcome policy-based barriers drawn from the primary data and policy analysis include:

- 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
- encourage 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)
- increase yet further the obligation on suppliers in the EU to decrease the GHG intensity of fuels by 2030 to encourage greater use of renewable liquid fuels
- ensure that minimum taxation rates of the different renewable fuels reflect their GHG savings potential compared to fossil fuels
- simplify and stabilise the regulatory frameworks in the EU to avoid undermining investor confidence and jeopardising investment in the biofuels sector
- encourage the development of knowledge-sharing platforms to link up investors (who may lack knowledge of the biofuels sector) with bioindustry project promoters (who may lack knowledge about public funding and financial mechanisms) for the leveraging private funding for scaling up biorefinery concepts such as BioMates

BioMates 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, Mika and Pawlusiński, 2018; Kim, Lee and Jaemyung, 2019). Indeed, advanced biofuels can make a substantive contribution to efforts to reduce the carbon content in road, air and water transportation fuels 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 (Panoutsou et al., 2021).

Overall, the prospects for the BioMates concept are promising, as it offers 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 within which it will implement face long-standing challenges, including the barriers discussed here, that need to be overcome through better articulation among all stakeholders, effective state support, and stable and coherent policy frameworks.

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