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European biofuels to 2020 and beyond

Final Project Report

Dr Andrew McMeekin
Reader, University of Manchester
Sustainable Consumption Institute

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Publication Address
Sustainable Consumption Institute
The University of Manchester
188 Waterloo Place
Oxford Road
Manchester M13 9PL

(T) 0161 275 4030
(F) 0161 275 0188
www.sci.manchester.ac.uk

European Biofuels 2020: Interim Report

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This report has been written by Sally Gee, Mark Harvey, Andrew McMeekin, Yanuar Nugroho, Sarah Pilgrim and Paul Upham.
Please address any correspondence to andy.mcmeekin@manchester.ac.uk

Executive Summary

Europe urgently needs to change gear in its ambitions to develop a market for transport biofuels in the coming decade. Liquid fuels of one form or another will remain the major source of energy for transport in 2020 and beyond, as other alternatives to oil - renewable electricity, hydrogen cells – struggle to deliver equivalently effective energy solutions. Biofuels are of course not without their own problems – there is no doubt that some perform better than others in terms of climate change performance and also in terms of how cultivation of their feedstocks competes with other uses of land. But, the central question remains: to what extent will Europe reduce dependency on oil for transportation over the next decade and beyond – and what role can biofuels play? We believe that Europe needs to look to biofuels (alongside other options) to face the twin challenges of the approaching energy crisis of diminishing oil supplies and to reduce greenhouse gas emissions.

This Sustainable Consumption Institute research project sought to develop a better understanding of how biofuels could make a significant and sustainable contribution to European transportation in 2020 and beyond. To do so, the project analysed the current European biofuels landscape, interviewed expert stakeholders on their initial expectations of what *would* happen to European biofuels by 2020 and conducted a foresight exercise with a scenario workshop to consider what *could* happen to create a situation where biofuels do make a significant and sustainable contribution to European transportation. The headline conclusion from this research is that sustainable biofuels *should* be promoted in Europe, if Europe is to stand any chance of making the transition away from its

dependence on oil for transportation. In the following, we elaborate on this conclusion and explain how it was reached.

The Global Context

Globally, the emergence of biofuels for transport has been driven by depleting oil stocks, the need to address climate change, efforts to stimulate rural communities and by economic opportunities for firms and nations. With demand for liquid fuel based transportation unlikely to fall dramatically over the next decade or more, there is an urgent need to find alternatives to conventional oil based fuels. Biofuels have the potential to become part of the solution.

Global biofuel production is currently dominated by Brazil and the USA, based on bioethanol from sugarcane and maize respectively. Europe lags behind with its focus on biodiesel produced from rapeseed. Levels of biofuel consumption also display significant geographical variation, largely as a result of the way that different drivers have entered the political agendas in different countries. The early expansion of the Brazilian industry in the 1970s was motivated by energy security and the need to find alternative economic uses for sugar. It is now also shaped by the economic opportunities from the creation of an export market. The recent and rapid expansion of biofuels in the USA emerged as a political response to energy security. In Europe, by contrast, mitigating climate change has been the main driver and has not mobilised the same degree of political support for biofuels seen elsewhere. However, we believe that the issue of energy security, associated with rapidly depleting oil stocks and a fractious global oil market, will move up the European agenda over the next few years, creating a renewed demand for biofuels in the absence of any other viable technological alternatives (even the most optimistic predictions for

electric vehicles do not envisage major substitution of the European road transport fleet within a decade – and no-one is seriously contemplating the electric aeroplane). Finally, we anticipate growing recognition that increasing oil prices present a serious risk to the prospects of Europe moving out of the current economic downturn – and this will add to the growing demand for oil alternatives.

Overcoming obstacles

Two further issues will require resolution to establish this renewed demand for biofuels. We believe that a much more general debate on land use and food security will swallow up the relatively smaller concerns relating to competition between crops for fuel and food. Similarly, the almost intractable relationship between indirect land use change and greenhouse gas (GHG) emissions will need to be assessed much more broadly to take account of all drivers, most notably the changing demand for food and for urbanisation – and the benchmark for GHG comparisons needs to be revised as attention turns to the more carbon intensive unconventional oil reserves, including oil sands. Opportunities to drive up agricultural productivity for all types of farming will need to be seized: the diffusion of existing agricultural best practice can make much progress in this respect; the development and adoption of agricultural biotechnologies even more. At the same time, we expect the greenhouse gas saving potential of biofuels to become clearer – and those that perform badly in this respect will fail to find a market. New policies, technologies and practices can be developed to manage the climate impacts of direct and indirect land use change. This will need to be supported by research producing much better understanding of how the global agricultural system is evolving and the development of clear sustainability standards or regulations, an area in which Europe can lead the way.

What would a significant and sustainable European biofuels sector look like?

The research project concluded that these are the circumstances that would propel demand for biofuels in Europe. If the drivers do combine in these ways, we would expect European policy to respond with a revision to the way that alternative transport fuels are promoted. In our view, the Renewable Energy Directive would need to create a longer term framework for developing European biofuels, extending beyond the current 2020 cut off point. If policy moved in this direction, a viable European biofuels sector could develop by 2020 and expand significantly into the following decade. The scenario created by a range of expert stakeholders at the foresight workshop took the view that these circumstances were plausible and then set out to elaborate what a biofuels sector for Europe would look like in 2020 and beyond. To provide focus for this elaboration, the discussion was structured around an assumption that biofuels would constitute 12% of the transportation fuel market by 2020, with potential to develop to 30% over the following decades. The key features of this scenario (see section 3.2 for a full elaboration of the scenario), where biofuels can make a sustainable and significant contribution to European transportation, are as follows:

- The technologies already exist (in 2010) to meet the 2020 targets, the emphasis would be on optimisation and implementation of the best technologies much more widely over the next decade;
- New technologies, for example converting waste to bioethanol, would become increasingly important over the longer term to achieve the higher targets in the decade after 2020;
- Biofuel technologies would play a complementary role in substituting for oil, alongside developments in electric

powertrains – in particular, there would be the prospect to develop efficient hybrid electric vehicles that run on biofuels;
- European biofuel consumption would be provisioned by domestic production and by imports – the balance would depend on the comparative performance, in sustainability and economic terms, of biofuels from different global regions. As such European consumption of biofuels would diversify away from rapeseed biodiesel;
- The sustainability of biofuels would be regulated by global standards and Europe would lead the way in establishing these news international governance regimes;
- A vibrant European biofuel sector would provide significant opportunities for European firms – new supply chains would emerge engaging oil and agriculture firms in novel industrial configurations.

These are the main features of a scenario, produced by expert stakeholders, for European biofuels in 2020, setting out the circumstances and conditions required for biofuels to make a significant and sustainable contribution to European transportation. We recognise that this vision stands in sharp contrast to other prominent views and it is useful to describe three such visions in order to locate our vision in the wider debate (see section 3.1 for full elaboration of the scenarios).

What are the alternative visions for European transportation in 2020?

The business-as-usual scenario for Europe assumes the continued existence of targets for biofuel uptake set out in the Renewable Energy Directive. But, judging by current trends, it also assumes that these targets will not be met. In some quarters, most prominently advocated by the UK Gallagher Review[1], this downward adjustment of targets, whether by statute or by default, would be very welcome.

[1] Gallagher (2008) The Gallagher Review of the indirect effects of biofuels production, The Renewable Fuels Agency, London

Alternatively, in the "eco-Europe" scenario, opposition to biofuels would grow to such an extent that Europe would effectively become a biofuel-free zone. Proponents of this scenario advocate a varying mix of improved fuel efficiency, major breakthroughs in electric car technology (with the necessary decarbonisation of electricity supply) and an overall reduction in levels of transportation. The environmental NGOs[2] are the most vocal supporters, although the King Review for Low Carbon Cars[3] also identifies with this vision to a large extent.

At the other extreme, it is possible to imagine a future for European biofuels that would develop in parallel to some of the most technologically optimistic visions currently held in the USA. The "all technological hands to the pump" scenario is assumes technological 'gamechangers' in the biofuels field, as predicted by US Secretary of State for Energy, Steven Chu[4].

These alternative visions are predicated on different assumptions about how the key drivers relating to transportation will evolve of the next decade. The scenario developed by the workshop is clearly distinct from each of these views. It rejects the assumption that electric vehicles will become a widespread reality by 2020. It assumes that political leadership will be mobilised in response to energy security concerns, breaking with the current stagnation in the support for European biofuels. But, it also dismisses the

[2] See for example, Oxfam (2008) Another Inconvenient Truth, Oxfam Briefing Paper, June 2008
[3] King, J. (2007) The King Review of Low Carbon Cars Part 1: The Potential for CO2 Reduction, UK Government HM Treasury October
[4] Interview in Financial Times, May 29th. http://blogs.ft.com/energy-source/2009/05/29/second-generation-biofuels-still-five-years-away/

extremes of US techno-optimism as unnecessarily focused on the technological silver bullet.

Biofuels for European Transportation

Overall, the workshop scenario has been constructed around the following stepwise logic:

1. The twin drivers of energy security and climate change mean that there is an urgent need to reduce Europe's – and the world's - overwhelming economic dependence on oil;
2. Of all economic activities, transportation – road, marine and air – is by far the most dependent on oil, and therefore a priority in the search for alternatives;
3. This endeavour should be addressed through a portfolio of initiatives, including innovations in fuel efficiency, electric vehicles and biofuels;
4. Any gains from efficiency (potentially significant) and alternative vehicle technologies (unlikely to make much difference by 2020, due to the time for the transport fleet to be replaced) can be significantly enhanced by adopting biofuels into the liquid fuel supply mix for European transportation;
5. Technologies already exist to produce biofuels at competitive prices and with significant greenhouse gas savings (especially Brazilian sugarcane-to-ethanol);
6. These existing technologies can be adopted and optimised in other global regions;
7. Current technology development programmes will produce better performing biofuels, in environmental and economic terms, to optimise location specific agronomic conditions around the world;
8. Strong political leadership in instituting standards to regulate the sustainability of biofuels can contribute significantly to maximising the gains and reducing the risks of a significant uptake of biofuels.

Whether the amount of liquid fuel consumed by the European transport system increases, decreases or remains the same there will still be a choice over the proportion of that liquid fuel that is fossil-based or bio-based. We have set out an argument and a

scenario that sees biofuels making a significant contribution to European transportation by 2020 and on an upward trend over the following decade to 2030.

It is clear that one of the conditions for the achievement of this success scenario would be more vigorous political leadership and a change in political direction at the national and European level. This was clearly identified by the scenario workshop participants as critical to the future of European economies. Consequently, as authors of the report, based both on the research and the development of a workshop scenario, we have drawn out the principal policy implications, and expressed them as a series of recommendations. These are the policy issues that would need to be addressed in order to achieve a significant and sustainable contribution of biofuels to the future of European transport (see section 4 for further discussion of these policy recommendations).

We recommend that the European Commission and European national governments:

1. Promote the expansion of renewable biofuels as a contribution to transport energy (for road, air and sea), in recognition of the imperative to reduce fossil fuel dependency in the context of an impending energy crisis.

2. Replace the existing single target of 10% renewable transport energy for Europe in 2020 by a more ambitious progressive mandate of a 1% per annum increase in the biofuel proportion of transport energy until 2030.

3. Promote the development of a robust, comprehensive and integrated regulatory framework for the sustainability of all agricultural commodities and energy supply sources in place of one that singles out biofuels, to include

a. Impacts of land-use and direct and indirect land-use change for all agricultural outputs (logging, food, energy, cosmetics, etc.)
b. all forms of energy, including extraction of non-conventional oil (tar-sands, shale oil, etc.,) and the refinement of the current estimation of the carbon footprint of conventional oil extraction.

4. Review trade barriers and tariffs to facilitate the import of biofuels from more land-use efficient geographical zones, notably the sub-tropical zones in South America, Africa, India and East Asia.

5. Promote the diffusion of best practice farming techniques and eliminate barriers to the use of biotechnology such as genetic modification for intensifying and enhancing sustainable land use for agricultural crops of all kinds.

6. Fund demonstrator projects to promote integrated biorefineries using advanced technology based on cellulosic feedstocks and bio-wastes for the production of sustainable energy and chemical building blocks.

7. Implement public procurement for biofuels to stimulate markets and signal clear political leadership and commitment

8. Promote and assist in the formation and coordination of biofuel supply and distribution chains, especially in the context of the use of carbon waste as a feedstock.

1. Introduction

This report presents the outputs of a Sustainable Consumption Institute Foresight study to consider the future development of a European biofuels sector. The project developed and employed a structured framework to produce alternative scenarios for Europe in 2020 which will inform the development of company strategy and government policy and provide a key input to the public debate.

Context: Biofuels are an issue of great significance for the future development of the European economy. Liquid fuels for road transport (and aviation) are widely expected to play a significant role for many decades to come, whatever other energy/engine technological alternatives emerge. The question is whether these are to be fossil- or bio-based. The potential for a European biofuels sector remains highly uncertain and the public and policy debate has been characterised by strong advocacies and criticisms alike. There is little consensus regarding which technologies represent the best bets, which firms (or even types of firm) are likely to dominate, what modes of political governance are most likely to encourage the right responses, or how public attitudes towards biofuels are likely to evolve in the future. Such uncertainty presents serious challenges for long term planning.

The Foresight Approach: Foresight exercises have been used extensively by firms (in particular major oil companies, BP and Shell) and governments to inform the strategy and policy process, especially in situations where the long term future is highly uncertain. The distinctive feature of the foresight method is to address the unpredictability of the future by considering a range of alternative future scenarios. These scenarios highlight the key

trends and drivers and suggest how particular strategies and policies might be implemented to steer developments along desirable paths. As such, foresight methods offer a useful alternative to prediction and road-mapping.

Research Approach: The research that underpins this final report involved the following steps:

- Desk research to generate a landscape of current global biofuel capabilities and their geographical distribution;
- A survey of expert opinions and forecasts
- The development of 3 contrasting scenarios of the European biofuel system in 2020 as inputs for consideration and elaboration at the workshop
- A scenario workshop with invited experts and key stakeholders
- Analysis and presentation of policy implications that arise from the research

A Participatory Workshop: Foresight is a participatory methodology, drawing on the expertise of key stakeholders and encouraging them to think systematically beyond their current expectations. A key factor for the success of the methodology is the selection of participants for the workshop. This project assembled representatives from the full spectrum of stakeholders in the development of biofuels: farmers, agricultural processors, oil companies, dedicated biofuel firms, car companies, biotechnology companies, retailers, government departments (UK and EC) and NGOs. The main task for the workshop was to produce a 'success scenario' for European biofuels in 2020, which is both environmentally sustainable and economically viable.

Structure of the Report: The next section presents our analysis of European biofuels within the wider global landscape in 2009 and also the results from the stakeholder expectation survey. Section 3 presents the scenario elements of the project, including the three preliminary scenarios developed by the project team and the 'success scenario' developed by participants at the scenario workshop. Section 4 concludes the report with a set of recommendations for European Policy.

2. Analysing the emerging biofuel sector in six dimensions

The emergence of the biofuels sector is contingent on a high number of interdependent issues incorporating the economic, political, social, environmental and technological. The analysis presented here is organised into six relatively simple dimensions that provide conceptual and structural coherence to this complex topic. The six dimensions are; 1) Drivers of biofuel development; 2) Governance and government policy; 3) Technologies, products and processes; 4) Reconfiguring the industrial landscape; 5) Markets, demand and public acceptability; 6) Europe and the international context. These dimensions are intended to capture the main characteristics shaping the future of biofuels in Europe, and other regions of the world. For each dimension we provide an assessment of the current situation, which is based on our own analysis drawing on the existing literature and our other research activities. This is followed by a summary of the main issues that arose from our survey of expert stakeholders (see the appendices for a full list of the experts interviewed).

2.1 Drivers of biofuel development

Biofuels have emerged as a potential solution to a number of partially interconnected problems. In the recent period, the principal drivers have been:

Absolute energy availability and price (related to the peak oil[5] issue):

The International Energy Agency's (IEA) World Energy Outlook[6], published in November 2007, warned for the first time that oil prices will continue to rise as a result of increased demand from developing countries (particularly India and China), combined with a sharp decline in production from existing oil fields. This supply and demand issue is further compounded in nations with an increasing dependency on imports because of the increasingly fractious, and unstable, geopolitical oil economy. In those countries highly dependent on imports, absolute energy availability is more likely to be framed as an energy security issue[7].

Lower carbon fuel sources to mitigate climate change:

The OECD (2008) asked a number of EU and non EU states, as well as the EC, to prioritise current drivers of biofuel policy. Reducing green house gas emissions (GHGs) was amongst the top priorities for most governments[8]. Climate change has the potential to cause severe social, environmental and economic disruption around the world and it has been estimated that in financial terms this could cost our economies between 5-20% of global GDP[9]. Biofuels are perceived to be an important tool for reducing GHGs whilst maintaining high levels of economic activity, thus enabling governments to meet international environmental commitments such as the Kyoto Protocol (Convention on Climate Change 1997) whilst maintaining economic growth and political obligations.

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[5] GAO (2007) Crude Oil: Uncertainty about Future Oil Supply Makes It Important to Develop a Strategy for Addressing a Peak and Decline in Oil Production, US Government Accountability Office report to Congressional Requesters, GAO-07-283, February.
[6] www.worldenergyoutlook.org
[7] OECD (2008) Biofuel Support Policies; An Economic Assessment.
[8] OECD (2008) Biofuel Support Policies; An Economic Assessment.
[9] Stern (2006) The Stern Review on the Economics of Climate Change, HM Treasury, London.

Stimulating rural communities and economies:

Through the creation of new markets for agricultural products, the biofuels sector can provide support for the agricultural sector, stimulating economic growth and rural development[10]. In Europe, rapeseed cultivation has been stimulated to a significant extent by the growth in demand for biodiesel. It has also been widely argued that the emerging biofuels industry could benefit the world's rural poor, in both traditional agricultural areas and in areas previously unsuitable for cultivation. Although a complex and controversial issue, when analysed on a country specific basis, there appear to be significant opportunities for biofuels to reduce poverty and aid economic development[11]. Both energy security and the stimulation of rural communities have been important drivers in countries such as Brazil.

Economic opportunities for firms and nations:

The emerging biofuels industry provides economic opportunities at the individual firm and nation state level. The emerging market, and related technological trajectory, provides significant opportunities for firms able to capitalise on existing, or leverage latent, capabilities. At the interface of the energy, agriculture and biotechnology sectors, the changing industrial configurations enable individual firms to enter historically 'closed' industries. Similarly, nation states are also able to reassess national strategies and redeploy internal capabilities to meet this emerging demand.

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[10] USDA/DOE (2005) Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply, April.
[11] Worldwatch (2007) Biofuels for Transport: Global Potential and Implications for Energy and Agriculture, Earthscan.

Many commentaries have discussed these drivers, but the key point for this current analysis is to emphasise that the balance of the influence of these drivers, relative to each other, varies across different geographical regions and is subject to significant change over time. Shifting political responses to these drivers have already had a major impact on the business and market environment shaping the biofuel environment in the different regions. A schematic view of new biofuel production capabilities in Brazil, Europe and the USA helps to make this point. The early period of sugarcane-to-ethanol biofuels in Brazil was stimulated by energy security concerns after the 1970s oil shocks and pressure to identify markets for Brazilian sugarcane. In the current period, expansion and innovation in this field is additionally motivated by the opportunity to establish export markets for economic development, primarily to the USA and some European countries, such as Sweden. In the USA, the rapid expansion of corn-to-ethanol was motivated almost entirely by energy security concerns. Now sustainability issues have emerged strongly to stimulate efforts to develop lignocellulosic ethanol technologies. For Europe, the combined drivers of agricultural policy and climate change mitigation, particularly challenges set out in the UNFCCC, Kyoto Protocol and Millennium Development Goals stimulated the development of biodiesel production capabilities based on the widely available oilseed crops. As such, global unevenness in the development of biofuels can be seen to result from significant variation in the translation of these drivers into national political agendas.

Until quite recently, biofuels had been considered a 'magic bullet' which could meet the triple challenge of economic, social and environmental concerns. Then controversies started to emerge over the greenhouse gas performance of some biofuels and the potential

struggle to find sufficient agricultural land to meet food and fuel demands[12]. To varying extents in different regions, these issues have raised concerns among policymakers and NGOs leading to some calls for the planned expansion of biofuels to be reversed.

Food vs. Fuel

In 2007/2008, the price of several major agricultural commodities, notably maize, wheat, vegetable oil and rice, spiked and reached record levels, at least in nominal terms. This drew attention to the role that biofuels might play in wider concerns around food prices and food security issues, leading to some alarming statements from international bodies, most notably the United Nations Food and Agriculture Organisation (FAO) and the OECD[13]. Although the FAO and OECD acknowledged a range of factors driving the spike in prices, the headlines picked up the competition between food and fuel for agricultural crops as the major story. The ensuing debate attracted significant attention, especially with an impassioned address by Brazil's President Luiz Inácio Lula da Silva at major summit hosted by the FAO in Rome in June, 2008. Since then, further evidence has emerged to suggest that biofuels played a relatively insignificant role in the price rises. Longer term trends of a gradual increase in prices of the major agricultural commodities can be explained with a combination of demand and supply factors, with some evidence that speculation and panic in the commodity markets played a significant role in the price spike[14]. Of course, a major increase in the cultivation of crops as a feedstock for biofuel would still place pressure on the availability of land for food crops. But, the impact of such increases would be considerably lower, at

[12] EAC (2008) Are biofuels sustainable? House of Commons Environmental Audit Committee, First Report of Session 2007-2008, London, 21st January.
[13] OECD-FAO (2008) Agricultural Outlook 2008-2017, OECD/FAO
[14] Wiggins, S., Stevens, C., Nussbaum, R. and Bottriel, K. (2008) Production and Use of Biofuels in Developing Countries, Overseas Development Institute

least per unit of biofuels supply, if agricultural residues or waste are used or if energy crops are grown on marginal or degraded land. This has created a renew impetus to develop advanced biofuel technologies, which can alleviate the competition between food and fuel uses of crops. More broadly, the debate on food security has led to new calls for a 'sustainable intensification of agriculture'[15] in general to make better use of land.

Biofuel carbon emissions and the indirect land-use change factor

Initially, as the sector developed, there was a widespread belief that biofuels could make a significant contribution to climate change mitigation. However, in early 2008, these claims were contested in a prominent article by Searchinger and colleagues, published in *Science*[16]. The article presented an argument suggesting that the GHG emissions arising from a major shift to energy crops would, for some feedstocks, result in an increase in GHG emissions compared to fossil fuels. These results were reached by considering displacement patterns within the entire global agricultural system that would occur when land previously used for food crops was moved over to cultivation for biofuel feedstock. The approach makes predictions about chains of knock-on effects in the global agricultural system. For example, it was argued that the expansion of maize cultivation in the US would result in lower soya cultivation, which would lead to an increase in soya cultivation in Latin America. For Europe, it has subsequently been argued that a diversion in the use of oilseed rape from food and cosmetics to fuel results in greater demand for a substitute, in particular palm oil from south-east Asia. This phenomenon has been labelled the *Indirect Land Use*

[15] Royal Society (2009) Reaping the Benefits. Science and the sustainable intensification of global agriculture. Royal society, London

[16] Searchinger, T., Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., Yu, T.H., (2008) Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change, Science 29 Vol. 319. no. 5867, pp. 1238 – 1240, February.

Change (ILUC) factor and has had a major impact on the public debate and in the policy community, especially in Europe. In the UK in particular, the government responded by commissioning the Gallagher Review[17], which looked at the existing evidence and recommended that the UK should slow the rate of uptake of biofuels. Subsequently, however, the model, assumptions and data have all been questioned[18], as has the failure to consider the importance of co-products in the calculations and the singling out of biofuels as the only driver of ILUC. There remains little doubt that the expansion of the global biofuels sector will have some ILUC effects, but the scale and importance relative to other drivers will continue to be debated by the scientific and policy communities until greater consensus is reached.

These challenges to the sustainability credentials of biofuels have been hotly debated, as have the precise characteristics of some of the other drivers (e.g. peak oil). Clearly, in a climate of high uncertainty across all of these dimensions, the impact of different drivers for the development of biofuels remains highly volatile. These uncertainties have only been compounded by the recent economic crisis, the scale of which would have been unthinkable only eighteen months ago.

Stakeholder Expectations Survey

When we asked expert stakeholders what they thought the main drivers for biofuel development would be in 2020, they responded in the following way:

- Opinion was evenly split between climate change, energy security and oil price as being the main biofuels drivers in 2020. However, some interviewees grouped energy security

[17] Gallagher (2008) The Gallagher Review of the indirect effects of biofuels production, The Renewable Fuels Agency, London.
[18] See letters in *Science* **320** (5882)

and oil price together and a couple of interviewees argued that energy security was a more important driver in the USA than in Europe. Climate change mitigation was perceived by two interviewees as the only justification for the large public subsidy of biofuels.

- Highly ranked influences, rather than core drivers, included access to sustainable feedstocks and the price of land and commodities. One interviewee emphasised the role of waste management, taking the view that a lack of waste disposal options will drive the industry towards waste-derived biofuels because of the negative feedstock costs.
- Lower down in priority were economic opportunities, EU agricultural protection and the agricultural lobby.
- Four interviewees emphasised the on-going importance of policy measures designed to mitigate the higher cost of biofuels relative to fossil fuels. One interviewee, however, was confident that the cost of (presumably taxed) fossil fuels and particular biofuels will eventually reach parity and this could be before 2020.

2.2 Governance and Government Policy

The development and scale of markets for biofuels in Europe has been significantly shaped and driven by national and EC policy. Policy has set mandatory targets so initiating and guaranteeing market creation, but by so doing, has set limits to market expansion. Currently, Europe stands at the low end of ambition for biofuel markets compared with the US. The principal and common framework for the promotion of biofuels in Europe that are currently in place are the Renewable Energy Directive (December, 2008) and the Fuel Quality Directive (December, 2008). Earlier mandated targets for biofuel use have been replaced following the major controversies over land-use by a requirement for renewable energy for transport, no longer specifying a particular technology, such as biofuel. The Directive now requires 10% for energy from renewable sources in transport by 2020. Secondly, the Directive now enshrines sustainability criteria and regulation for biofuels, requiring 35% greenhouse gas savings from now until 2017, and 60% GHG savings from new installations and processes thereafter. A review, and possible tightening of sustainability criteria, is timetabled for 2013. The Fuel Quality Directive requires the continued provision of petrol with a *maximum* of 5% ethanol blend until 2013, and the gradual phasing in of 10% bioethanol (E10) over the coming years. It also requires a 6% reduction in GHG emissions from units of energy supplied for transport fuels by 2020. The FQD therefore leaves options open for technological solutions, but biofuel blends of 15% (bioethanol) or 12% (biodiesel), would meet the mandate provided the biofuel in question achieved the required 60% GHG saving.[19]

[19] Watson, M. 2009. 'Renewable Fuel Directive', http://www.dft.gov.uk/rfa/_db/_documents/RFA_Renewable_Energy_Directive_January_2009_used.pdf

The mandatory provisions of the Renewable Energy Directive and Fuel Quality Directive set the framework for biofuel market development in Europe. At a national level they can be implemented by measures such as the RTFO in the United Kingdom. As a secondary instrument, government interventions can also directly stimulate expansion of biofuel production, for example by offering subsidies to farmers and processors.

The mandatory measures have been combined in Europe and supported by financial incentives, such as farmer subsidies in the form of Energy Crop Aid (farmers receive 45 Euros per ha for up to 2million ha for growing sugar beet on non set-aside land). Recent developments in the use of these instruments have shifted the focus from expansion of any biofuel to expansion plus stimulation of innovation in advanced biofuels. As such, targets and mandates in some countries, most notably the USA, stress the proportions of advanced biofuels, and of biofuels that meet minimum sustainability standards, that will be required in the overall supply mix of the future. A number of commentators have argued that targets should only be increased if it is possible to demonstrate the sustainability of biofuels[20] and there is controversy emerging around acceptable definitions of sustainability (further discussed in Section 2.6). Some stakeholders have raised concerns about the capacity of producers to meet the targets at all.

While the policy stimulus for biofuel development in Europe is dominated by the EC frameworks outlined above, implementation in member states is uneven and based on alternative policy measures. Different tax incentives, obligations, and trade tariffs, present a

[20] Gallagher (2008) The Gallagher Review of the indirect effects of biofuels production, The Renewable Fuels Agency, London

picture of considerable complexity (see Table below that summarises primarily tax incentives).

Country	**Biodiesel**	**Bioethanol**
France	25 cents per litre subsidy to national French quota producers	33 cents per litre subsidy for national French quota producers
Germany	9 cents per litre on pure and 15 cents per litre on blends until 2011 Tax planned to increase annually, e.g. tax on pure biodiesel will increase to 15 cents, 21 cents, 27 cents, 33 cents, and 45 cents from 2012	Lack of information No tax on 2G including E85 until 2015
Greece	Full tax exemption	Lack of information
Italy	Full tax exemption for 200,000 tons pa until 2010	Reduced excise duty up to a total national expenditure of €73mn
Poland	Full tax exemption for pure and 1.0 PLN reduction in duty on each litre of biofuels added on blends over 2%	Full tax exemption for pure and 1.5 PLN reduction in duty on each litre of biofuels added on blends over 2%
Spain	Full tax exemption (including blends) until 2012	Full tax exemption (including blends) until 2012
Sweden	Reports not translated	Reports not translated
UK	20p per litre duty differential until 2009/10 Also 15p per litre buy-out price (price paid by fuel suppliers who fail to meet their obligation) under RTFO Currently these incentives combined are equivalent to 35p per litre, this will be reduced to 30p per litre by 2010/11	20p per litre duty differential until 2009/10 Also 15p per litre buy-out price (price paid by fuel suppliers who fail to meet their obligation) under RTFO Currently these incentives combined are equivalent to 35p per litre, this will be reduced to 30p per litre by 2010/11

Source: Country reports at http://www.ebb-eu.org/legislation.php

These market-based measures have been introduced to stimulate new directions in biofuel innovation, but perhaps more significant are the Europe-wide government funding and coordination efforts for biofuel R&D. There are no programmes to match the Genes-to-Life or the Biomass Research and Development Initiative (which includes major investment in commercial scale cellulosic ethanol facilities) of the USA, but national and EC research funders have instituted a variety of biofuel or wider bio-energy programmes. Equally, there have not yet been any moves by European governments to emulate the Brazilian government in coordinating the adoption of flex fuel engine technologies by major vehicle manufacturers, something that the Obama presidency appears to be considering for the USA.

A further issue is the impact of government policy on international trade of biofuels and this currently works in two directions. On the one hand protectionist policies, in the form of import tariffs, have been employed in several notable cases, most recently by the European Commission for imports of US biodiesel. This was instituted to end the almost-fraudulent practice of "splash and dash", whereby non-US soy biodiesel was briefly imported to the US and then exported, taking advantage of a US export subsidy. Another example is the EC's most-favoured nation tariff, which currently adds at least 25% to imported ethanol. This tariff is reduced however if the exporting country has signed a free trade agreement or is covered by the General System of Preferences[21]. These measures are defended as necessary to promote domestic production capacity. On the other hand, some governments have been particularly active in forming governmental bilateral agreements for trade in biofuels. The recent endeavours of the

[21] Biofuels Research Advisory Council, 2006

Brazilian government are notable is this regard, for example with the agreement that has been established with the Swedish government to drop import taxes on Brazilian sugar cane ethanol.

Finally, a number of non-governmental initiatives have emerged over the past few years to create standards for biofuels. The most prominent examples have been the Roundtables for Sustainable Palm Oil (RSPO) and for Sustainable Biofuels (RSB), and the Better Sugar Cane Initiative (BSI). These initiatives incentivise private sector self-regulation. They draw together key commercial players within the industries of the respective commodities with representatives from NGOs to establish criteria for judging the sustainability of biofuels, especially those relating to the impact of expanded agriculture for biomass feedstocks. As such, they have essentially pre-empted government regulatory action and appear to continue to grow in importance and recognition. However, there are concerns that industry involvement will compromise regulatory standards. For this reason, many NGOs are pushing for national and international sustainability criteria (including carbon reduction standards of 60-80% based on full lifecycle analysis data) in an effort to control markets as they emerge. Responding to this, the UK government has established a metastandard to which reporting is not yet mandatory.

Stakeholder Expectations Survey

When survey respondents were asked to comment on the likely European policy frameworks for biofuels in 2020, they responded as follows:

- The majority of experts (twelve) forecast that mandates/targets will remain the most important government policy for the biofuels sector in 2020. Two experts identified the Renewable Energy Directive as the

critical piece of legislation. There was consensus that mandates are necessary to create a market for a relatively expensive product. Most experts agreed that mandates are the simplest and cheapest policy tool to stimulate the industry, partly because they don't require direct government funding. A majority of these experts emphasised that the current targets are ambitious and could be difficult to meet; this concern was compounded by the current economic situation. One expert argued that the target would be scrapped and replaced by targeted supports; another argued that some member states would set higher targets in transportation to meet national renewable energy targets.

- Two experts identified the Fuel Quality Directive (FQD) as an important driver of the biofuels sector. Article 7A of the FQD directive legislates for carbon reduction in transport fuels with the onus on companies who produce for the market (incl. oil firms) to demonstrate this reduction.

- Two experts stated that R&D funding (at the European level using FP) will be the most important policy tool in 2020. A further two experts argued that R&D support is a secondary supporting tool. One expert argued that R&D should not be supported at all as the majority of production costs are associated with converting agricultural commodities to energy commodities and private funding is readily available to spend in this area.

- Three experts argued that trade mechanisms for biofuels will be increasingly important. One argued that a trade dispute will open up this issue and will be instigated by the inclusion of social policy issues, i.e. ILUC and sustainability criteria. A significant number of experts identified sustainability standards as an important policy tool in 2020, in addition to technical standards. One expert argued that biofuels will be competitive with oil by 2020; enabling regulators to focus on ensuring biofuels are sustainable. Another expert argued that mandatory carbon reporting will be required across the agricultural sectors more generally (as ILUC is relevant to food too).

- Other important supporting policies in 2020 identified by experts included incentives, fiscal policy, duty exemptions, consumption tax breaks (for e.g. FFVs), removal of subsidies for food and non food based crops, possibly a fair trade forest certification scheme and the use of Renewable

Obligation Certificates (ROCs).

- One expert was concerned that regulation takes a tech-neutral approach based on performance rather than technology specificity. A number of experts emphasised the importance of clarity and consistency. One expert emphasised the systemic and complex nature of regulation, when small legislative changes have unexpected consequences in the system.

2.3 Technologies, products and processes

a) Biofuel production technologies

Current and potential technologies involved in the conversion of biomass to liquid fuel range from traditional fermentation (alcohols have, of course, been produced from grains and sugars for a very long time) to exotic visions of developing synthetic micro-organisms based on modern life science knowledge. There is clearly a lot in between these extremes, including the redeployment of some old approaches such as the Fischer-Tropsch process and the current efforts to develop technologies for lignocellulosic ethanol.

Discussions of biofuel technologies are typically framed in terms of generations. This can lead to some confusion, since it fails to differentiate between the different phases of biofuel production and end product[22], and poses the problem of how to establish the dividing lines between 2nd, 3rd and 4th generations. A better framework is one that distinguishes between innovation in feedstocks, refining and in the downstream product domain on the one hand and between the status of technologies as commercialised, prototype (i.e. field trials or demonstration plants) or laboratory status on the other.

The Table below offers some examples of the current technological landscape.

	FEEDSTOCKS	PROCESSING	PRODUCTS

[22] NNFCC (2007) NNFCC Position Paper: Biorefineries, January.

		(REFINING)	
COMMERCIAL	*Bioethanol:* *Sugar (beet and cane), corn, wheat, barley, sorghum, rye* *Biodiesel:* *Rapeseed, canola, sunflower, soya, palm*	*Thermochemical* *Fermentation* *Transesterification*	*Bioethanol* *Biodiesel* *Flexfuel engine* *Coproducts*
PROTOTYPE	*Lignocellulosics, Jatropha, switchgrass, sweet sorghum, 'waste', miscanthus, wood chip* *GM crop varieties*	*Thermochemical* *Fermentation* *GM microbes* *Gasification* *Fischer-Tropsch*	*Cellulosic Ethanol* *Synthetic Diesel Fuel* *Biobutanol* *Engine optimised for alcohols*
LABORATORY	*GM crop varieties, synthetic microorganisms, algae,*	*Integrated biorefinery*	*Hydrocarbons* *Jet fuels* *Co-products from integrated biorefinery*

One of the key technology issues concerns the energy intensity of different crops (feedstocks) for different fuels. The more Giga Joules of energy per hectare from a given crop, the less land is required. The table below presents energy intensity variation between feedstocks and provides approximate figures for the potential outputs of biofuels per hectare, per annum.

Potential Outputs of Biofuels per hectare per annum[23]

(These figures are extremely approximate and depend on geographical location, cultivation inputs and techniques, harvesting and processing, etc)

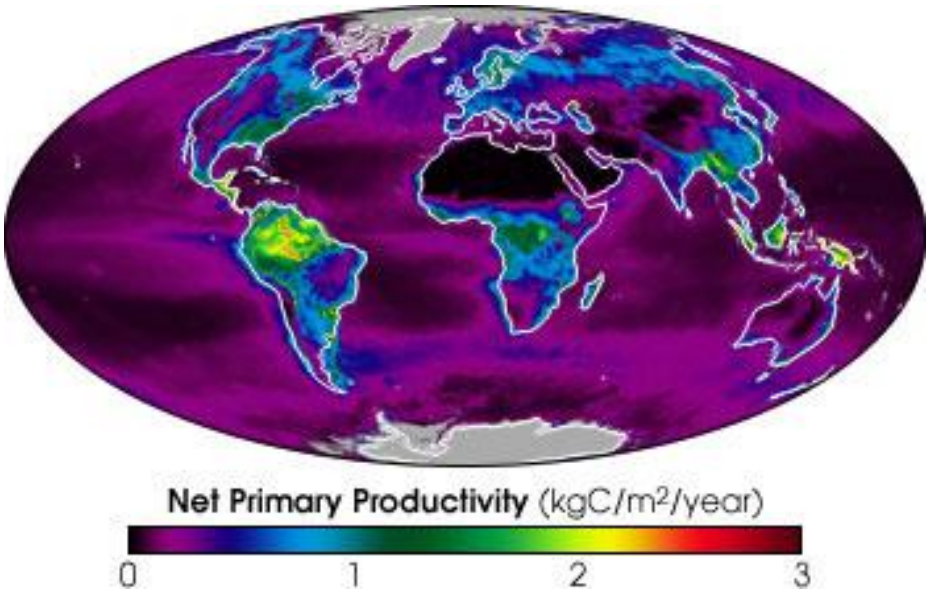
Fuel	Net calorific value (MJ/kg)	Output per hectare p.a. (t/ha.pa)	Energy per ha per annum	
			GJ/ha.pa	MWh/ha.pa
Wood (forestry residues, SRW, thinnings, etc.) @ 30% MC	13	2.9 (2 odt)	37	10.3
Wood (SRC Willow) @ 30% MC	13	12.9 (9 odt)	167	46
Miscanthus @ 25% MC	13	17.3 (13 odt)	225	63
Wheat straw @ 20% MC	13.5	4.6 (3.7 odt)	62	17
Biodiesel (from rapeseed oil)	37	1.1	41	11.3
Bioethanol (from sugar beet)	27	4.4	119	33
Bioethanol (from wheat)	27	2.3	62	17
Biogas (from cattle slurry)	20	0.88	18	4.9
Biogas (from sugar beet)	20	5.3	106	29

23 http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,163231&_dad=portal&_schema= PORTAL

The energy intensity of different feedstock varies greatly and is difficult to reliably calculate because it depends on a number of factors, such as geographic location, cultivation conditions, harvesting and processing techniques. The regionalisation of existing feedstock by historical and agronomic factors further constrains any location debate by providing a level of path dependency. The figures above summarise a view on European land use and energy intensity. But temperate zone biomass for biofuel compares poorly with crops grown in the subtropics, particularly sugarcane and palm oil. With current technologies, sugarcane produces up to 7,000 litres of fuel per hectare, as compared with the 2000 litres of rapeseed methyl ester (RME)[24]. This contributes to the controversy of where funding is directed and what geographic locations and feedstocks are most efficient and sustainable. As such, multiple solutions are being sought for different locations and the relative advantages of specific global regions is clear when we consider the average carbon fixation rate of plants in different parts of the world.

[24] DEFRA, 2008. *Review of work on the environmental sustainability of international biofuels production and use*.

The Earth's carbon "metabolism": productivity and location[25]



This map shows that average annual carbon capture (hence input-output energy yield) is much higher in subtropical than in temperate zones, and this has clear implications for the demand for land. It is substantially cheaper to produce biofuels in tropical and subtropical countries[26]. These issues will undoubtedly have a major impact on European future directions, and the balance between home-grown or imported fuels.

The other key technological issue for biofuels concerns the varied levels of GHG savings of different crops for different fuels. The table below[27] illustrates this variation and also the performance of the biofuels against their fossil fuel alternatives. Clearly, from this data, the potential for biofuels looks very promising, with sugarcane as the best performing commercial scale option.

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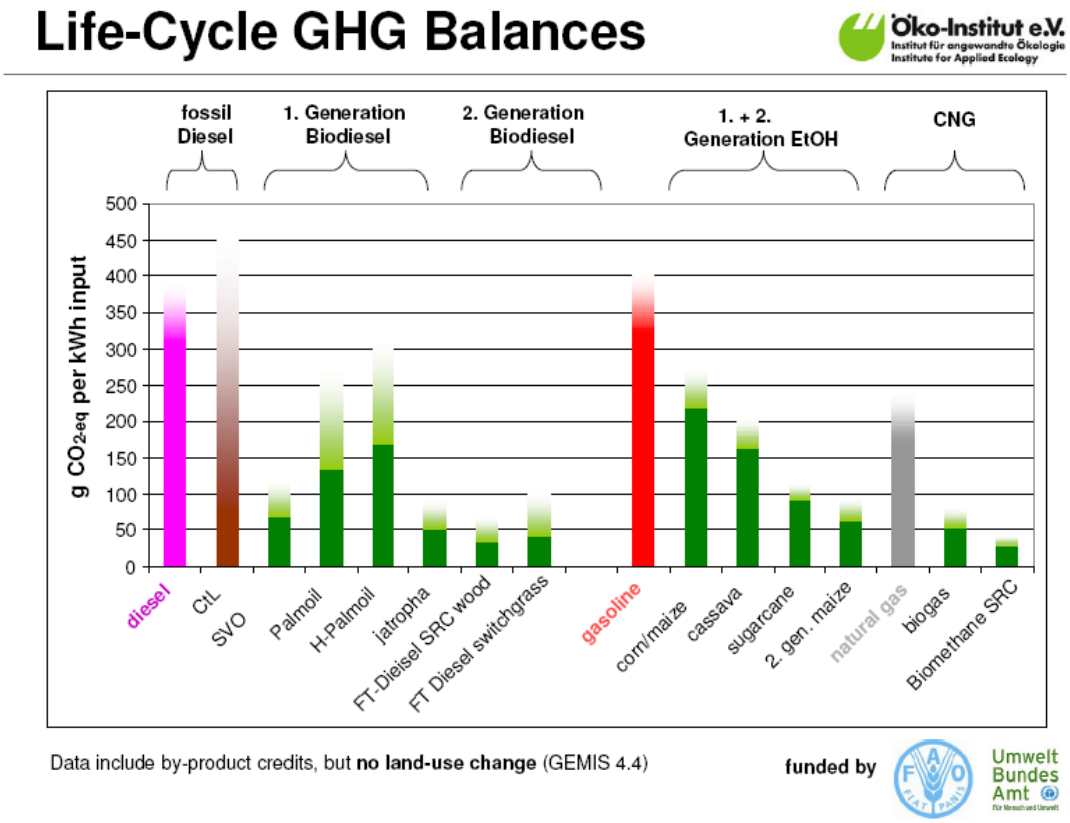
[25] NASA (2003) http://earthobservatory.nasa.gov/Newsroom/view.php?old=2003042214379

[26] International Energy Agency (2004) Biofuels for Transport: An international perspective,

[27] Fritsche, U. et al. (2008) 'The "iLUC Factor" as a Means to Hedge Risks of GHG Emissions from Indirect Land-Use Change Associated with Bioenergy Feedstock Provision', working paper prepared for BMU, Darmstadt (forthcoming), Oeko-Institut.



However, as discussed earlier, the carbon reduction claims of biofuels have been significantly reassessed using models that assess the potential impacts for carbon emissions that occur through shifts in land-use that would follow from a major increase in land devoted to biofuel feedstocks. Analysis of indirect land-use change (ILUC), especially where displaced agriculture is predicted to encroach on rainforests, results in an overall increase in carbon emissions for some biofuels. As the table below shows, this effect appears differs significantly according to feedstock and geographical location of cultivation. The analysis also accounted for varying degrees of risk that indirect land use change would occur ranging from a minimum of 25% risk to a maximum 75% risk. This is intended to take account of the potential for biofuel feedstock cultivation to use idle, marginal land or intensifying the use of existing cultivation. From

this analysis, the prospects for European rapeseed-to-biodiesel look particularly unpromising.

Life Cycle GHG Emissions of biofuels and impacts from indirect land use change[28]

	kg CO_{2eq}/GJ with iLUC factor including conversion/by-products, without direct LUC			relative to fossil diesel/gasoline, including conversion/by-products		
biofuel route, life-cycle	max	med	min	max	med	min
Rapeseed to FAME, EU	260	188	117	201%	118%	35%
palmoil to FAME, ID	84	64	45	-3%	-25%	-48%
soyoil to FAME, Brazil	101	76	51	17%	-12%	-41%
sugarcane to EtOH, Brazil	48	42	36	-44%	-52%	-59%
maize to EtOH, USA	129	101	72	50%	17%	-16%
wheat to EtOH, EU	144	110	77	67%	28%	-11%
SRC/SG to BtL, EU	109	75	42	26%	-13%	-51%
SRC/SG to BtL, Brazil, tropical	34	25	17	-61%	-71%	-80%
SRC/SG to BtL, Brazil, savannah	59	42	25	-32%	-51%	-71%

These recent studies have had a dramatic impact on policy, especially in Europe. The UK government reacted by establishing the Gallagher Review to reassess government support for biofuels, with the final recommendations suggesting a slow down in biofuel uptake.

But, the ILUC approach has stimulated a much wider global scientific debate. The original data and models have received considerable scrutiny from the scientific community and there currently is a wide range of views about the significance of the claims that were made. For example, one important omission from the original Searchinger study was the carbon saving potential of coproducts from the production of biofuels. The carbon footprint of biofuel is greatly reduced if the biorefinery process delivers a number of products beyond biofuel, chemical building blocs for plastics, protein for animal feed, and so on.

[28] *Ibid*

In addition to uncertainties over the real impact of ILUC, other critics of the approach have questioned why biofuels should be singled out for their impact on land-use, with little or no equivalent analyses of other pressures on the availability of agricultural land. Increased demand for food, and dietary shifts towards more meat eating on a global scale, remain much more significant sources of GHG emissions than those from transport, and are a much greater driver of land use change.[29] Furthermore, the GHG emissions of biofuels have been compared against a static measure for fossil fuels, despite widespread agreement that the energy intensity of oil extraction will increase significantly for tar sands and oil shales.

There is similar complexity when evaluating processing technologies. Although processing techniques are influenced by the chosen input and the desired output, there remains considerable variety within each process. For example, refiners using fermentation as opposed to thermochemical techniques (or in addition to thermochemical) vary in their choice of enzyme, and their strategic approach. Some firms focus on modifying specific enzymes whilst others focus on integrating and industrialising existing processes. This diversity extends the debate over best production models, for example whether to build stand alone refinery plants or plants integrated with existing feedstock mills. Both configurations are in operation. Similarly, should refineries focus on fuel production or are new integrated refineries for fuel and biomaterial production essential to improving the outlook for biofuels[30]?

[29] World Resources Institute (2005) Navigating the numbers: greenhouse gas data and international climate change policy. Washington DC: World Resources Institute.

[30] Biofuels Research Advisory Council (2006) Biofuels in the European Union: A vision for 2030 and beyond, EUR 22066, EC

Apart from fuel-refining technologies, perhaps the single key aspect of refinery for enhancing overall GHG saving performance concerns the development of co-products. The British Sugar refinery at Wissington is exemplary of a multi-product integrated production system (sugar, bio-ethanol, tomatoes, topsoil, animal feed, fine chemicals), of which bio-ethanol from sugar beet is but one component, making the whole output more environmentally sustainable. Likewise, one of the main co-products of wheat-to-ethanol refinery, Dried Distillers Grain with Solubles (DDGS), is a high-protein animal feed, which, by substituting for soybean, reduces pressures on indirect land use in sub-tropical areas. But there are as yet few developed or accepted standards for measuring overall greenhouse gas reductions from these complex, integrated, refinery processes. European proponents of the integrated model have argued that the UK RTFO is stimulating fuel-only development and markets, rather than an integrated biorefinery model. Critics of integrated biorefineries argue that high end chemical products, as opposed to liquid fuels, cannot be produced from poor feedstocks and that the processes should remain distinct. Analysis is further complicated as refineries can vary from no flexibility of inputs and outputs, to full flexibility for inputs and outputs. Currently, as different enzymes are required for different feedstocks, it is unclear how much flexibility can be achieved using existing fermentation processes, for example, or how achievable a 'one-stop-shop' truly is. As such, there remains significant experimentation in production models.

Stakeholder Expectations Survey

When expert stakeholders were asked about which technologies would dominate the European biofuels sector in 2020, the main responses were as follows:

- Most interviewees expect bioethanol and biodiesel to be the most widely available biofuels in 2020 and are evenly split on which will dominate. Reasons for the differing views vary, ranging from the belief that the diesel fuelled internal combustion engine (ICEs) will dominate vehicle technology in Europe, to the view that bioethanol will exhibit faster growth because the conversion technology is more advanced.
- Over half of interviewees believed that lignocellulosic technologies will either dominate or will have entered the market by 2020. About a quarter believed that biobutanol will be more widely available. Other notable comments included increased use of hydrogenated oils, BTL, biogas, algae, and jatropha. In general there was some agreement that the variety of feedstocks and processing technologies will increase, this was also captured by the diversity in responses.
- A number of experts agreed that first and second generation fuels would exist in parallel for a number of years. Most experts implied that second generation biofuels are more desirable, in contrast a couple of interviewees argued that first generation biofuel technologies are simpler and more efficient. It was notable that interviewees often had very clear but very different understandings of what second generation meant, using the term to refer to feedstocks, processing technologies and fuel types.
- There was an even split among those interviewees who commented on whether fermentation or thermal based processing would dominate. Two individuals commented that enzyme development would be important. One expert commented that while enzymes require a homogenous input, this could be a problem for the heterogeneous nature of waste as a feedstock.
- Several interviewees commented that GM crops would be increasingly important, though one commented that special purpose crops (i.e. strains for either food OR energy) would not be successful, as farmers are inclined to choose crops with the broadest capabilities.

b) Biofuels & transport technologies

Biofuels are primarily used in road transport light vehicles, with small quantities being used in trains and airplanes. The existing infrastructure has a significant influence on the emergence, and organisation, of the biofuels industry. Both ethanol and biodiesel are predominately sold as low-percentage blends in Europe, for example E5 or B5 (5% blends of ethanol and biodiesel respectively). This low percentage blend does not require changes to existing engine design or distribution infrastructure and current mandates could be met by increasing the volume of biofuels sold at this percentage. Some European countries do sell biodiesel blends up to 30%, and pure biodiesel (B100) is available in Germany but can only be run on modified vehicles. As modified vehicles are required for higher or pure blends, vehicle manufacturers play a vital role in the future development of the biofuels industry.

The conventional diesel powered internal combustion engine (ICE) dominates in Europe influencing the development of domestic biofuel production capabilities and the geographical distribution of imports. Debates ensue about the relative proportions of bioethanol and biodiesel in Europe in the future. Competition is emerging between engines modified for biofuel production and alternative designs. Flexible-fuel vehicles (FFVs), electric cars and hybrids are available (in limited quantities) in Europe and significant variety is exhibited across countries; for example Sweden, as discussed in Section 2.5, is proactively pursing an importation of Brazilian bioethanol approach whereas the UK is moving towards electric cars and nuclear power. A number of commentators argue that electric cars are the long-term solution to reducing carbon emissions[31,32].

[31] WWF (2008) Plugged In – The End of the Oil Age, Questions and Answers, 2nd April.

This position assumes the power sector is decarbonised through compatibility with multiple sources of renewable energy or nuclear generation. Hydrogen vehicles are perceived as another long term another competitor with biofuel powered vehicles. Advocates of these perspectives tend to view biofuels as a 'stop gap' between fossil-fuel based liquid fuels and energy storage technologies serviced by a new infrastructure and energy production paradigm. But, these alternative perspectives need to consider whether 'green electricity' or other alternatives will substantially eliminate the demand and use of liquid transport fuels, in the short, medium and long term. Furthermore, even the most optimistic scenarios for electric vehicles project a relatively modest impact on the European transportation fleet by 2020. In a study commissioned by BERR[33] (now BIS) in the UK, the high range scenario saw a 4.9% market penetration for electric vehicles and the extreme uptake scenario set an aspirational level of 10% So even if electric vehicles diffuse rapidly over the next decade, the choice will largely remain between fossil fuels and renewable biofuels.

Stakeholder Expectations Survey

When survey respondents were asked about the relative importance of different transport modes in 2020, the main issues raised were:

- The majority of interviewees agreed that ICEs will dominate and that hybrids, FFVs and plug-in hybrids will be more widely available.
- Four interviewees explicitly referred to biofuels as a transitional technology. Two argued that they are a stop gap to electric cars, nuclear power and a more integrated

[32] King (2007) The King Review of Low Carbon Cars: Part 1: the potential for CO2 reduction, October.
[33] BERR (2008) Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plugin Hybrid Vehicles. BERR, London

transport system. Another argued that the transition will be from ICE to FFV to biobutanol and thence to hydrogen storage technology. Another argued we will leap past hybrids to hydrogen because it is a known technology. However, the latter was a relatively unusual view: of those experts commenting on hydrogen technology, the majority believed it to not be technologically possible by 2020; two believed it possible; and one expected hydrogen to have 5-10% of the market by 2020.

- A couple of experts emphasised that electric vehicles are more suited to city living or shorter trips. A couple of experts mentioned problems with batteries – either as a negative driver due to heavy metal and exotics use – or stating that vehicle innovation will be driven by battery innovation – similar to mobile phone technologies.
- Several experts also pointed to energy efficiency as a key driver of vehicle innovation.

2.4 Reconfiguring the industrial landscape and the emergence of new business models

All significant technological transitions are accompanied by major shifts in industrial organisation. Incumbent firms disappear, shrink or adapt. New types of firm emerge with novel business models and these changes bring about reconfiguration of supply chains. In times of transition, the extent to which fully integrated business models or a sharp division of labour emerges is up for grabs. The current industrial landscape for biofuels reflects this uncertainty. The existing petroleum industry is of course highly integrated, with the dominant oil companies controlling the process across exploration, extraction, refining, distribution and to a lesser extent in retail. The biofuel system currently presents a more fragmented picture and the development of new supply chains to achieve the required coordination is a significant challenge.

The large oil firms are not major players in the European biofuel system at the moment, but their activity in biofuel research and innovation suggests that they might become key actors in the future. The current landscape is dominated by three types of firm: incumbent crop processors moving into the biofuel field (e.g. British Sugar and Südzucker) through diversification strategies; new processing firms and ventures which have been established to produce ethanol (e.g. Ensus, CropEnergies, Biogasol and Agroetanol) or biodiesel (e.g. Perstorp BioProducts, Campa AG and Choren Industries); and, new firms that have focused mainly on sourcing and importing biofuels for the production of blended fuels for distribution and retail (e.g. Greenergy – who do also produce biodiesel - and Sekab).

Main biodiesel producers in Europe, 2007 (tonnes)

Entreprises/ *Firms*	Pays/ *Countries*	Nombre d'unités/ *Plants number*	Capacité de production (tonnes/an)/ *Total capacity (tons/year)*
Diester Industrie	France/*France*	7	1 240 000
VERBIO AG	Allemagne/*Germany*	2	380 000
Cargill	Allemagne/*Germany*	2	370 000
Biopetrol	Allemagne/*Germany*	2	350 000
Ital green oil	Italie/*Italy*	1	300 000
Gate	Allemagne/*Germany*	2	260 000
Novaol	Italie/*Italy*	1	250 000
Saria Bio	Allemagne/*Germany*	3	212 000
Greenergy	Royaume-Uni/*UK*	1	200 000
Petrotec	Allemagne/*Germany*	2	185 000

Source : EurObserv'ER 2008 (d'après Reuter).

Main bioethanol producers in Europe, 2007 (million l)

Entreprises/ *Firms*	Pays/ *Countries*	Nombre d'unités/ *Plants number*	Capacité de production *Total capacity*	Matières premières/ *Raw materials*
Tereos	France/*France*	7	740	Betterave sucrière, blé/*Sugar beet, wheat*
Abengoa Bioenergie	Espagne/*Spain*	3	520	Céréales, alcool vinique/*Cereals, wine alcohol*
VERBIO AG	Allemagne/*Germany*	2	330	Céréales (seigle, blé, orge)/ *Cereals (rye, wheat and barley)*
CropEnergies AG	Allemagne/*Germany*	1	300	Blé, betterave sucrière/*Wheat, sugar beet*
Cristanol	France/*France*	3	290	Betterave sucrière, alcool vinique/ *Sugar beet, wine alcohol*
Agrana Bioethanol GmbH	Autriche/*Austria*	1	240	Blé, maïs/*Wheat, maize*
IMA (Bertolino Group)	Italie/*Italy*	1	200	Alcool vinique/*Wine alcohol*
SEKAB	Suède/*Sweden*	1	100	Alcool vinique/*Wine alcohol*
Akwawit	Pologne/*Poland*	1	100	Céréales (blé, maïs, orge, seigle), mélasse/ *Cereals (wheat, maize, barley, rye), molasses*
Saint Louis Sucre	France/*France*	1	90	Betterave sucrière, mélasse/*Sugar beet, molasses*

Source : EurObserv'ER 2008 (d'après Epure).

However, the cast of firms involved in developing new biofuel technologies is much broader. European oil companies have been

increasing their investments in biofuel R&D, through collaborative projects and joint ventures with firms occupying different phases of the potential value chain (e.g. BP, NesteOil and Total). As such, the oil companies have become significant actors in stimulating the search for advanced biofuels, ranging from R&D into cellulosic ethanol, to new crops (such as Jatropha and Miscanthus) and also algae based biodiesel. Indeed it is worth noting that the JV between BP and D1 for the development of Jatropha as a feedstock for biodiesel promoted a vision of an integrated business model, where agriculture, processing and fuel distribution would come under one corporate roof.

Multinational agricultural technology firms, including Monsanto, Syngenta and Archer Daniels Midland are active in Europe in the search for advanced biomass feedstock, with research programmes addressing both yield and traits (crops tailored specifically for energy biomass purposes). Clearly, the orientation of their research programmes and the extent they are based on genetic modification techniques has been influenced by the contrasting regulatory regimes of Europe and the USA.

Innovation in biorefining is undertaken by incumbent and new crop processors, chemical companies, plant manufacturers and relatively new science-based companies. The technological landscape outlined in section 2.3 is populated by these firms placing bets, through internal R&D ventures or in collaborative partnership, on which technologies will prove most viable. Finally, parts of the R&D landscape are heavily reliant on knowledge produced in universities and government laboratories. There is some degree of interaction between public and private research activities in Europe, but it is notable that there is nothing to match the colossal investment by BP

to create the Energy Bioscience Institute at Berkeley and Illinois Universities in the USA.

Stakeholder Expectations Survey

When expert stakeholders were asked to consider the types of firm that will dominate the European biofuels sector and the likely reconfiguration of supply chains, they responded as follows:

- Eight experts forecast that the large agri-business and oil companies will dominate the biofuels sector in 2020. Most of these agreed that agri-business would dominate upstream and oil companies would dominate downstream. Economies of scale were given as the main reason for this. Most experts agreed that there would be no forward or backward integration – two reasons were given for this; the different cultures and fast changing government regulations suited to different elements of the supply chain. It was agreed that agri-business and the oil companies would be integrated by a variety of modes of coordination (primarily collaboration or market mediated interactions). One expert argued that this depended on geography, for example, it is possible to buy sugar on the open market in Europe but in Brazil plants need to be more integrated with sugarcane plantations. Two experts argued that coordination would be performed by trade orientated organisations and that commodity transactions would dominate (these trade houses will themselves experience consolidation). Three experts argued that joint ventures and partnerships would dominate. Reasons for this included the development of technologies (which would be followed by consolidation and vertical integration), the reduction of risk, the importance of co-products (animal feed requires distributing as well as biofuels) and that traceability/sustainability criteria are more suited to agricultural supply chains than oil supply chains. A number of experts did not comment directly on the mode of coordination.

- Five experts forecast that oil companies will dominate the sector in 2020. Two main explanations for this vertical integration were given; firstly, that sustainability criteria will move supply chain organisation towards direct contracting and away from international commodity market; and secondly, that oil companies are making significant investments in infrastructure and R&D and have the finance

available to continue these investments. The biofuels sector was compared to the pharmaceutical industry where smaller tech companies are bought out, as well as to the supermarket model where the entire chain is not wholly owned but is coordinated by retailers who control the bulk of profits.

- A minority of experts forecast that oil and agri-business will fragment and move out of the biofuels industry. One expert argued that oil companies will continue to move out of blending and distribution and agri-business will move out of biofuels so plants will be taken over by the new distributors (this was seen as necessary to remove the commodity price squeeze). The other expert argued that the sector is increasingly heterogeneous and new companies will continue to enter e.g., energy, food, chemical, biomass etc, so coordination will occur through partnerships.

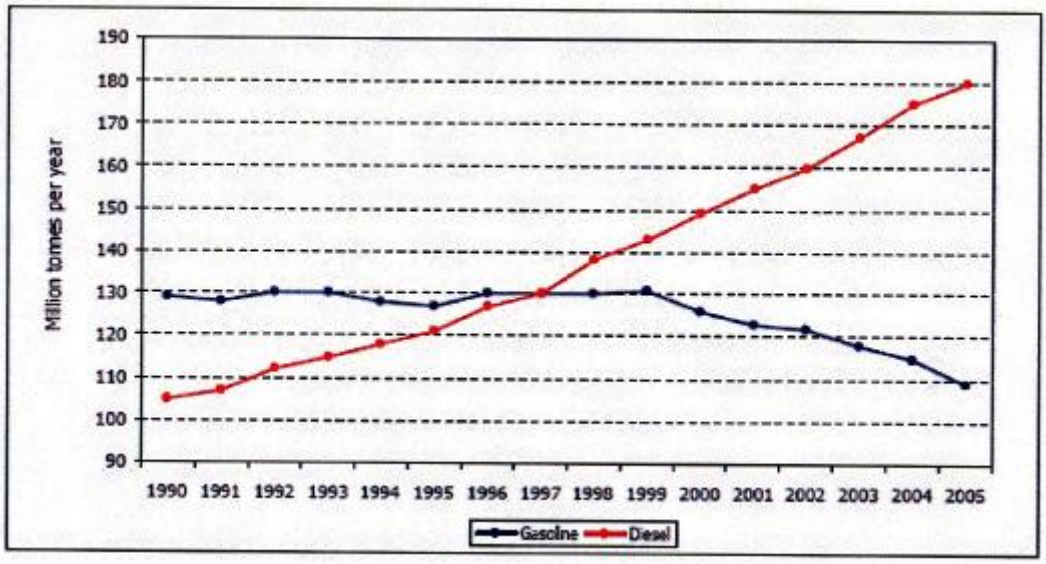
- One expert predicted that integrated agribusiness will dominate the sector, primarily because they own the assets and also because agribusiness is more able to meet the sustainability criteria discussed above. This expert argued that we will see downward integration and specialist biofuels firms will prove to be transient.

2.5 Markets, demand and public acceptability

The current market for biofuels can be characterised in three overlapping dimensions. First, it is important to distinguish between personal private transportation, public transport, public procurement, and commercial distribution of goods. The potential for biofuels to substitute for mineral fuels is therefore dependent on changing the purchasing behaviour of individual consumers, commercial and government public transport organisations and companies that require significant fuel to obtain and distribute raw materials, part assembled goods and final products. One important difference is that for personal private transportation, the consumption of biofuel is largely 'invisible', blended by obligation

into all fuels, whereas companies with significant distribution fleets make strategic decisions of the proportion of biofuel in their fuels.

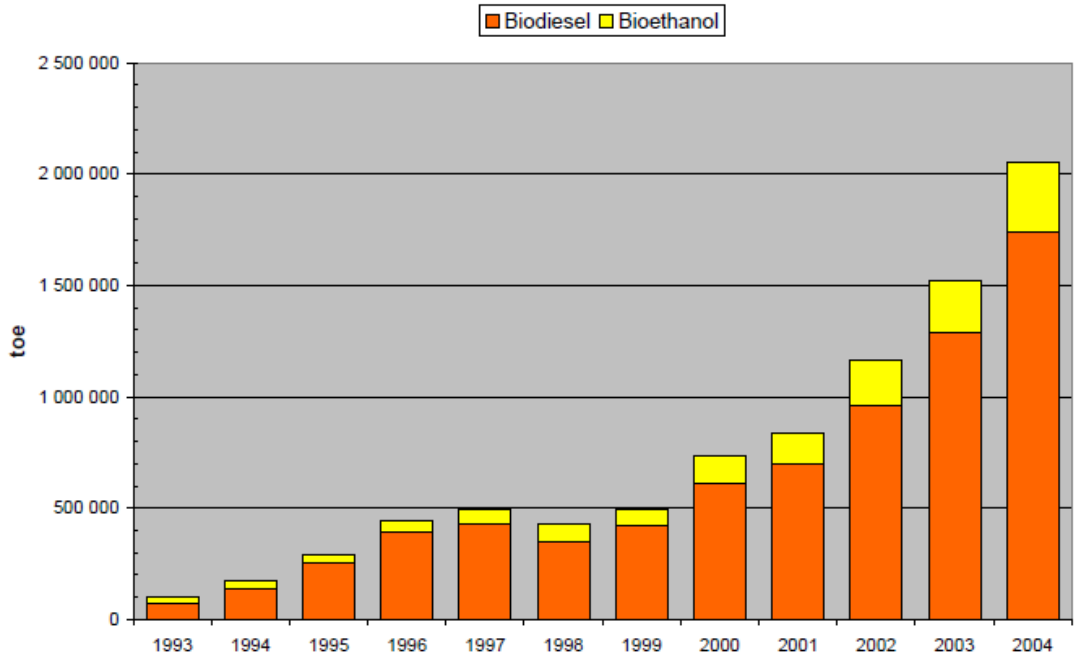
The second key split in the market relates to the relative importance of ethanol and biodiesel, which is obviously dependent on the current and projected balance between vehicles with the respective engine designs. And within each of these, there is further differentiation of fuel blends, with different proportions of biofuel and mineral fuels. In respect of this, it is important to note that the overall European transportation system has a greater reliance on diesel than other global regions, and that it has become significantly more so in the 1990s (see table below).[34] Over 70% of all new vehicles purchased in Germany, France, Italy and Spain are diesel, creating a significant historical fleet legacy.



As a direct consequence of this fossil fuel legacy, biodiesel currently represents 80% of all biofuel usage in the EU. Of this total, 80% derives from rapeseed. This relates to the third significant dimension, which involves geographical unevenness of markets for biofuels, both within and beyond Europe. In contrast to either Brazil

[34] Eurostat, 2007.

or the USA, the figure below demonstrates the dominance, albeit diminishing slightly, of biodiesel in Europe.



Nonetheless, this dominance masks some striking contrasts, and it should be noted that Germany alone has reached a significant level of biofuel consumption, at 6.9% of total transport fuel in 2007. Germany is the dominant biodiesel user, from a 'home-grown' rapeseed feedstock of 5.3 million MT in 2006. Incentivising the growth of this market, pure biodiesel (B100) has received 100% fuel tax exemption in previous years culminating in over 1,500 gas stations now selling B100[35]. By contrast, Sweden, notably its urban transport fleets, runs on imported bioethanol from Brazil, and requires that all large petrol stations (selling >3000m^3 fuel p.a.) offer a bioethanol pump to consumers, supporting the new national flex-fuel markets of Volvo, Saab and Ford. This was incentivised by the 30% investment subsidy offered to companies that use clean vehicles in their fleets. Sweden even gained permission from the EC

[35] Biofuels Research Advisory Council, 2006

to reduce import tax on Brazilian ethanol from 6.5% to 0%[36] and in 2007 signed an agreement with Brazil to further biofuels research and market creation. As a consequence, almost 90% of biofuel used in Sweden is bioethanol, of which 80% is sourced from Brazil. The price of Brazilian imports in 2006 ranged from SEK 4.2 to SEK 5.5 per litre including customs revenue, compared with SEK 5.0 per litre when produced domestically[37].

The table below summarises some major national contrasts within Europe. Biofuels consumption is highest in Germany, France, Sweden and Spain. These figures reflect population levels, preferred fuel types, levels of car ownership and other factors. We discuss production and international trade of biofuels in more depth in section 2.6.

Country		Biodiesel/thou tons 2006	Biodiesel/thou tons 2007	Bioethanol/ mn l 2006	Bioethanol/ mn l 2007
Germany	**Production**	2662[e]	2890[e]	395[b]-431[ac]	394[ac]-399[b]
	Consumption	2481[f]-2944[g]	3318[h]-3439[g]	580[b]	580[b]
	Imports	0-282	428-549	149-185	181-186
	Exports	0-181	0	0	0
Greece	**Production**	42[e]	100[e]	3[b]	0[b]
	Consumption	54[g]	94[g]	0[b]	0[b]
	Imports	12	0	0	0
	Exports	0	6	3	0
Spain	**Production**	99[e]	168[e]	396[bc]-402[a]	348[ac]-383[b]
	Consumption	63[g]	303[g]	220[b]	223[b]
	Imports	0	135	0	0
	Exports	36	0	176-182	125-160
France	**Production**	743[e]	872[e]	250[a]-293[bc]	539b-578[ac]
	Consumption	685[g]	1350[g]	295[b]	530[b]
	Imports	0	478	2-45	0
	Exports	58	0	0	9-48
Italy	**Production**	447[e]	363[e]	78[c]-128[ab]	60[abc]
	Consumption	173[g]-200[j]	162[g]	0[b]	0[b]
	Imports	0	0	0	0

[36] Biofuels Research Advisory Council, 2006
[37] Swedish Ministry of Enterprise, Energy and Communications, 2007

	Exports	247-274	201	78-120	60
Poland	**Production**	116[e]	80[e]	120[a]-161[c]	120[b]-155[ac]
	Consumption	49[g]	18[g]	110[b]	120[b]
	Imports	0	0	0	0
	Exports	67	62	10-51	0-35
Sweden	**Production**	13[e]	63[e]	72[b]-140[c]	70[abc]
	Consumption	52[g]	116[g]	340[b]	370[b]
	Imports	29	53	200-268	300
	Exports	0	0	0	0
UK	**Production**	192[e]	150[e]	0[abc]	18[b]-20[ac]
	Consumption	140[k]-153[g]	315[g]	95[bd]	153[b]
	Imports	0	165	95	133-135
	Exports	39-52	0	0	0

NB: bioethanol and biodiesel are in different units due to data available for both fuel sources

[a] European Biofuels Platform, 2008 [b] UEPA, 2008 [c] eBIO, 2008 [d] UK Dept for Transport, 2007

[e] EBB, 2008 [f] EBB Member State Update Report: Germany, 2006 [g] EurObserv'er, 2008

[h] Federal Office of Economy and Export Control, 2008 [j] EBB Member State Update Report: Italy 2006

[k] HM Revenue and Customs, 2007

The structure of the fuel market according to these three dimensions has clearly been influenced by government policy (see above, 2.4) and by the behaviour of 'lead users'. The car manufacturing industry forms a particularly strong lobbying force in the European context since blends over 5% need manufacturer approval. Moreover, certain vehicle manufacturers (VW, Audi, Skoda, Seat and BMW) have only approved the use of rapeseed oil methyl ester at present. But there are further technological and infrastructural factors that have been equally important. The availability of biofuels in the forecourts of fuel retailers plays an important part in this, and again the situation across Europe is variable. Equally, the availability of vehicles with engines designed to use higher biofuel (e.g. E85) blends can stimulate or constrain biofuel demand. Following the points made above (in 2.2), the availability of flex fuel vehicles is considerably lower in Europe than

in Brazil, for example, where its widespread introduction has had a major impact on the consumption of bioethanol.

The level of demand and public acceptability across Europe is difficult to estimate and there do not appear to be any authoritative studies on this issue. Clearly, biofuels have come under increasing scrutiny over the past two years.

The 'public debate' over the desirability of biofuels has been dominated by large environmental NGOs, including some new issue-specific bodies, established specifically to campaign against the rapid adoption of biofuels. But, often the NGOs present a fragmented and sometimes conflicting picture, often having formulated their policy positions internally at the highest level. As well as those with campaigns to slow, or indeed halt, the development of a biofuels sector, such as Greenpeace and Friends of the Earth, some have positioned their campaigns to encourage the development of sustainability measures (most notably WWF involvement in the Roundtable for Sustainable Palm Oil). WWF advocate a position of engagement, collaborating with industrial bodies to bring about sustainable markets, whereas Greenpeace, Friends of the Earth, Oxfam and the RSPB are taking an external lobbying approach calling for a moratorium on targets until sustainability is proven. On the other hand, lobbying pressure has also emerged from rapeseed farmers to create a new European market for oilseeds in the form of biofuels, yielding a guaranteed market and reducing price fluctuations. It is now estimated that two-thirds of all rapeseed produced in the EU is crushed for biodiesel.

Stakeholder Expectations Survey

When the expert stakeholders were asked what the European market for biofuels look like in 2020, and what will be the state of public opinion, they answered as follows:

- Just less than half the experts interviewed stated that 10% of total transport fuels in Europe will be biofuels by 2020. Two experts believe only 5-10% of transport fuels will be biofuels in 2020. Two experts predicted that 10-20% of transport fuels will be biofuels as bioethanol can be mixed up to 15% with petrol in current engines (others did not provide proportions). The majority of these experts believe biofuels will be an invisible component of the fuel supply. Related to this, the majority of experts argued that infrastructure will not limit uptake but that car technology will.

- The majority of experts (nine) predict that biodiesel will dominate over ethanol due to efficiency drivers and lock in to the existing 'car park'. But almost half the experts argued that bioethanol demand will grow faster as there are more ways to improve crop, conversion and vehicle technology on the biogasoline side.

- The vast majority (fourteen) of experts agree that Germany, France, Scandinavian Countries and the UK will lead in Europe, but that new entrants will lag – however one expert emphasised the importance of new member states for feedstock production.

- The majority of experts believe that public perception about biofuels will be positive in 2020. A wide variety of reasons were given for this: strict sustainability criteria will be met, second generation biofuels will address food vs. fuel issues, NGOs will be satisfied and fighting the next battle, biofuels will be competitive, the public will understand that biofuels will not negatively affect their cars (cited as the number one concern today), that energy security will be more important and economic nationalism will be on the increase, the benefits will override concerns, waste will be a feedstock, there will be general public concern about environmental issues, biofuels will be seen as a necessity (like nuclear) and that the biofuels sector will be bigger and have a better lobbying effort by then (thus able to counteract the food, oil and car companies). However one expert entirely disagreed about the biofuel optimism and believed that by 2020 public would not perceive biofuels as a green alternative. Three

experts emphasised the continued importance of NGOs for presenting and shaping public opinion - and ultimately the end market.

2.6 Europe and the International Context

The European Union produces approximately 60% of the world's biodiesel[38]. As shown in the previous table in section 2.5, Germany and France are the biggest producers of biodiesel in the EU, primarily from rapeseed. However, there was rapid growth in world biodiesel production in 2007; the US is gaining capacity whilst Indonesia and Malaysia have started to produce biodiesel for the European market. The EU does also produce bioethanol but in much smaller quantities (approximately ten percent of US production levels[39]).

There has been some debate about the potential for European countries to meet EC mandates through domestic production[40] [41]. However, despite the attractiveness of this prospect from an energy security perspective, the wide consensus is that Europe will need to supplement its own production capacity with imports from other global regions[42].

[38] OECD (2008) Biofuel Support Policies; An Economic Assessment
[39] F.O Licht (2007) dated provided by the company to the OECD Secretariat in 2007 and CF OECD (2008) Biofuel Support Policies; An Economic Assessment.
[40] CSL (2002) Liquid biofuels – prospects and potential impacts on UK agriculture and farmed environment, landscape and rural economy, Report prepared for DEFRA, Organics Forestry and Industrial Crops Division, London.
[41] The Royal Society (2008) Sustainable biofuels: prospects and challenges, Policy document 01/08, January.
[42] Biofuels Research Advisory Council (2006) Biofuels in the European Union: A vision for 2030 and beyond, EUR 22066, EC.

International trade in ethanol represents approximately 9% of global ethanol production[43]. Brazil is the world's largest ethanol exporter and the USA imports almost half of Brazilian ethanol exports. The EU is the second largest import region with half of its 2006 imports from Brazil[44]. The leading consumer is Sweden, which is the destination of about 80% of bioethanol imports to Europe, mainly from Brazil[45]. Similarly, international biodiesel exports in 2007 accounted for about 12% of total world production[46]. The EU is the largest importer of biodiesel, primarily from the USA and also from Indonesia and Malaysia. However, a significant proportion of the biodiesel from the USA in fact came from Latin America, passing through the USA via the 'splash-and-dash' practice.

The issue of how the relative importance of different drivers impacts on the trajectories of biofuel sector development in different regions has already been highlighted (in section 2.1). But increasingly, the regional trajectories are becoming intertwined as some regions seek to develop export markets, while others become more dependent on imports to meet mandated targets.

As international trade in biofuels grows, the development of sustainability standards for biofuels has become complicated by objections that these criteria are being used to create new trade barriers as regions attempt to protect their domestic industries. Global agricultural markets have been characterised for a long time by protectionism and liberalising the market for biofuels could be difficult[47]. In all cases, the question of sourcing the most

[43] OECD (2008) Biofuel Support Policies; An Economic Assessment
[44] F.O Licht (2008) World Ethanol and Biofuels Report, Vol 6, No 10 (January 29)
[45] Sustainable Development Commission (2007) $100 a Barrel of Oil: Impacts on the sustainability of food supply in the UK, November
[46] OECD (2008) Biofuel Support Policies; An Economic Assessment
[47] Doornbosch, R. and Steenblik, R. (2007) Biofuels: Is the cure worse than the disease? Round Table of Sustainable Development at the OECD, 11-12th September.

sustainable biofuels from wherever they originate seems to be compromised by these other drivers. The current combinations of policy instruments play a significant role in shaping patterns of international trade in biofuels and in some instances, it is far from clear that domestic production-oriented measures (subsidies and import tariffs) pull in the same direction as policies to stimulate demand (fiscal measures, RTFOs).

Going beyond the current patterns of international trade, there are also important issues regarding the international distribution of biofuel innovation activities, especially the location of key R&D initiatives. It has already been noted, in 2.4 that the scale and orientation of R&D efforts in different geographical locations differs quite markedly. This has several implications for how the resultant knowledge might subsequently be used:

1. Current R&D initiatives would be likely to influence the future competiveness of different nation's biofuel capabilities
2. The emerging internationalisation strategies of firms (for example, ADM to Brazil, Monsanto to Brazil) with already developed knowledge resources is likely to escalate
3. Current efforts to create proprietary knowledge and technology, including the use of patents, would be expected to develop new markets for technological knowledge and new patterns of international joint ventures to exploit knowledge resources

These are issues that are not yet high on the political agenda, but the seeds of which have already been planted through the development of different innovation policies and strategies. The key question is, irrespective of European production or consumption of

the biofuels themselves, what role is there for Europe in developing sustainable biofuels for global consumption?

Stakeholder Expectations Survey

When stakeholders were asked about the position and role of European biofuels within the wider international situation in 2020, they responded as follows:

- The majority of experts (nine) agree that Europe will be a net importer of biofuels. The main reasons given were that Europe does not have the land capacity or the cheap production capabilities to meet the high demand. However three experts argued that European regional production will increase, and stated that a third, half, or two thirds, respectively, of biofuels consumed in Europe could be produced in Europe by 2020. One expert stated that the biofuels targets can be met domestically. Another expert argued that Europe could become a net exporter of biofuels in 2020 if waste becomes the main feedstock. The reasons given for this were that Europe produces more waste per capita than the rest of the world (bar the USA); waste has a negative feedstock cost and the energy demand from developing countries will continue to grow. Another issue raised was that of water availability which may have an impact on biofuels production, and favour northern Europe. Within Europe, most experts agreed that production could be dominated by countries with agricultural capability and scientific capacity, such as Germany, France and Northern Europe. Alternatively if waste becomes the main feedstock that producers in Europe will include Italy, Germany, Spain and the UK

- The vast majority of experts (fourteen) agreed that Brazil will be the dominant producer and exporter of biofuels in 2020. Primarily because of low production costs and expanses of agricultural land. A significant number (six) agreed that the US will also become a dominant producer. Four experts argued that the Ukraine, the former Soviet Republics and Eastern Europe generally will become increasingly important producers. Reasons were similar to those of Brazil; large land mass, cheap feedstocks and cheap labour. A significant number of experts believe that

Indonesia and Malaysia will be important producers and exporters. One expert specifically identified Argentina for biodiesel (though many mentioned South America) and one expert mentioned China.

- Three experts agreed that Africa has untapped potential but that there are issues of infrastructure, intervention, colonialism and existing oil supplies in western Africa. It was pointed out that Europe is the biggest providers of aid and has an interest in stimulating economic development – this could be a driver for biofuels in Africa. One expert suggested that technologies will be developed in Europe and exported to Africa and Asia – and biofuels will be imported again. Conversely, another expert argued that we will not buy fuel from South East Asia or Africa due to deforestation and food vs. fuel concerns. One expert stated that he hopes we will not use African agricultural land but there is a danger it could happen.

- The majority of experts agree that Europe will continue be an important market for biofuels due to desire to maintain leadership in climate change and attempts to diversify energy supplies. However consumption in Europe will be country specific as drivers are different, e.g. Italy for heating and Germany for transportation. A number of experts pointed out those exporters of biofuels will tend to develop a domestic market. There was some disagreement whether China would be a dominant consumer or not.

- The majority of experts agreed that the US will continue to dominate biofuels R&D investment, with Europe, Japan and Asia following. Within Europe the UK, France and Germany will dominate and we will see a more pan European partnership approach to R&D. One expert argued that China will dominate R&D, arguing that China already has 300,000 tonnes of biobutanol capacity.

2.7 Summary

In this analysis of the current landscape, we have highlighted the significance of biofuels in addressing the issues of global climate

change, energy security and sustainable economic growth. Europe presents a unique picture of an overall contrast with many other regions of the world and yet great internal diversity. Future prospects clearly depend very heavily on policy initiatives, and these have been influenced by NGOs, the media, and mobilised public opinion. Although there are Europe-wide targets and objectives for renewable fuels, national governments are pursuing very different paths, using different policy instruments. In addition, we are on the cusp of many technological innovations, as well as public choices on systems of transport provision, both public and market. In short, there is high uncertainty coupled with high risks of failing to take the necessary steps to mitigate greenhouse gas emissions or failing to find alternatives to depleting fossil fuel resources. The analysis attempted to provide sufficient information to contribute to the development of future scenarios, based on realistic assessment of the key dimensions underpinning the future of biofuels in Europe. Evidence-based and systematically grounded scenarios are useful for addressing this uncertainty.

3. Alternative Visions of the Future

Scenarios are visions of the future that provide a context for strategic decision making. In particular, scenarios are a good way to expand the parameters for thinking about the future through thinking the unthinkable or the undesirable. They can be developed and used in a number of different ways, depending on the specific objectives that they are intended to meet.

In this project, the objective was to generate a scenario for a viable European biofuels sector in 2020, in the context of global developments. In addition, the scenario was required to represent a credible and desirable portrait, defined in this case as a vision of the circumstances that would be required for biofuels to make an **economically viable, significant and sustainable contribution** to European transportation by 2020.

3.1 'Input' Scenarios

In order to explore the range of alternative futures and to provide a stimulus for the development of a success scenario in the workshop, the research team developed three alternative scenarios for the future of biofuels in Europe. These alternative scenarios were predicated on the responses received from the expert stakeholder survey and our own desk research. They have been constructed in an attempt to capture three prominent contrasting visions that currently define the political and public debate.

To develop the scenarios we drew on potential points of significant variation within the six dimensions listed below. For each of the

three scenarios, we flesh out what could occur by 2020, by considering how each would be shaped by:

- Contrasting trajectories in the evolution of the various drivers
- The degree of globalisation versus local European domestic biofuel production and markets.
- The role of governments, both at the national and European level in regulating, stimulating, or restricting the use of biofuels.
- Different rates and foci for innovation (biomass, biofuels, car engine technologies, etc.), including organisational innovations in transport provision, as well as 'hard technology' innovations.
- Alternative configurations of industrial organisation
- The evolution of public opinion, its mobilisation, and impact on policy and consumption behaviour.

The scenarios are clearly differentiated by the level of uptake of biofuels in Europe, in terms of both production and consumption. These are the 'biofuel outcomes' of the three scenarios. We have developed three contrasting scenarios, elaborated to demonstrate the range of future possibilities. They are:

- Biofuels Free Europe;
- European business as usual;
- All technological hands to the pump.

The degrees of potential variation highlighted across the dimensions are enormous. In selecting three plausible scenarios, we identify the key factors that might lead to their emergence. Following the conventional foresight approach, we present these alternative visions in historical terms, told from an imagined future beyond 2020.

- **Biofuels-free Europe**

By 2013, as Europe pulled out of recession, major heat waves affected Southern Europe for two years running. These reached southern Britain leading to over 200,000 deaths across the region and widespread severe water shortages and rationing. At the same time, crop failures of wheat in the Ukraine and maize for animal feed across Europe resulted in the recurrence of severe food price spikes. Public panic was mobilised by NGOs to create a major food-fuel scare, as the price of food staples more than doubled. The price of oil increased quickly with rekindled economic growth in China and India and the rapid adoption of cars among the growing middle classes in those countries.

As a result of the impact of these events, the urgency for a political response to global climate change sharply increased, leading to the abandonment of renewable fuels targets by the EC, and a change in direction of policy. Biofuels were deemed unsustainable by new criteria related to competition for land use, and the need to dedicate land-use to food production alone. Having peaked at 4% of use for transport in 2012, biofuels for terrestrial transport were phased out by 2020.

Between 2015 and 2018, a major strategic plan for changing patterns of commercial and domestic transport was proposed and implemented across Europe. Major investments in public transport infrastructure were made. A coordinated innovation programme for battery technologies had been launched, which started to deliver promising advances in the cost and performance of electric vehicles. But, car use, particularly for personal household needs, had reduced considerably, and new policies of car-pools, and public provision of

"white" electric cars for intra-urban traffic, had been put in place in many cities in Europe. Some cities provided a public maxi-taxi to provide a new flexible and low-cost public service. There was innovation in both technology and organisation of provision.

Commercial traffic had shifted to canals and rail, limiting road transport to short-haul electric vehicles from distribution points at new railheads insofar as practical. In 2016, the German government nationalised VW to prevent bankruptcy and to redirect innovation towards the rapid promotion of publicly-procured electric vehicles. By 2020, VW had become the global leader in electric vehicle technology.

By 2020, scaled-up production capabilities coupled with significant innovation in high speed trains had diverted traffic from both road and air, leading to industrial expansion of the railway industry, especially in France.

NGOs, in alliance with major parties across the political spectrum, played a major role in mobilising change in consumer behaviour and expectations. High prices for all modes of transport had led to a significant reduction in personal mobility, but this had been widely accepted as a necessary price to pay to avert further ecological disasters.

The radical restructuring of the European transportation system produced an exodus of companies involved with liquid fuels. The major oil companies moved major operations to the US and China and firms with expertise in bioeconomy technologies either sold their intellectual property (IP) or moved to other global regions.

European food security policies progressively reclaimed land previously used for biofuels back to food, and palm oil imports for food and cosmetics were drastically reduced. With a policy emphasis on limiting carbon footprints from global sourcing, sustainability criteria buttressed by subsidies stimulated a dramatic increase of local production for local consumption. Biofuels were developed in Europe, but only for aviation, where no low carbon alternatives had emerged, and all new airport development had been frozen. Only second generation, ligno-cellulosic biomass was used, importing technologies from the USA.

By 2020, Europe had proclaimed the ecological high ground in governmental negotiations, claiming to be the one region in the world to have made the necessary choices to meet the challenge of global climate change and alleviate poverty by dedicating agriculture primarily to food production.

- **European business as usual**.

During the decade leading to 2020, the 10% of renewable energy directives remained in place, but progress towards them was quite uneven, some countries more than fulfilling their obligations, others failing to do so, and even falling back to higher reliance on fossil fuels. However, as with other mandates, no penalties had been imposed. Across Europe, the uptake of biofuels reached 7% in 2017, but fell back to 6.2% by 2020, as economic recovery turned into more rapid growth with higher demands for energy.

At the EC level, political fudge had replaced a clear direction towards reducing fossil fuel dependence, and the European transport and energy market had become increasingly fragmented. Europe's heavy reliance on diesel at 70% of transport fuel continued

to mark Europe out as exceptional. The production of rapeseed methyl ester (RME) had increased more slowly than demand, but within limits imposed by agriculture in terms of land availability, by the car manufacturers and the available engine technologies, and by the oil industry protecting their fossil fuel markets.

Eastern Europe had been the main source of new volumes of rapeseed, but car manufacturers, together with oil majors, had resisted the production of engines capable of using blends above 7%. The stricter sustainability criteria envisaged for 2017 in the 2009 Renewable Energy Directive implying a ban of RME, had been vigorously resisted, and had not been enforced.

A fragile investment climate, powerful NGO campaigning and wavering political leadership for Energy Policy across Europe had held back innovation in biofuel technologies. By 2020, no second generation biodiesel had emerged. Significant advances had been made globally for bioethanol, but with its impact restricted to the 30% of European cars using petrol, the impact had generally been marginal.

By 2020, patterns of biofuel consumption varied significantly between European counties. Sweden remained the highest user of biofuels with an uptake of 12%, having continued the policy of importing bioethanol, with diversification of supply from Brazil to Southern Africa. Germany held its place as by far the largest producer of biodiesel, followed by France. France also led in ethanol production, closely followed by Spain and Germany. Production levels in the UK remained relatively low and consumption heavily relied upon imports. Fiscal incentives in Europe ensured a strong market for domestic biofuels produced from home-grown

feedstocks, therefore limiting imported biofuels to only 30% of total consumption.

Similarly, different paths had been followed across Europe for other vehicle technologies. The UK and France had reduced transport carbon emissions to some degree with the expansion of hybrid electric and electric cars, but without economies of scale, these remained expensive. Moreover, neither nuclear power nor carbon storage and capture coal power stations had come sufficiently on stream to generate the necessary 'green' electricity. Spain had made greater progress towards electric cars based on solar generated electricity. Poland had fuelled its economic recovery using its coal resources and, without carbon capture and storage, became the ecological outcast of Europe.

Overall, by 2020, Europe had a fragmented and diversified market for fuel-transport systems, to the detriment of its motor industry. Considerable uncertainty had arisen over actual reductions of carbon gas emissions across Europe, with claims and counter-claims on various measures of sustainability and different national records.

Europe has become more dependent on US technology. The US has now become, proportionately, the second highest producer and consumer of renewable energy, behind Brazil, with China, as the world's largest economy, rapidly catching up. Having led the world with ambitious targets and promotion of international treaties on carbon gas reduction, Europe's lack of politically coherent direction resulted in the region being left behind in progress towards achieving renewable transport energy. Continued dependence on fossil fuels, at all-time record prices, slowed economic growth within Europe, now seen as the sick economic region of the world.

In a context of increasingly sharp contrasts between different regions of the world, there had also been a global failure in governance, with no international agreements on standards of sustainability. Consequently, Brazil was engaged in a dispute with Europe at the WTO on new trade barriers created by regional criteria for sustainability in Europe.

- **All technological hands to the pump**

During the early part of the decade to 2020, the climate change impacts on the global economy predicted by Stern had, in retrospect, lulled the UN and governments into a false sense of security, with policy objectives of carbon gas now appearing to be far too long in time-scale. Hurricanes had halted oil production in the Mexican Gulf in 5 of the last 7 years, large parts of Bangladesh were now under water (provoking mass migration), and the Nile had effectively dried up in 2019, reducing food yields in the region.

Towards the end of the decade, new evidence emerged that a tipping point in Atlantic oceanic currents had become increasingly likely in the imminent future, with major impacts on climate. At the same time, IEA estimates of conventional oil reserves had hit a new low, making the passing of Middle East peak oil in 2016 appear much more significant than it did at the time. New sustainability rules applied to oil from 2017, had effectively ruled out the extraction of non-conventional oil from tar sands and shale, so reducing total remaining fossil fuel resources by 60%. Most of the oil majors had responded by rapidly increasing their investment in renewable biofuels, but they were facing strong competition from Petrobras, a UK-German bioethanol producer and a French biodiesel producer. The first commercial-scale biodiesel from carbon waste,

using synthetic biology catalysts, came on stream in 2018, and promises to expand its market share in the next decade.

In the face of the twin crises of peak oil and climate change, new international treaty agreements had been reached on criteria for sustainability for goods and services, along with tighter targets to reduce carbon footprints. The new sense of urgency stimulated the European Union to steer innovation towards renewable, low-carbon technologies using a variety of policy instruments: direct state investment in industry-academia consortia on second generation biofuels and materials, public procurement for state transport fleets, investment in an integrated pan-European high-speed rail infrastructure, as well as the normal range of tax incentives and disincentives to bring about the shift from fossil fuel dependence. NGOs have been divided in their reaction to the changes in European policy, and following a number of high profile disputes between them, have seen their political influence diminish.

Car scrappage schemes had helped to address the fleet legacy bottleneck, as well as accelerating new market expansion. Discussions between the Commission and the car manufacturers, following a crisis in the industry, led to a shift towards common standards of fuel quality, engine design, and emissions targets, resulting in an expansion of electric-ethanol hybrid vehicles. In 2018, 85% of all new vehicles for private personal transport were of this type.

There had been further consolidation of European car manufacture, but market share has been retained against challenges from China and India. As a consequence of trade agreements and joint ventures between Europe, Brazil, and growing economies in the South, the majority of European bio-ethanol is produced in the sub-tropics.

Unlike the US, with its aim of achieving energy self-sufficiency through cellulosic bioethanol, Europe rededicated much agricultural land for food production, following the de-dieselisation of the majority of the European fleet. RME had been reduced to a small-scale, used for pre-2015 vehicles. The HGV road traffic that had not been diverted to rail was fuelled by advanced biodiesel after a major breakthrough in the commercial viability of algae-based fuels. Hydrogen cell cars, with hydrogen from biomass, had become a small, but growing niche in the market. Overall, biofuels accounted for 38% of the reduced demand for liquid transport fuels in Europe. If current (2020) trends continue, it is projected that by 2025 70% of European bioethanol will be imported from subtropics, the remaining 30% from ligno-cellulosic agricultural residues and energy crops in Europe. The diminished demand for biodiesel, and development of flex-diesel fleets, is providing and expanding the market for biodiesel from biowaste.

By 2020, a new international governance regime had emerged to support international trade in biofuels, with global standards for their sustainability and with significant global-governmental funding for ever-advancing biofuel technologies. Algae technologies, already commercialised to a small extent, showed increasingly promising signs of further breakthroughs at the prototype stage. There were also very promising results with synthetic microorganisms in laboratory studies. New intellectual property arrangements had been in instituted to stimulate global technology transfer of proven technologies.

Electricity flowing to Europe from Saharan solar panels accounted for 15% of demand in 2020, with wind and wave power contributing a similar proportion. Use of non-peak electricity for charging cars

has resulted in small overall increases in demand, more than met by the new 'green' electricity generation. Nuclear and carbon capture and storage power stations produced sufficient to meet the majority of industrial demand. Air transportation continued to grow, accelerating world trade and growth, using advanced biofuels adapted to sub-zero temperatures.

These three scenarios provide a useful lens for thinking about alternative trajectories for the future of biofuels, and for transportation more generally, in Europe. They incorporate and represent the views of some prominent advocates. They also show how each outcome for European biofuels corresponds with a particular set of assumptions about how some of the key drivers might be expected to evolve over the next decade. They are useful in their own right as an output from the research process, but were also used as an input to the participatory foresight event that was organised to bring together key stakeholders to discuss a viable way forward for biofuels to play a significant role in the future of European transportation. We now turn to a description of that event and an analysis of its outputs.

3.2 A 'success' scenario for European biofuels in 2020

On June 16th 2009, we convened a scenario workshop for major stakeholders to discuss the future of European biofuels. The aim of the workshop was to develop a success scenario for European biofuels in 2020, where success was defined in terms of the potential for biofuels to make a sustainable and significant contribution to European transportation. The workshop used a structured process of predefined exercises to meet this objective

and was run by professional facilitators and the SCI project team. In the following, we set out the main points that were discussed and present our attempt to synthesise these discussions into a coherent and consistent fourth scenario (the main points of discussion during workshop sessions are presented in appendix 1). It is important to note that, as 'editors' of the fourth scenario, we have made decisions to resolve major disagreements and inconsistencies to produce a scenario that we believe best captures the convergence of opinion of the majority of participants. After presenting the scenario, we then offer a commentary on its significance and present some important recommendations that follow from this exercise and the background research that has supported the project as a whole.

Scenario 4 – "Driving Europe towards sustainability and security"

In the following, we present our 'edited version' of the fourth scenario, which captures the spirit of the workshop and reflects as far as possible a convergence of the majority of views. It is the history of how European biofuels made a significant and sustainable contribution to European transportation in 2020.

As the world pulled itself out of recession, the price of oil began to rise significantly, with a considerable amount of volatility, from between $110 to $160 per barrel. In the early part of the decade to 2020, the recession had damaged investment in new oil fields, and continuing political instability in the Middle East had led to uncertainty of future supply. But it had been recognised that diminishing supply in relation to growing demand in BRIC countries raised a renewed threat of global recession from an energy crisis. Amongst developed economic regions, Europe had been particularly

badly affected, because of its high dependency on fossil-fuel diesel, and low targets for renewable transport fuels. By the time of the review of renewable energy in 2014, it had become clear that even the original 2020 targets were unlikely to be achieved without much stronger governmental action. The European economy was suffering with high energy prices and oil dependency in comparison to the USA, where more ambitious targets for renewables had stimulated the emergence of commercial-scale cellulosic biofuels in 2014 and raised the overall level of all biofuels to 15% of total consumption, on track for achieving 30% by the mid-2020s.

Economic stagnation and rising unemployment in Europe, had become increasingly identified with high energy costs and fossil fuel dependency, and this pushed the political leadership in Europe into a new sense of urgency. Oil price and energy security – as had been the case in the USA and Brazil – required that targets for renewables were driven higher than had been the case to meet Global Climate Change commitments alone. The impact of high energy prices proved to be a more direct, immediate and publicly recognised factor in changing policy than the effects of global warming. Strong political leadership in shaping future energy markets had risen to the top of the agenda.

Following the 2014 review, the 2020 target of 10% renewable energy for road transport had been abandoned in favour of a longer term, progressive plan for incremental increases of 1% per annum from the then current average level of a 6.5% in Europe through to 2030. Although subsidiarity had been permitted for the exact measures to be nationally adopted, these new targets were mandatory, to be enforced by significant penalties for shortfalls, monitored by the Commission. The extraordinary reliance on diesel powertrains in the European transport fleet had been recognised to

be a barrier to switching to renewables on the scale required. Tax advantages for diesel fuel and cars were reversed, in order to rebalance the European transport fleet within 10 years in favour of a proportion more typical of other economic regions. Mandates for ethanol flex-fuel vehicles as a European standard had been put in place for all new cars from 2018.

To achieve the new targets, the policy framework had recognised that in the short and medium term, the European transport fleet would require high volumes of liquid transport fuel. The preferred powertrains, promoted by incentives and scrappage schemes, had been hybrid biofuel-electric and flex-fuel bioethanol cars, although biodiesel retained a smaller but significant share of the market, varying from country to country. Electric cars had assumed a niche share especially for intra-urban traffic by 2020, but the low energy efficiency for their use of 'green' electricity meant that it had not been a widespread governmental priority across Europe. Moreover, renewable and nuclear electricity had been slow to come on stream, and was considered better dedicated to other forms of energy consumption.

The requirements for sustainability for biofuels, previously set out in the Renewable Energy Directive, and the Fuel Quality Directive, had been encompassed in a wider regulatory framework. Progress had been made towards establishing a level sustainability playing field across all uses of land, in order to regulate land use change in a comprehensive framework. The strategic use of land as a global resource with multiple claims had been included in the Copenhagen 2018 meeting, as subject to international agreement. Fossil fuel extraction (oil and coal) had also been included so as to take account of the higher carbon footprint of non-conventional oil (e.g. oil shale and tar sands) and open-cast mining. As a consequence,

the time-frame for liquid fossil fuel substitution by renewable alternatives had been reinforced and accelerated.

To achieve the new progressive and incremental targets to 2030, the new Renewable Energy Directive promoted the continued and expanding use of imported bioethanol from sub-tropical regions. 'First generation' biofuels from sugarcane had improved their performance, with new hybrid strains being adopted, and Brazilian agricultural and refinery technology had been developed across the sub-tropics. European trade barriers had been scrapped to facilitate and diversify the sourcing of biofuels, and to simulate rural economies especially in sub-Saharan Africa and India.

However, it had been recognised that advanced ligno-cellulosic biofuels and the use of biowaste feedstocks were to become an increasingly important share of the overall biofuel market. The European Commission invested heavily in new demonstrator projects, and many countries had provided innovation incentives for next generation technologies, with European support. Integrated multi-product biorefineries achieved commercial scale for the first time in Europe in 2019, some five years behind the USA. Feedstocks for advanced refineries were being planned to be primarily grown on set-aside land in Europe, as well as forming an integral part of recycling of carbon waste. The use of GM technologies for non-food crops and for biorefinery processes had been ratified by the European Parliament in 2016, although restrictions on dual-purpose food-fuel crops still placed Europe at a competitive disadvantage to most other regions in the world. Rapeseed biodiesel had continued to enjoy a significant share of the market, benefiting from improved agricultural techniques and hybrids, and the raising of yields across Europe, including Eastern European countries. But investment in advanced biodiesel from syngas had been relatively limited, owing

to the decline in diesel vehicles in the transport fleet. Biodiesel had become increasingly dedicated to the HGV segment of the European transport fleet.

From 2014, clear political leadership and the 1% annual ratchet in targets for European consumption of biofuels had created a new impetus for commercial investment in biofuels. Major European oil and agri- businesses had joined forces in joint ventures and partnerships to integrate across the new value chains. Smaller specialist companies with successful technologies and business models had been acquired in highly lucrative deals. A vibrant biofuel innovation climate across Europe had resulted in a proliferation of new technology start-ups in the latter part of the decade to 2020 creating yet more opportunities for European economic competitiveness.

As a consequence of the strengthening of European political leadership, the greater ambition of the biofuel targets, and the threat of an energy crisis, biofuels had already achieved 12% of the liquid fuel market by 2020, and were set on an upward trend in line with the mandate for progressive expansion. Biofuels had become accepted as central to the vision for sustainable, climate-friendly, economic growth and energy security.

3.3 Commentary on the workshop scenario

We believe that the vision for European biofuels set out in this scenario makes a novel contribution to current debates. To capture why this scenario is distinctive, it is useful to reflect on how it differs from the three other visions for the future of European biofuels that we described earlier. It is important to note that each of the

scenarios gains credibility when certain assumptions are made about the key drivers that will shape the development of European biofuels to 2020. The 'input scenarios' also reflect prominent visions that are advocated or implied by key stakeholders. Our scenario 1 reflects the view held by NGOs and also by the enthusiasts of electric vehicles and fuel efficiency, as presented in the King Review. Scenario 2 is the business as usual scenario, where current trajectories European targets are not met because of a persistent lack of political support resulting from concerns over the sustainability performance of biofuels – this is the Gallagher scenario. The third scenario assumes the type of techno-enthusiasm prevalent in the USA, where bullish predictions have been made regarding the probability of major breakthroughs in advanced biofuel technology – this is the Stephen Chu, 'game-changer' scenario[48].

The fourth scenario, developed by the workshop, is clearly distinct from each of these. It rejects the assumption of the first scenario that electric vehicles will become a widespread reality by 2020. And, where hybrid electric vehicles have started to emerge, the success scenario assumes that the liquid fuel of choice to power them will be biofuel rather than conventional petrol or diesel. It also assumes that there will be no major shift in Europe away from personal transportation.

The business-as-usual trajectory of scenario 2 is rejected as being too conservative to offer any potential for European transportation to deal with the twin challenges of energy security and climate change. The current policy framework directing the development of

[48] King, J., 2007. The King Review of low-carbon cars. Part I: the potential for CO_2 reduction, HM Treasury, October 2007; Gallagher (2008) The Gallagher Review of the indirect effects of biofuels production, The Renewable Fuels Agency, London; Speech by US Secretary of Energy, Steven Chu,

European biofuels is based almost entirely on the climate change driver and this was assumed to continue in the business-as-usual scenario. In contrast, the success scenario assumes that political leadership will be mobilised much more in response to energy security concerns, and that this will precipitate a break with the current stagnation in the support for European biofuels.

The success scenario does share some features with the vision articulated in scenario three. In particular, both visions are predicated on the assumption that the public and political debate will shift towards recognition that the overwhelming dependence on oil of current transportation systems will need to be reduced on a massive scale. Both visions also assume that biofuels can make a significant contribution to this endeavour. However, the scenarios are different in the weight that is placed on major technological breakthroughs. The success scenario dismissed the techno-optimism of scenario 3 as unnecessarily focused on the technological silver bullet. Instead, more emphasis was placed on implementing and optimising already existing technologies. Rather than waiting for major technological breakthroughs, for example in lignocellulosic technology, or indeed in electric vehicles, a 12% target for the uptake of biofuels could be met by sourcing the most sustainable and economically viable biofuels, wherever globally the best practices had been adopted.

Overall, the workshop scenario has been constructed around the following logic: first, the twin drivers of energy security and climate change mean that there is an urgent need to reduce the overwhelming dependence of transportation on oil; second, this need should be addressed through a portfolio of initiatives, including innovations in fuel efficiency, electric vehicles and biofuels; third, any gains from efficiency (potentially significant) and alternative

vehicle technologies (unlikely to make much difference by 2020) can be significantly enhanced by adopting biofuels into the liquid fuel supply mix for European transportation; fourth, technologies already exist to produce biofuels at competitive prices and with significant greenhouse gas savings (especially Brazilian sugarcane-to-ethanol); fifth, these existing technologies can be adopted and optimised in other global regions; sixth, current technology development programmes will produce better performing biofuels, in environmental and economic terms, to optimise location specific agronomic conditions around the world; finally, strong political leadership in instituting standards to regulate the sustainability of biofuels can play in maximising the gains and reducing the risks of a significant uptake of biofuels.

4. Policy consequences

The "**Driving Europe towards sustainability and security scenario"** was the outcome of a workshop and an extensive research programme that supported it. Research into the current state of biofuel production and consumption, the European regulatory framework, and the faltering progress towards the achievement of 2020 targets for renewable energy, provided the informational context for the workshop itself. An extensive programme of interviews with key informants in government, industry and NGOs was undertaken in order to frame the workshop, and establish the parameters of what might constitute a significant and sustainable contribution of biofuels to terrestrial transport energy in Europe.

The workshop itself was not asked to develop recommendations to policy makers. However, it is clear that one of the conditions for the

achievement of the success scenario was more vigorous political leadership and a change in political direction at the national and European level. This was clearly identified by the scenario workshop participants as critical to the future of European economies. Consequently, as authors of the report, based both on the research and the development of a success scenario, we have drawn out the principal policy implications, and expressed them as a series of recommendations. These are the policy issues that would need to be addressed in order to achieve a significant and sustainable contribution of biofuels to the future of European transport.

Recommendations

We recommend that the European Commission and European national governments:

9. **Promote the expansion of renewable biofuels as a contribution to transport energy (for road, air and sea), in recognition of the imperative to reduce fossil fuel dependency in the context of an impending energy crisis.**

   To date, climate change concerns have provided the main motivation for the European transportation system to adopt biofuels into the fuel supply mix. This stands in sharp contrast to Brazil and the USA, where the initial driver has been the threat of diminishing energy security. We believe that there is an urgent need to reduce fossil fuel dependency in transportation through a portfolio of different approaches. Based on the assumption that the great majority of European transportation will still be dependent on liquid fuels by 2020, we strongly recommend the

promotion of sustainable biofuels as a viable substitute for a growing proportion of that liquid fuel supply.

10. Replace the existing single target of 10% renewable transport energy for Europe in 2020 by a more ambitious progressive mandate of a 1% per annum increase in the biofuel proportion of transport energy until 2030.

At present, the principal policy framework for European biofuels is short term and is punctuated by a final target for the cut off date of 2020. The twin drivers of energy security and climate change mitigation require much longer visions and also a recognition that progress will necessarily progress along an incremental trajectory. Instituting a 1% per annum incremental target would take levels of biofuel uptake to around 12% by 2020 and also provide a context for continuing momentum into the decade to 2030 and beyond.

11. Promote the development of a robust, comprehensive and integrated regulatory framework for the sustainability of all agricultural commodities and energy supply sources in place of one that singles out biofuels, to include

c. Impacts of land-use and direct and indirect land-use change for all agricultural outputs (logging, food, energy, cosmetics, etc.)

d. all forms of energy, including extraction of non-conventional oil (tar-sands, shale oil, etc.,) and the refinement of the current estimation of the carbon footprint of conventional oil extraction.

The environmental impact of biofuels has been the subject of considerable debate and has arguably received disproportionate attention compared to other demands on land and the greenhouse gas performance of all other energy sources. It is clear that regulatory standards will be required to promote the sustainability of biofuels, but we recommend that this be

developed within a wider framework that addresses the bigger picture of sustainable land use change for all purposes and the decarbonisation of energy.

12. Review trade barriers and tariffs to facilitate the import of biofuels from more land-use efficient geographical zones, notably the sub-tropical zones in South America, Africa, India and East Asia.

The recent phase of the expansion of global biofuel production has been shaped by national interests in protecting and developing fledgling production capacity. Many global governments have instituted trade barriers and tariffs for this purpose. But these measures have stifled the establishment of global export markets for some of the better performing (in cost and sustainability terms) biofuels. These measures should be reviewed and the European government should seek to establish trading relationships to source the most sustainable and effective biofuels from sub-tropical zones.

13. Promote the diffusion of best practice farming techniques and eliminate barriers to the use of biotechnology such as genetic modification for intensifying and enhancing sustainable land use for agricultural crops of all kinds.

Currently, there are very wide global differences in the productivity and environmental impact of agriculture. Significant improvement is possible through the widespread diffusion of current best practice farming techniques and these improvements have the potential to significantly reduce pressures on the availability of land for cultivation. However, we believe that much greater advances are possible with the application of modern biotechnologies to agriculture to increase

yields and to develop crops that are more amenable to conversion into biofuels. Moreover, innovation needs to be directed to achieving complementarities between energy, material, and food crops, as well as developing crops in high stress environments in order to increase carbon capture and to optimise land use generally.

14. Fund demonstrator projects to promote integrated biorefineries using advanced technology based on cellulosic feedstocks and bio-wastes for the production of sustainable energy and chemical building blocks.

Europe should match the level of technology development support seen in the US to overcome the 'investment gap' that currently acts as an obstacle to the translation of promising laboratory / prototype research into commercial scale operations. There is considerable potential for further technology improvement at that scale to further enhance yields, open up the possibility for a greater range of feedstocks and improve economic and sustainability performance by integrating the production of fuels with coproducts, including animal feed and higher value chemical building blocks. This can have significant impact in reducing the carbon footprint of biofuels.

15. Implement public procurement for biofuels to stimulate markets and signal clear political leadership and commitment

Although public procurement of biofuels will at most provide a minor proportion of the total market opportunity, it can demonstrate political leadership and commitment to raising levels consumption of renewable fuels. Several initiatives are already in place across Europe, (the Stockholm bus fleet, urban

transport in 35 cities in France). It is significant that those countries with public procurement policies are also those which have already achieved progress towards meeting European targets

16. Promote and assist in the formation and coordination of biofuel supply and distribution chains, especially in the context of the use of carbon waste as a feedstock.

Governments can play an important role in facilitating the development of the new infrastructures required to achieve the more ambitious levels of biofuel consumption. Policy frameworks on blends and fuel quality set necessary standards across biofuel markets in Europe. There is much greater scope for coordination between recycling and the use of carbon waste as a feedstock for biofuels, requiring coordination between public and market actors.

Appendix 1: Summary of workshop discussions

At the start of the workshop, participants were asked to cast a preliminary 'vote' on the following question: For BioFuels to have made a significant and sustainable contribution to European Transportation, what level of uptake would have to be achieved?

Half of the workshop participants voted below 12% and half above. In the discussion that followed, the workshop resolved to adopt 12% as the base level for biofuel uptake in the 2020 success scenario, but with the important corollary that there would be momentum for a rapid upward trend towards 30% over the decade following 2020. These levels were used as a guide for the ensuing discussion about the 2020 scenario. It was particularly interesting to consider the trajectory of biofuel development through 2020 and into the following decade, rather than presenting a scenario whose history stopped in 2020. This has important implications for European Policy for biofuels and transportation which will be discussed in more detail below.

In the following, we first present the key points that were raised in the workshop exercises, before presenting the final scenario, commentary and recommendations. In keeping with the style adopted at the workshop, these features of the scenario are described in the past tense, *looking back on 2020 from a later date*.

In the first exercise, we explored what drove Europe towards the 12% uptake by 2020 and the momentum trajectory towards 30% over the ensuing decade.

- The depletion of oil, with associated price rises and challenges to energy security emerged as the dominant driver, creating massively increased demand for an alternative liquid fuel for transportation.
- Climate change, the principal driver of European biofuels in 2009, had still been important, but secondary to the oil substitution driver. In particular, wider public *awareness* of climate change had increased and had been critical in creating renewed political leadership. Some in the workshop added that a natural catastrophe related to climate change cemented public and political concern.
- The sustainable management of land for *all* uses emerged as a key societal challenge. Direct and indirect land use change was increasingly understood as the inevitable product of a dynamic and evolving agricultural system. The issue had been refocused as how best to manage the change process to minimise detrimental effects and promote opportunities for GHG reductions.
- European politicians had responded to these drivers with much greater conviction and leadership, given their significance as core issues for the continued development of human societies, and in the context of significant public pressure.

In the afternoon sessions, we elaborated the key features of the 2020 scenario:

<u>Industrial Landscape</u>

- The biofuels sector had become dominated by the 'usual suspects' – large multinational oil and agri- businesses
- New modes of economic organisation had been established with different forms of integration across the new value chains: a

mixture of vertical integration and joint ventures between key players.

- Small biofuel specialist firms had been acquired where successful with their technologies and business models, leading to a highly consolidated sector
- There continued to be a high degree of technological experimentation in a perpetually changing cast of small technology companies.

Governance and government policies

- Spurred into action by the twin drivers of energy security and climate change, European politicians had embarked on major coordinated efforts to stimulate the transition to biofuels.
- The 2020 targets had been enforced in the years preceding 2020, but longer term annual incremental targets for the years after 2020 came into force – replacing the 2020 end-point policy approach with the sliding scale for year on year development and expansion.
- Major funding and investment support had been provided by governments to accelerate the commercialisation of new refining facilities.
- Government procurement policies had created important niche demand for biofuels, further strengthening the signal of political leadership. E.g. for state owned buses and police forces in a number of European cities
- New global governance arrangements had been instituted to ensure the sustainability of biofuels, including the management of forestry and land use change. Governance of biofuel sustainability had been incorporated and aligned with sustainability for all other economic activities (i.e. biofuels had no longer received disproportionate attention).

Markets and Demand

- Dynamics of the car market and lead times for fleet replacement had continued to play a major role in shaping the pace of biofuel uptake. As such, flex fuel vehicles saw significant rates of adoption from 2009 onwards, backed by government incentives.
- Bioethanol had overtaken biodiesel as the major biofuel for Europe. [There was significant disagreement in workshop discussions regarding the proportion of bioethanol vs. biodiesel consumption in Europe in 2020 – but with a slight majority going for bioethanol]. The ongoing shift to bioethanol had placed increasing pressure on a switch away from biodiesel powertrains in Europe.
- While the 12% level had been met by domestic European biofuel production, the momentum and trend implied by the aspirational 30% target and the ongoing switch to bioethanol, increasingly required significant imports
- [Disagreement over whether the success scenario had been better supported by NGOs being marginalised or by their increased engagement in supporting the adoption of sustainable biofuels]

Technologies

- An uptake of 12% consumption of biofuels in Europe had been achieved largely on the basis of implementing and diffusing the best already existing biofuel production technologies. Performance of these technologies had been optimised by incremental innovations. The spread of best practice agricultural practices had resulted in significant per hectare yields.

Modifications to existing refinery technologies had increased feedstock-to-fuel productivity.

- But, for a high momentum scenario moving towards 30% uptake, technology development to 2020 had resulted in important advances in:
    - agricultural technologies (including biotechnology-based) to enhance input (drought tolerance, phosphorous and nitrogen uptake) and output (enzymes; sugar, starch and oil content) traits
    - new crops and crop varieties, optimised to maximise performance for a wider range of locations
    - cellulosic technology, which opened up the possibility for using agricultural residues and waste as a viable feedstock
    - integrated biorefineries in niche settings that provided significant and favourable economic advantages through the production of valuable co-products
- There had been advances, still in the relatively early stages of development, towards refining technologies that could deal with heterogeneous feedstocks, and could produce multiple fuel and chemical building blocks.
- New technologies showing great promise in trials in 2020 had helped to create a positive context for politicians and the investment community to continue backing the uptake of biofuels in the decade following 2020.

Europe in the global context

- Energy security, climate change, water availability and land use had continued to emerge as global issues, demanding global coordination. New deals had been struck, creating new geopolitical configurations for the supply and consumption of fuel. Brazil and China had invested heavily in African production.
- USA had continued to be the dominant producer, but almost entirely for domestic consumption.
- China and India had become major consumers of liquid fuels, creating a burgeoning demand for biofuel alternatives to fossil fuels.
- Trade barriers had been dropped to strengthen the global market for the most sustainable biofuels, wherever they were produced.
- The USA had dominated in biofuel science and innovation. Other regions had optimised technologies to suit local conditions.

Europe had taken the lead in the promotion of global sustainability standards for biofuels. This had become a key factor in the development of a global market.

Appendix 2: List of stakeholders interviewed for the expectations survey

	Expert	**Organisation**
1.	Dr Dirk Carrez	The European Association for Bioindustries (EuropaBio)
2.	Dr Chris Dowle	The Centre for Process Innovation
3.	Dr Sohail Ali	Plymouth Marine Laboratories
4.	Dr Tom Jenkins	BBKTN
5.	Mr Iain Grime	Petroplus
6.	Mr Paul Temple	National Farmers Union
7.	Dr Colin Merrit	Monsanto
8.	Dr Ray Elliot	Syngenta
9.	Dr Adrian Higson	NNFCC
10	Mr Paul Hodson	European Commission, DG TREN
11	Mr Olivier Mace	BP
12	Mr Jonathan Williams	Czarnikow
13	Mr Eric Urbani	Black Emerald
14	Mr Martin Farrow	ADM, USA
15	Mr Gene Gebolys	World Energy USA
16	Mr Sean Sutcliffe	Greenbiologics
17	Dr. Doug Parr	Greenpeace
18	Mr Kenneth Richter	FoE, UK

Appendix 3: List of scenario workshop participants

Name	**Organisation**
Sohail Ali	Plymouth Marine Laboratory
Sue Armfield	UK Department for Business Innovation and Skills
Camille Burel	EuropaBio
Clive Card	Lotus Engineering
Martin Christie	BP
Ray Elliott	Syngenta
Phil Gamlen	Manchester Business School
Gloria Gaupmann	European Bioethanol Fuel Association
Iain Grime	Petroplus
Adrian Higson	National Non Food Crop Centre
Tom Jenkins	Bioscience for Business Knowledge Transfer Network
Jon Lovett	Natural England
Laszlo Mathe	WWF
Colin Merritt	Monsanto
Nigel Mortimer	North Energy Associates
Andrew Owens	Greenergy
John Reynolds	One North East, Farmers Club
Sandra Sharples	Biofuel Research Centre
Rachel Solomon-Williams	Tesco
Richard Stark	British Sugar
Eric Urbani	Black Emerald
Clare Wenner	Euro PA
Alex Simuyandi	Czarnikow
Jeremy Woods	Imperial College, University of London

Sustainable Consumption Institute
The University of Manchester
188 Waterloo Place
Oxford Road
Manchester, UK
M13 9PL

E sci@manchester.co.uk
T 0161 275 4030
W www.sci.manchester.ac.uk