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Biofuels for transport in Europe: Lessons from Germany and the UK

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Abstract

The utilisation of biofuels is attracting growing support from the European Union and member states as a strategy to tackle climate change, enhance energy security, and contribute to regional development. This paper describes, compares, and analyses the markets for biofuels in Germany and the UK. The introduction of biofuels for transport in these member states provides contrasting pictures, and the success or failure of biofuels here is pertinent to the development and diffusion of biofuels across Europe. This paper concentrates on the socio-political context for the biofuels industry in Germany and the UK, discusses the lessons learned from the German and British experiences, and presents general conclusions for policy-makers that are predominantly relevant for the early stages of a biofuels industry.

Keywords: Biofuels; Bioenergy; Renewable energy

1. Introduction

Biofuels or liquid fuels for transport produced from biomass are attracting considerable attention in Europe as a strategy to tackle climate change by decreasing greenhouse gas emissions from transport, to enhance energy security and respond to rising oil prices by substituting or blending petrol and diesel with biofuels, and to contribute to regional development by increasing employment opportunities and diversifying activities for farmers through energy crops. The objective of this paper is to describe, compare and analyse the development and diffusion of biodiesel and bioethanol, and the socio-political context for the biofuels industry, in Germany and the UK. There are many insights for policy-makers in the European Union (EU) and member states from the German and British experiences.

This paper comprises several sections. Section 2 deals with the context for biofuels in Europe, including the types of fuels and vehicles on the market, advantages and disadvantages of biofuels, and the many policies, directives, standards and norms affecting the biofuels industry. Section 3 explains the methodology applied to develop the country studies on Germany and the UK. Section 4 provides a description and analysis of the biofuels industry in Germany and the UK, which divides the country studies into markets, institutions (regulatory frameworks and stakeholder views), and actors and networks. Section 5 comprises a comparison and discussion of the lessons learned from Germany and the UK, including the formation and evolution of technological systems, critical factors (drivers and barriers) for biofuels, and general conclusions for policy-makers.

2. Context

In this paper, biofuels are considered liquid fuels for transport produced from biomass. There are a range of biofuels with different feedstocks and conversion processes (see Fig. 1). Currently, the only biofuels that can be supplied in considerable amounts are the first generation biofuels of bioethanol (from sugar and starch) and biodiesel (see Fig. 2). Bioethanol and biodiesel have some important advantages over many alternative fuels in that they can be used in conventional vehicles. Biodiesel consists of fatty acid methyl esters (FAME) and it is agreed that it

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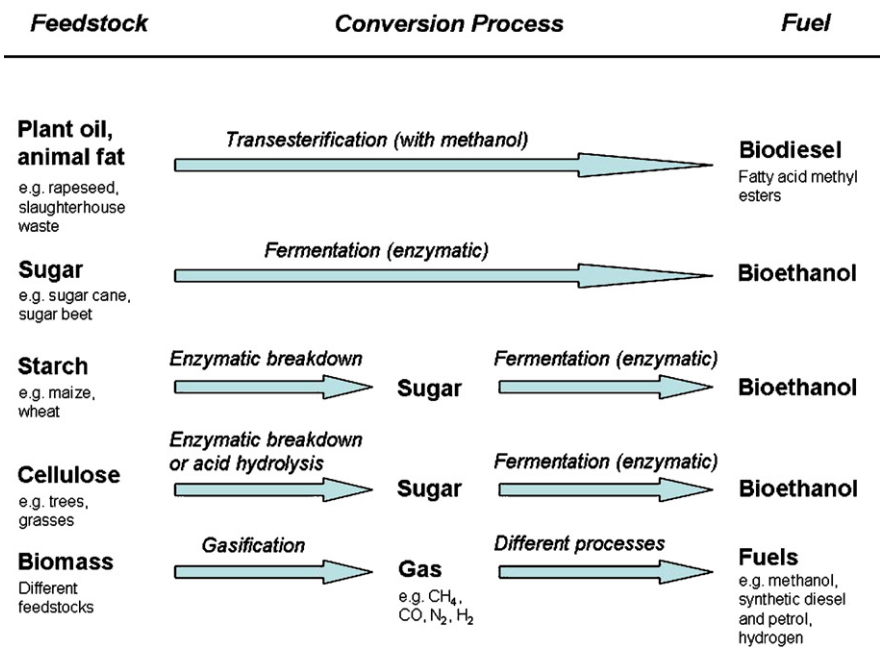

Fig. 1. Feedstocks, conversion processes and fuels from biomass.

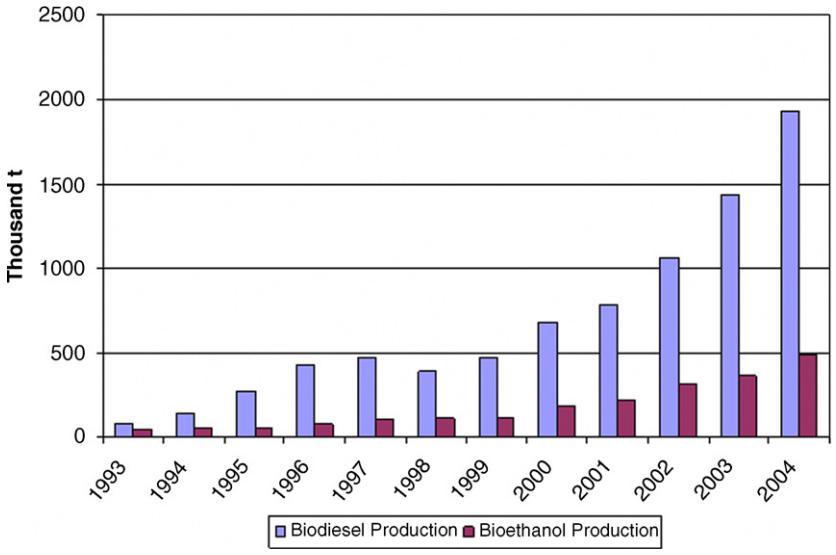

Fig. 2. Production of biodiesel and bioethanol in the EU15. Note: From 1993 to 2003 data is for production in the EU15. In 2004 data is for production in the EU25. *Source*: Biofuels Research Advisory Council (BIOFRAC) (2006).

can be used in pure form or any blends in conventional diesel vehicles with only minor engine alterations (International Energy Agency (AEA), 2004). For bioethanol, it is generally accepted that all recently produced conventional petrol vehicles are compatible with blends up to 10% bioethanol and 90% petrol or E10 (International Energy Agency (AEA), 2004).

Flexi-fuel vehicles can use both bioethanol and petrol. They are often designed for blends of 85% bioethanol or E85. In flexi-fuel vehicles there is a sensor system that detects the bioethanol and petrol blending currently used and it automatically adjusts the engine (International Energy Agency (AEA), 2004). The ability of consumers to switch between bioethanol and petrol in flexi-fuel vehicles allows the diffusion of E85 across a network of service stations. Furthermore, it is feasible for bioethanol and biodiesel to use the distribution infrastructure designed for petrol and diesel with no major changes. Biodiesel can use the transport, storage and retail systems of diesel. Bioethanol faces a few difficulties. To avoid some problems it can be converted to ethyl tertiary butyl ether (ETBE) and then blended with petrol (Biofuels Research Advisory Council (BIOFRAC), 2006).

A disadvantage associated with biofuels is a lower energy density than diesel and petrol. More than a litre of biodiesel or bioethanol is necessary to substitute a litre of diesel or petrol. However, both biofuels are also reported to have higher combustion efficiency, which partially makes up for the lower energy density (International Energy Agency (IEA), 2004). Furthermore, there is considerable attention on the environmental impacts from biofuels. In terms of tailpipe emissions, both biodiesel and bioethanol are generally considered to be less polluting than petrol and diesel (Biofuels Research Advisory Council (BIOFRAC), 2006). The well to wheels (WTW) greenhouse gas balance of biofuels is also attracting interest. A range of studies indicate that it depends on the way feedstocks are produced, processed into biofuels, and distributed (International Energy Agency (IEA), 2004). The use of fossil fuels and fertilisers to produce biofuels can result in less than impressive greenhouse gas savings. However, in Brazil there are estimates of 90% greenhouse gas savings when sugarcane is utilised to produce biofuels (Alckmin and Goldemberg, 2004).

The limitations of land availability in Europe for energy crops and the environmental impacts of planting and harvesting energy crops clearly requires sustained investigation. However, the European Environment Agency (EEA, 2005) recently released a statement that the EU can meet the targets for bioenergy and biofuels for 2010, 2020, and 2030 with no damage to biodiversity, soil or water resources. The EEA believes there is sufficient land availability to expand biomass production over the next few decades. However, if the biofuels industry is to expand then production costs and prices for biofuels need to compete with petrol and diesel. The only biofuels that are price competitive presently are from Brazil, which is bioethanol produced from sugarcane (see Fig. 3).

There are many policies, directives, standards and norms in the EU designed to stimulate and support the biofuels industry. The Renewable Fuels Directive defines targets for 2% of petrol and diesel for transport by the end of 2005 and 5.75% by the end of 2010 (Directive, 2003/30/EC). To support the biofuels industry the Energy Taxation Directive allows exemptions or reductions from energy taxation for biofuels (Directive, 2003/96/EC). The recently released Biomass Action Plan (BAP) outlines more than 20 actions to stimulate the development and diffusion of bioenergy in Europe. Many of the actions in the BAP are focused on meeting the targets in the Renewable Fuels Directive. Finally, there are a range of fuel standards and emission norms for petrol, diesel, bioethanol and biodiesel. The fuel standards for petrol and diesel in Europe allow up to 5% bioethanol and FAME in blending, which opens up a market, but also limits the market.

3. Methodology

This paper is based on country studies of Germany and the UK (Yin, 2003; Stake, 1995). The research focused on biodiesel and bioethanol in these member states because the success or failure of biofuels here is pertinent to the development and diffusion of biofuels in Europe. These member states are also interesting to compare because of contrasting national contexts. The German Government has supported the biofuels industry since the early 1990s. In the UK the biofuels industry is only recently emerging and the British Government has provided ambiguous signals on biofuels. It is important to recognise that the biofuels industry in both Germany and the UK are evolving rapidly, so it is challenging to present an up-to-date paper.

The research for this paper involved a combination of different methods and triangulation (Bloor, 1997; Morrow

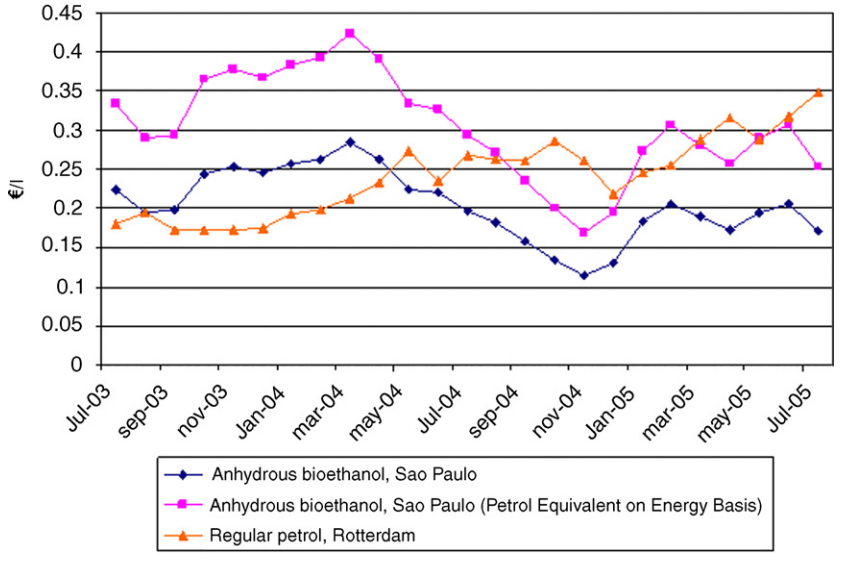

Fig. 3. Prices for anhydrous bioethanol from Sao Paulo, Brazil and for regular petrol in Rotterdam, Netherlands. *Source*: Centro de Estudos Avançados em Economia Aplicada (CEPEA) Center for Advanced Studies on Applied Economics (2005); International Energy Agency (IEA) (2005).

and Brown, 1994). First, key stakeholders were identified and then contacted to participate in interviews. The key stakeholders encompassed government officials, research experts, and representatives from biofuels producers and suppliers, trade associations, oil companies and automobile manufacturers. Second, a range of documents related to biofuels were reviewed, including legal documents, press releases, position papers, policy documents, technical standards and research reports. Third, a novel technique for investigating the content of articles in the media was tested, which involved searching the internet for articles on biofuels published in the German and British media in 2005. The articles were then classified as positive, mainly positive, neutral, mainly negative and negative. The technique provided insights into the debate on biofuels in the German and British media and how biofuels are presented to the general public.

To conduct the research in a structured way and facilitate cross-country comparison this paper utilises an analytical framework developed by Jacobsson and Johnson (2000). The analytical framework distinguishes between the components and the functions of a technological system, which is defined as networks of actors interacting in a technology area under an institutional infrastructure to generate, diffuse and utilise technology (Carlsson and Stankiewicz, 1991). In this paper the technology area under discussion is the biofuels industry. The main actors and networks are the biofuels producers and suppliers, trade associations, oil companies and automobile manufacturers. The institutional infrastructure involves both formal and informal institutions, which shape the technology area. The focus in this paper is on regulatory frameworks for the biofuels industry in particular and stakeholder views on biofuels in general.

4. Description and analysis

Germany and the UK provide contrasting pictures of biofuels in Europe in terms of markets, institutions (regulatory frameworks and stakeholder views), and actors and networks in the biofuels industry. There are many regulatory frameworks related to the development and diffusion of biofuels, including capital grants for biofuels plants, support for research, development and demonstration, information activities and public relations, public procurement of biofuels and flexi-fuel vehicles, fuel standards, emission standards, and alcohol legislation. This paper concentrates on the transport biofuels or fuels strategy and excise duty exemptions or reductions in Germany and the UK.

In terms of stakeholder views, the National Government (and political parties), environment groups, and the general public are important to an emerging biofuels industry. The general public are both citizens and consumers who are able to influence the public sector and the private sector. However, it appears that in both Germany and the UK the general public is not playing any role at present in either supporting or blocking biofuels. The main actors and networks in the biofuels industry include the biofuels producers and suppliers who construct and operate biofuels plants, trade associations, oil companies and automobile manufacturers. This paper outlines the different roles played by the main actors and networks.

4.1. Biofuels in Germany

4.1.1. Markets

Germany is the leading producer and consumer of biodiesel in the EU. Both consumption and production have expanded since the introduction of biodiesel in 1993. Most of the biodiesel is produced domestically with some imports and only negligible exports (Verband der Deutschen Biokraftstoffindustrie (VDB) Association of the German Transport Biofuels Industry, 2005a). Until 2004, biodiesel was only utilised as B100 by some car users, truck operators and bus fleets. Since 2004, the excise duty exemption was extended to low-level blends, such as B5, thereby stimulating oil companies to initiate blending. Bioethanol was not utilised for transport until 2004 (German Government, 2005). Most bioethanol is imported for the production of ETBE. Negligible amounts are used for blends. To meet the indicative target of 5.75% by 2010 the consumption of biofuels in Germany needs to expand by a factor of 3 (see Table 1).

4.1.2. Institutions

The transport fuels strategy and excise duty exemption in Germany are the main regulatory frameworks supporting the biofuels industry. The National Government in collaboration with oil companies and automobile manufacturers, as well as research institutes in Germany, have formulated a transport fuels strategy, which explicitly addresses biofuels (German Government, 2004b). It states that biodiesel and bioethanol (from sugar or starch) are important for blends but potentials are limited by land availability (German Government, 2004a). Since 2004 biofuels, both in pure form and blends, are covered by an excise duty exemption, which makes biofuels price competitive with diesel and petrol on a volume basis and energy basis (see Fig. 4 and 5). However, the recently installed German Government has suggested changes to the excise duty exemption and the introduction of an obligation for biofuels.

The National Government in Germany has been promoting biofuels in particular and bioenergy in general since the early 1990s. Bioenergy is viewed as an important energy source for environmental reasons and energy security, but also as a way to support the agricultural industry and regional development (German Government, 2004b). The main political parties support the development of biofuels. In contrast, some of the leading environmental groups are extremely critical of biodiesel and bioethanol. Friends of the Earth in Germany (Bund Umwelt und Naturschutz Deutschland, BUND) are opposed to the

Table 1
Biofuel quantities and market segments required for meeting 2010 target (5.75% market share for biofuels) in Germany

	2004	2010a	2010b
Biofuels share of total fuels market (energy basis) (%)	1.91	5.75	5.75
Diesel consumption (million tonnes)	28.6	31.3	31.3
Biodiesel share of diesel market (energy basis) (%)	3.58	5.75	9.34
Biodiesel quantity (million tonnes)			
Total	1.2	2.1	3.4
B5	0.3	1.7	1.7
B100	0.9	0.4	1.7
Petrol consumption (million tonnes)	25	22	22
Bioethanol share of petrol market (energy basis) (%)	0.16	5.75	0.63
Bioethanol quantity (million tonnes)			
Total	0.065	2.0	0.2
ETBE	0.065	0.2	0.2
E5	0	1.2	0
E>5	0	0.6	0

Note: For 2010a, it assumes the EU target is met with a 5.75% biodiesel share of diesel sales and a 5.75% bioethanol share of petrol sales. For 2010b, it assumes the EU target is met with a 9.34% biodiesel share of diesel sales.
Source: Verband der Deutschen Biokraftstoffindustrie (VDB) Association of the German Transport Biofuels Industry (2005a); Mineralölwirtschaftsverband (MWV) Association of the German Petroleum Industry (2005); German Government (2005).

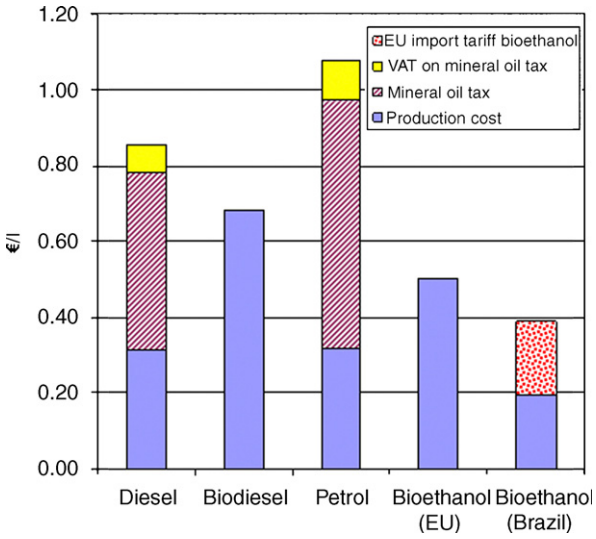

Fig. 4. Production cost and taxation of transport fuels in Germany in 2004 (prices on volume basis). *Source*: Eurostat (2005); German Government (2005); Centro de Estudos Avançados em Economia Aplicada (CEPEA) Center for Advanced Studies on Applied Economics (2005).

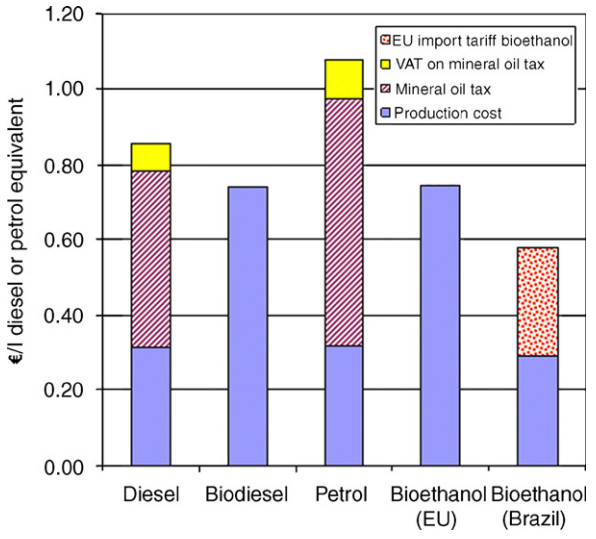

Fig. 5. Production cost and taxation of transport fuels in Germany in 2004 (prices on energy basis). *Source*: Eurostat (2005); German Government (2005); Centro de Estudos Avançados em Economia Aplicada (CEPEA) Center for Advanced Studies on Applied Economics (2005).

excise duty exemption because of fears it decreases fuel prices and therefore stimulates and increases driving (Bund Umwelt und Naturschutz Deutschland (BUND) Friends of the Earth in Germany, 2004).

The German Environmental Protection Authority (Umweltbundesamt, UBA) has also raised concerns with biofuels. The UBA argues that first generation biofuels are not a cost-effective option for climate mitigation; growing energy crops for biofuels decreases the land availability to produce biomass for heat and power generation, which is a cost-effective option for climate mitigation; biodiesel and bioethanol from sugar or starch are perceived as fuels with only short- to medium-term prospects; intensive farming of energy crops has environmental impacts; and investments are needed in fuels and technologies with long-term prospects (Umweltbundesamt (UBA) German Environmental Protection Agency, 1993; Umweltbundesamt (UBA) German Environmental Protection Agency, 1998).

4.1.3. *Actors and networks*

There are many biofuels producers and suppliers in Germany. The production of biodiesel has expanded since the early 1990s. In 1998, the capacity was 65,000 t/y but by

2004 it was 1.2 million t/y (Verband der Deutschen Biokraftstoffindustrie (VDB) Association of the German Transport Biofuels Industry, 2005b). There are currently around 25 biodiesel plants in Germany ranging from 1500 to 150,000 t/y (Internationales Wirtschaftsforum Regenerative Energien (IWR) International Economic Forum Renewable Energies, 2005). In 2006, the construction or expansion of 10 biodiesel plants has been announced. Most of the biodiesel producers are selling B100 to the market, but some are selling to oil companies for blending. In contrast, until 2005 no bioethanol was produced for transport in Germany. Recently, three bioethanol plants were started with a capacity of 500,000 t/y (Fachagentur Nachwachsende Rohstoffe (FNR) Agency of Renewable Resources, 2005a). The construction of six bioethanol plants with a capacity of a further 500,000 t/y has been announced (Fachagentur Nachwachsende Rohstoffe (FNR) Agency of Renewable Resources, 2005b).

The biofuels industry in Germany is organised through several extensive trade associations that lobby policy-makers, coordinate research, promote products, and exchange information. There is considerable cooperation between the biofuels industry, oil companies and automobile manufacturers, which is facilitated by the trade associations (Verband der Deutschen Biokraftstoffindustrie (VDB) Association of the German Transport Biofuels Industry, 2005b). With the National Government in Germany as a prominent advocate for biofuels, the trade associations have been instrumental in EU policies and directives on biofuels. The leading trade association in Germany is the Union for the Promotion of Oil and Protein Crops (Union zur Föderung von Oel und Proteinpflanzen, UFOP).

The Association of the German Petroleum Industry (Mineralölwirtschaftsverband, MWV) representing the interests of oil companies is critical of first generation biofuels, and opposes any excise duty exemptions or reductions (Mineralölwirtschaftsverband (MWV) Association of the German Petroleum Industry, 2005). The argument is that biomass for heat and power generation is superior to biofuels for transport in terms of climate mitigation. Furthermore, both biodiesel and bioethanol are viewed as insignificant contributions to energy security, in contrast to developing second generation biofuels and hydrogen (Mineralölwirtschaftsverband (MWV) Association of the German Petroleum Industry, 2004).

In the past many automobile manufacturers in Germany allowed B100 to be used in some models of cars. At present the situation is changing with the market for biodiesel shifting to trucks (Verband der Deutschen Biokraftstoffindustrie (VDB) Association of the German Transport Biofuels Industry, 2005a). Automobile manufacturers are making significant efforts to provide warranties for B100 on trucks (Union zur Förderung von Oel und Proteinpflanzen (UFOP) Union for the Promotion of Oil and Protein Crops, 2005). The German Automobile Industry Association (Verband der Automobilindustrie, VDA) has declared support for blending bioethanol at E5 with the possibility for E10 after testing compatibility with all models of cars (Verband der Automobilindustrie (VDA) Association of the German Auto Industry, 2005).

Table 2
Biofuel quantities and market segments required for meeting 2010 target (5.75% market share for biofuels) in the UK

	2004	2010
Biofuels share of total fuels market (energy basis) (%)	0.03	5.75
Diesel consumption (million tonnes)	18.5	18.5
Biodiesel share of diesel market (energy basis) (%)	0.06	5.75
Biodiesel quantity (million tonnes)		
Total	0.01	1.2
B5	0.01	1.0
B>5 or B100	0	0.2
Petrol consumption (million tonnes)	19.5	19.5
Bioethanol share of petrol market (energy basis) (%)	0	5.75
Bioethanol quantity (million tonnes)		
Total	0	1.8
E5	0	1.0
E>5 or ETBE	0	0.8

Note: For 2010, it assumes the EU target is met with a 5.75% biodiesel share of diesel sales and a 5.75% bioethanol share of petrol sales.
Source: British Government (2005); Department for Transport (2006).

4.2. Biofuels in the UK

4.2.1. Markets

Production and consumption of biodiesel in the UK only started in 2002. Most of the biodiesel is produced domestically from waste vegetable oil (WVO), which is the cheapest feedstock. Biodiesel is mostly available in low-level blends, such as B5 (British Government, 2004a). Bioethanol was not used for transport until 2005. Consumption has quickly expanded and bioethanol is now more important than biodiesel in the UK. Bioethanol is only utilised in low-level blends, such as E5. No bioethanol is produced in the UK with imports predominantly from Brazil (British Government, 2005). To meet the indicative target of 5.75% by 2010 the consumption of biofuels in the UK needs to expand by a factor of 300 (see Table 2).

4.2.2. Institutions

The main regulatory frameworks in the UK related to biofuels are the transport biofuels strategy and excise duty reduction. The National Government places biofuels in the context of creating a low carbon economy. It is therefore concerned about the limited role biofuels is able to play in a low carbon economy in the UK because of land availability and environmental impacts (British Government, 2003). Biodiesel has received a reduction but not exemption in excise duty since 2002, which was extended to bioethanol in 2005 (British Government, 2005). It applies to biofuels in

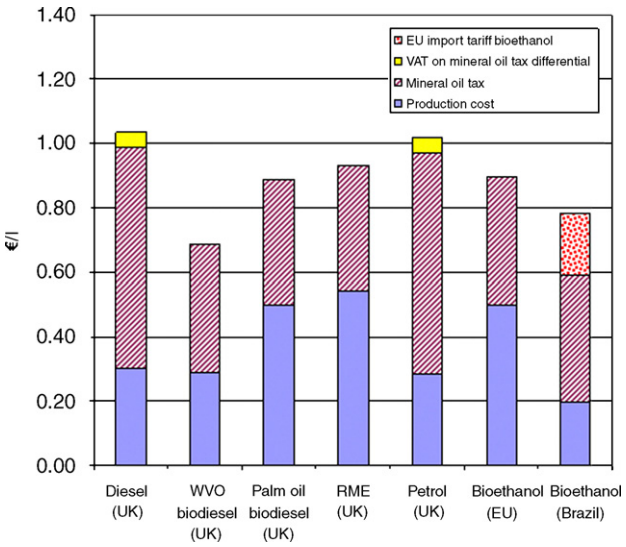

Fig. 6. Production cost and taxation of transport fuels in the UK in 2004 (prices on volume basis). *Source*: Eurostat (2005); British Government (2005); Centro de Estudos Avançados em Economia Aplicada (CEPEA) Center for Advanced Studies on Applied Economics (2005).

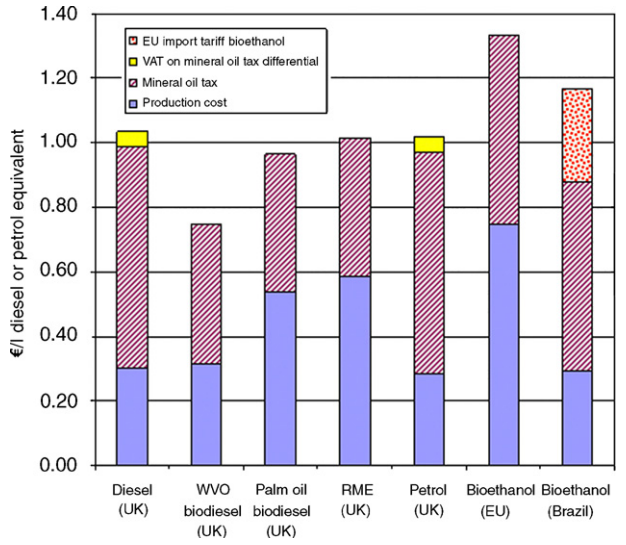

Fig. 7. Production cost and taxation of transport fuels in the UK in 2004 (prices on energy basis). *Source*: Eurostat (2005); British Government (2005); Centro de Estudos Avançados em Economia Aplicada (CEPEA) Center for Advanced Studies on Applied Economics (2005).

pure form and blends. On a volume basis, biodiesel and bioethanol are price competitive with diesel and petrol. However, on an energy basis, only biodiesel from some feedstocks, such as WVO and to some extent palm oil, are price competitive (see Figs. 6 and 7).

The British Government has announced the introduction of a Renewable Transport Fuel Obligation (RTFO). The effects of the RTFO on the excise duty reduction for biofuels are unclear. Further announcements from the British Government are expected. What is evident about the RTFO is that it will probably require reporting on greenhouse gas balances for biofuels and any environmental impacts associated with the production of biofuels (Department for Transport (DFT), 2006). The ambition is therefore to reward the more sustainable biofuels and punish the less sustainable biofuels.

The National Government in the UK acknowledges that producing and utilising biofuels is a potential way to support British farmers and diversify energy supply. However, analysis shows that biodiesel and bioethanol are expensive options for climate mitigation (British Government, 2003). Furthermore, it is anticipated that imports of biofuels will dominate the market in the UK rather than creating opportunities for British farmers (British Government, 2004a). Environmental groups in the UK are surprisingly supportive of biofuels. Friends of the Earth (2005), Greenpeace (2003) and the Royal Society for the Protection of Birds (RSPB, 2004) support biofuels under the condition of delivering reasonable reductions in greenhouse gas emissions and farming practices not resulting in environmental damage.

4.2.3. *Actors and networks*

The number of biofuels producers and suppliers is growing in the UK. However, biodiesel production only started in 2002. There is no market for B100 in the UK and all biodiesel is utilised for blending (British Government, 2004b). Capacity is about to expand with several biodiesel plants under construction. By 2006, the capacity is expected to exceed 450,000 t/y (British Government, 2005). No bioethanol is produced in the UK, and most is imported from Brazil. There are several proposals to build bioethanol plants utilising wheat and sugar beet. However, many entrepreneurs with proposals appear to be waiting on policies and actions from policy-makers before investing into biofuels.

There are only a few trade associations in the UK for the biofuels industry, which include the Allied Biodiesel Industries (ABI), the British Association for Biofuels and Oils (BABFO), the Environmental Industries Commission (EIC) and the Renewable Energy Association (REA). BABFO has dissolved recently, so the REA is now the leading trade association. The REA employs staff, maintains an up-to-date website and conducts lobbying. There is some cooperation between the trade associations, oil companies and car manufacturers, mostly through the National Government sponsored low carbon vehicles partnership, which aims to shift away from high carbon transport systems (Low Carbon Vehicle Partnership (LCVP), 2005). The trade associations remain relatively weak, however there are signals that the biofuels industry is becoming more organised.

The UK Petroleum Industry Association (UKPIA, 2005) demand clear direction from the National Government on whether the objective of biofuels is for climate mitigation, energy security or to support British farmers. UKPIA state that biomass production in the UK is limited so if the objective is climate mitigation then heat and power

generation is superior to biofuels for transport. There is a petrol surplus and diesel shortage in the UK, so oil companies want support for biodiesel rather than bioethanol. Furthermore, many oil companies view bioethanol (and biodiesel) as short-term products in contrast to second generation biofuels, which are perceived as long-term products (UK Petroleum Industry Association (UKPIA), 2005).

The Society of Motor Manufacturers and Traders (SMMT, 2004) accept both E5 and B5 because of the compatibility with existing vehicles and distribution systems. SMMT suggests that if B100 becomes available on the market then many vehicles with EU warranties will also be covered in the UK. Some automobile manufacturers want to introduce flexi-fuel vehicles for E85. However, more support is required to create a network of E85 refuelling stations across the UK, which is necessary to stimulate the diffusion of flexi-fuel vehicles (Society of Motor Manufacturers and Traders (SMMT), 2004).

5. Comparison and discussion

The formation and evolution of the biofuels industry in Germany and the UK is influenced by the dominant technological system for transport based on oil. Any discussion on the identification of drivers and barriers for the biofuels industry in Europe therefore demands an understanding of technological systems, and the process of shifting to a new technological system. Unfortunately, there is no step-by-step guide on how to promote biofuels. However, the assessment of the German and British experiences generates a range of general conclusions for policy-makers, which are particularly relevant for the early stages of a biofuels industry.

5.1. Technological systems

Once a technology has become the standard in society it becomes increasingly difficult to replace by competing technologies (Hughes, 1989; Arthur, 1989; Utterback, 1994). When a technology is the standard, the phenomenon of increasing returns to scale is often observed, which entails that the more the technology is applied, the more it improves, becomes less expensive and expands its market (Organisation for Economic Cooperation and Development (OECD) and International Energy Agency (IEA), 2003). Once the process has gained momentum, a society may 'lock-in' to a technology and may therefore 'lock-out' competing technologies (Tsoutsos and Stamboulis, 2005). Currently, the dominant technological system for transport is based on oil. Biofuels are part of a new technological system, which is embedded in the dominant technological system.

What is attractive about biofuels to many actors is that low-level blends, such as E5 and B5, are able to utilise the existing distribution systems of the oil industry. Furthermore, many types of conventional vehicles are compatible with low-level blends. So the transition to low-level blending of biofuels with petrol and diesel is almost unrecognised by vehicle users. The dominant technological system in which oil companies and automobile manufacturers operate is therefore able to adapt to the introduction of biofuels with few difficulties. It is only high-level blending that requires more adaptations for oil companies, automobile manufactures, and vehicles users.

There is more to the process by which a technology becomes dominant than the phenomenon of increasing returns to scale. Society becomes adapted to the technology through changes in its formal and informal institutions (North, 1990). The institutional infrastructure creates systems of incentives and disincentives for individuals and organisations (Ornetzeder and Rohracher, 2006). Proponents of a technology try to influence the evolution of the institutional infrastructure, so that it accommodates the technology. If a technology achieves supremacy and establishes a dominant technological system, institutions in society become aligned with it, supporting its development and obstructing that of competing technologies (Jacobsson and Bergek, 2004). The emerging biofuels industry in Germany and the UK is engaged in transforming the institutional infrastructure as well as the physical infrastructure.

Dominant technological systems comprise a multitude of artefacts and physical infrastructure (Hughes, 1989). If a new technological system were to become dominant, then the established artefacts are at risk of becoming obsolete. Actors that have invested in a dominant technological system therefore have a vested interest in it and often oppose any competing technologies. Important actors for a new technological system are prime movers or system builders, which are technically, financially and politically able to defend and build a new technological system (Jacobsson and Bergek, 2004). The experience in Germany demonstrates that creating conditions for prime movers or systems builders through the excise duty exemption and the transport fuels strategy was critical to the development of the biofuels industry.

Under some conditions actors embedded within the dominant technological system embrace a new technological system and promote its development. In terms of biofuels, it appears that oil companies in both Germany and the UK are more supportive of biodiesel than bioethanol. In Europe, the demand for diesel is growing while demand for petrol is stagnating (see Fig. 8). The expanding demand for diesel makes biodiesel interesting to oil companies as it allows a 'stretching' of diesel through blending. In contrast, the 'shrinking' market for petrol is resulting in some resistance from oil companies to bioethanol. Furthermore, the appearance of biodiesel has attracted the attention of bus fleets, truck operators, and agricultural vehicles because it is price competitive and reliable in conventional vehicles.

New technological systems often require supportive economic policies. However, there are always debates about if subsidies should have sunset clauses and whether

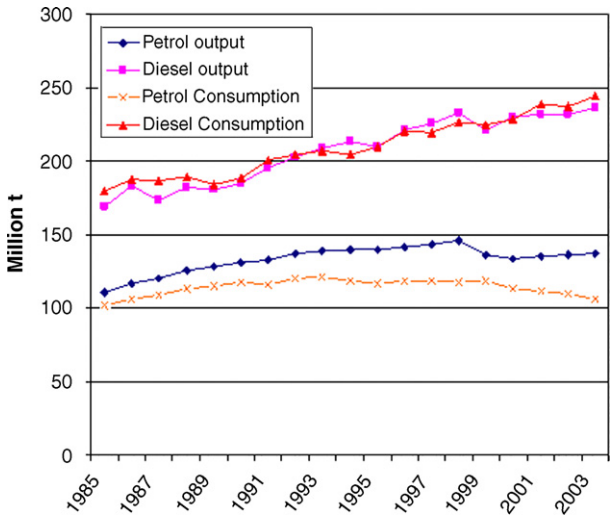

Fig. 8. Diesel and petrol consumption and production in the EU15. *Source*: Eurostat (2005).

tax breaks are necessary (Organisation for Economic Cooperation and Development (OECD) and International Energy Agency (IEA), 2003). For biofuels there are two justifications for supportive economic policies. First, biofuels often have lower environmental impacts and greenhouse gas emissions compared to fossil fuels. Second, biofuels may be competitive with fossil fuels in the long-term but require assistance in the short- to medium-term to establish a new technological system. The second argument weakens as the biofuels industry grows and strengthens. Supportive economic policies, such as subsidies, should therefore be temporary and involve sunset clauses. However, permanent tax breaks in relation to fossil fuels are justified because of the first argument on lower environmental impacts and greenhouse gas emissions.

There are many discussions in Germany and the UK regarding cost/price developments for biofuels. The technologies and systems for first generation biofuels are relatively mature (Biofuels Research Advisory Council (BIOFRAC), 2006). There are possibilities for incremental improvements through scale economies and learning effects. However, the main production cost is the price for the feedstocks, which are often agricultural crops. For the costs/prices to go down significantly on first generation biofuels, the cost/prices for agricultural crops will have to go down. A strategy to achieve cost/price developments is to focus production in favourable climates, which for Europe translates to imports from places, such as Brazil.

Many member states have adopted policies that restrict imports of biofuels from favourable climates (International Energy Agency (IEA), 2004). So to achieve reductions in costs/prices, member states and the EU will have to invest in technologies and systems for second generation biofuels. It is second generation biofuels that promise to extend the range of feedstocks beyond valuable agricultural crops, thereby significantly altering the conditions for the main production cost of biofuels (Biofuels Research Advisory Council (BIOFRAC), 2006). However, it is important to recognise that cost/price developments for biofuels in relation to fossil fuels depend on oil prices, which are far more volatile than improvements in biofuels.

5.2. Critical factors

The main driver for biofuels in Germany has been the excise duty exemption, at the beginning for B100 and since 2004 also for low-level blends of biodiesel and bioethanol. Automobile manufacturers allowing B100 in their conventional vehicles and service stations supplying B100 have also been critical for the development and diffusion of biofuels. The main barriers that biofuels face in Germany are their higher production costs; the uncertainty if the National Government will continue to support biofuels; the reluctance of oil companies to utilise bioethanol for blending in petrol; and the declining number of conventional vehicles with warranties for blends higher than B5.

Since biodiesel was not addressed by the mineral oil tax in Germany until 2004, it was therefore exempt from the mineral oil tax, if utilised as B100. The rise in oil prices helped biofuels producers and suppliers to provide biodiesel that was more or less price competitive with diesel. Furthermore, many automobile manufacturers responded by allowing B100 in conventional vehicles designed for diesel. The appearance of biodiesel has attracted truck operators, bus fleets and agricultural vehicles because they are sensitive to changes in oil prices. They can purchase conventional vehicles at the same price and with the same performance, and they can then switch between diesel and biodiesel depending on availability and price.

Establishing the distribution systems for B100 and E85 is difficult because it requires dedicated pumps across a network of service stations. However, in 1996 petrol with lead was prohibited in Germany by the National Government and more than 1000 pumps at service stations required replacements. The market for biodiesel in Germany was at that moment able to seize the opportunity. Until 1996, the use of biodiesel was predominantly in niche markets. The shift away from petrol with lead resulted in many service stations adopting biodiesel as an attractive option and over 600 pumps were converted to provide B100. This transition in distribution systems transformed the biofuels industry in Germany.

In Germany, the National Government has played an active role in the development of a market for biofuels and a domestic industry. The National Government has sponsored research on bioethanol and biodiesel, and invested in demonstrations of flexi-fuel vehicles and B100 in agricultural vehicles. The trade associations have also been important for supporting the domestic industry. The critical attitude of some leading environmental groups in Germany appears so far not to have hindered the development of the domestic industry. For most consumers the price of biofuels is clearly more important than

environmental considerations regarding biofuels. Furthermore, in the UK the general public has not been prepared to purchase biofuels, which are marketed at a price premium.

The main driver in the UK has been the excise duty reduction introduced since 2002. The main barriers are the higher production costs of biofuels which—except for the cheapest feedstocks—are not sufficiently compensated by the excise duty reduction to induce blending in the UK. National Government signals on support for biofuels have so far been ambiguous. Furthermore, the domestic industry for biofuels is undeveloped and inexperienced. In contrast to Germany, where biodiesel has been produced and used since the early 1990s, the experience in the UK has only started recently. Similar to Germany, the adjustments to the excise duty have triggered the development of a domestic industry.

In the UK, biofuels are considered an expensive option for climate mitigation, rather than a means of strengthening energy security or supporting British farmers to diversify activities to food and fuels. Currently, the excise duty reduction is only guaranteed until 2008. Many biofuels producers and supplies (especially for bioethanol) are waiting for strong signals from the National Government. The limited support for the domestic industry is also connected to weak trade associations, which are unable to lobby and influence policy-makers as they are in Germany. In the absence of convincing support for biofuels from the National Government and a higher excise duty reduction most of the oil companies have adopted a wait-and-see strategy.

5.3. General conclusions

The introduction of biofuels in Germany and the UK provide contrasting pictures and many insights into the drivers and barriers that can shape markets for biofuels in Europe. This paper has derived a range of general conclusions from the assessment of the German and British experiences with biodiesel and bioethanol that are particularly relevant for the early stages of a biofuels industry. As suggested, the dominant technological system for transport based on oil has established a formidable institutional infrastructure. Biofuels are part of a new technological system that requires support to establish prime movers or system builders.

Consumers purchase cheap rather than green: The experience in Germany and the UK shows that most consumers only purchase bioethanol and biodiesel if they are price competitive with petrol and diesel. In Germany, the availability and price of biodiesel has allowed B100 to establish a market and biodiesel sales continue to grow. In the UK, the experience indicates that only few consumers are prepared to purchase B5 at a price premium. The environmental reasons for purchasing biofuels are simply overshadowed by price and availability.

Excise duty exemptions or reductions are instrumental for stimulating investments in biofuels: Excise duty exemptions or reductions can ensure biofuels are price competitive. In Germany, the excise duty exemption has been instrumental in stimulating the domestic industry for both biodiesel and bioethanol. In the UK, the excise duty reduction has triggered the sales and production of biofuels. However, it is only sufficient for biodiesel production from some feedstocks, such as WVO and palm oil, which limits the developing market for biofuels.

National Government commitment is the foundation for a biofuels industry: To achieve the 2010 targets for biofuels in Europe, it is important for National Governments in member states to provide clear signals. In Germany, the consistent backing of biofuels by the National Government and most political parties has encouraged investments in the biofuels industry, the oil industry to implement blending, and automobile manufacturers to provide warranties on conventional vehicles. In the UK, the National Government support of biofuels has been ambiguous, resulting in many oil companies adopting a wait-and-see strategy.

Low-level blending is the easiest and cheapest way for marketing biofuels but not sufficient to meet targets: The distribution of B5 and E5 requires negligible investments in distribution systems and no different pumps or labels. Most oil companies are therefore prepared to support low-level blends more than B100 or E85, which require more investments. However, B5 and E5 are not sufficient to meet the 2010 targets for biofuels. There are two options to respond to this dilemma. First, promote the diffusion of high-level blends, which in many instances requires the production and marketing of flexi-fuel vehicles, and distribution of biofuels at service stations. Second, alter the fuel standards for petrol and diesel to allow blending of E10 and B10, which is an effective way to meet the targets and expand the market for biofuels.

Niche markets are an opportunity for bioethanol and biodiesel: Rather than only produce low-level blends for conventional vehicles, a parallel strategy for bioethanol and biodiesel is to address niche markets, such as bus fleets for public transport, truck operators, and agricultural vehicles. Niche markets are able to utilise high-level blends or pure forms of biofuels; switch to flexi-fuel vehicles or vehicles for only biofuels; and establish dedicated refuelling stations. It is important to place biofuels in the context of shifting to sustainable modes of transport. If biofuels are used in bus fleets for public transport then not only are the fuels more sustainable but so are the modes of transport.

Oil companies are more supportive of biodiesel than bioethanol: Oil companies in Europe face an oversupply of petrol and a shortage of diesel. In both the UK and Germany, oil companies are more critical of bioethanol than biodiesel. If policy-makers want to diffuse bioethanol on the market, they have to exert more pressure on oil companies and provide clear direction. Furthermore, policy-makers need to engage with

automobile manufacturers to provide warranties for conventional vehicles and to produce flexi-fuel vehicles in parallel with service stations offering high-level blends, such as E85.

Environmental impacts and carbon balances of biofuels vary: The environmental impacts and carbon balances of biofuels depend on feedstocks and the way they are farmed, processed and distributed. Clearly, environmental impacts associated with energy crops require sustained investigation. Biodiesel and bioethanol in the EU has been calculated to result in 15–70% greenhouse gas savings when compared to fossil fuels (Hass et al., 2003), while bioethanol from Brazil results in over 90% greenhouse gas savings (Alckmin and Goldemberg, 2004). However, it is clear that both biodiesel and bioethanol are expensive options for climate mitigation as compared to biomass for heat and power generation.

Sustainability certification scheme for biofuels is necessary: Presently, all biofuels are treated equally irrespective of greenhouse gas balances or environmental impacts. The introduction of the RTFO in the UK appears to encompass reporting on greenhouse gas balances for biofuels and any environmental impacts associated with the production of biofuels. The ambition is therefore to reward the more sustainable biofuels and punish the less sustainable biofuels. A consistent and transparent sustainability certification scheme for biofuels in the EU is necessary to maintain confidence in the performance of biofuels from environmental and social perspectives.

Support for bioethanol and biodiesel is not expected to 'lock-in' or 'lock-out' any technologies: As first generation biofuels, both biodiesel and bioethanol can be blended with petrol and diesel with no major changes in distribution systems and can be used in conventional vehicles. Second generation biofuels can also be supplied in the distribution systems and used in conventional vehicles with only minor adaptations. It is important to provide sufficient support for second generation biofuels so as to expand the range of feedstocks for the production of biofuels, and to promote technologies with the most flexibility and best performance.

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