

The European Biofuels Policy: from where and where to?

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1. Introduction

Energy demand in transport has increased constantly in the EU and is linked to increased oil dependency and greenhouse gas emissions. This has entailed major efforts to identify alternative fuels and technologies to change development paths in the sector. In face of limited energy technology options for transport, liquid biofuels became a natural target for policy efforts (Steenberghen, 2008). In addition to lower carbon-intensities, some liquid biofuels such as ethanol are price-competitive with their fossil equivalents and compatible with the distribution and tanking infrastructure in place for light vehicle fleets (Pacini and Silveira, 2011). Consequently, liquid biofuels have been at the forefront of renewable energy in EU transport policies by way of the Renewable Energy Directive 2009/28/EC, or RED, adopted in April 2009 (Eikhout, 2008; EC, 2009).

Biofuels had previously been part of national energy initiatives in some EU member states. EU efforts made scaling up their use in leading countries possible, while others were to follow. The subsidiary character of energy policies in the EU allows countries' some freedom in their choices to meet the targets set in the directives. This allowed member states to choose different introduction pathways, such as low and high blends, pure vegetable oil, bio-esters, etc.

Today, most biofuels used in the EU are domestically produced. According to Eurobserv'er (2010), biofuel imports amount to approximately 30% of the ethanol and 20% of the biodiesel consumption, while other biofuels such as biogas are almost exclusively sourced from within EU borders. The RED requires EU member states to achieve a 10% share of renewable energy in transport by 2020. As a result, the share of biofuel imports is expected to increase. In order to reduce the potential negative impacts of their utilization, the EU introduced mandatory sustainability criteria which have to be met if biofuels are to be counted in the fulfillment of the 2020 targets. As the expected utilization of biofuels could turn Europe into the largest market of its kind, the European policy sends strong signals for both producers and consumers of biofuels internationally (Pacini and Strapasson, 2012).

This paper analyzes the development of the European biofuels policy, from its origins in the form of scattered national initiatives to current directives enforced at EU level. Future trends are discussed based on a forecasting exercise for biofuels consumption in the EU27 following three steps. Firstly, the origins and evolution of biofuels policy in Europe are presented, with particular attention to the gradual shift from national initiatives to EU-level directives after 2003. Secondly, the

paper analyses recent developments, such as the implementation of the RED, the Renewable Energy Action Plans (NREAPs), the mandatory sustainability criteria for biofuels and the development of certification schemes. To conclude, the paper provides projections for the future use of biofuels in the EU27 based on the policy framework in place as well as recent information from member states' strategies. These projections serve as a tool for policy benchmark and baseline for policy adjustments. Key messages are summarized in the conclusion.

2. The establishment of biofuel policies in Europe

Different parallel processes converged over the last few decades towards the present ambitious goals set by the EU in relation to renewable energy in transport. In this context, biofuels are expected to make a large contribution to enhance energy security and reduce the impacts of transport on the environment and climate system. This section provides an overview of this process.

2.1 Before 2003: National policies for biofuels

Liquid biofuels for transport were used in Europe long before being the subject of a formal European directive, which was first adopted in 2003 (EC, 2003b). Dating back to years before the First World War, busses were already rolling in Paris on a mixture of ethanol and petrol. Between 1920 and 1950, the French continued using sugar-beet-based ethanol to reduce energy dependence and trade deficits (Kutas et al, 2007 p. 15). The use of ethanol as fuel blend was only abandoned once oil prices achieved record lows in the 1960's, being then replaced by octane enhancers of fossil origin such as MTBE and ETBE.

In the 1970s, oil price shocks led to serious concern about the European exposure to imported energy, particularly oil. This led to a number of actions which started changing the prospects for biofuels in Europe. By 1973, biodiesel research was being conducted in Wieselburg, Austria. In 1982, the country had built its first pilot plant for biodiesel produc-

tion (fatty-acid methyl ester - FAME). Sweden started its ethanol research program in the 1970s, already focusing second generation biofuel production (Zacchi and Vallander, 2001). At the EU level, the first directive that opened potential markets for biofuels was the Council Directive 85/536/ECC, which authorized blends of 5% ethanol and 15% Ethyl Tertiary Butyl Ether (ETBE) on petrol¹. On the demand side, thirty ethanol buses were operating in Sweden on a testing ground by 1989.² However, a broader usage of bioethanol blending was hampered by lack of coordinated policies and low oil prices which prevailed from the late 1980s throughout most of the 1990s.³

In addition to the sectoral developments mentioned, other processes were evolving which came to play a significant role in the development of biofuel policies in Europe. This includes the evolution of the global environmental agenda particularly the commitments made by European countries at the United Nations Conference on Environment and Development (UNCED or Rio-92). The Climate Convention (UNFCCC) turned out to be the most influential when it comes to energy and transport policy.

Although biofuel initiatives had existed at individual countries' level since the price shocks of the seventies, those were scattered and uncoordinated. An attempt to formulate a biofuel-specific legislation at the European level would first take place in the early nineties. In 1992, the European Commission (EC) proposed the *Scrivener directive*, which sought the promotion of agriculture-based biofuels in the European Community for the first time. The proposal was not adopted by the Council but a key element of it – the preferential tax treatment for

1 See: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31985L0536:EN:HTML>

2 Source: www.sekab.com (history of ethanol in Sweden).

3 Calls for air quality control prompted the introduction of oxygenating chemicals into gasoline, producing the so-called reformulated (oxygenated) gasoline which emits less pollutants into the atmosphere. Due to low prices and synergies with oil refineries, methyl tertiary butyl ester (MTBE) was the main gasoline oxygenate since the 1980s, only recently being challenged by bioethanol. See: Linak et al (2009).

biofuels – was subsequently used by member states in the development of their national policies in the sector. According to Kutas *et al* (2007), Italy, France, Sweden, Poland, Slovakia and Germany all applied lower tax rates towards biodiesel in the late 1990s.⁴

Another incentive for biofuels in the early 1990s was the reform of the EU Common Agricultural Policy (CAP), which introduced a 15% set-aside obligation on farmland and sponsored payments for the unused fields.^{5 6} While the set-asides could not be used to grow food crops, no restriction was imposed on the production of oily seeds for energy purposes.

During the 1990s, there was intensive activity at national levels to establish and adopt technical standards for biofuels, especially biodiesel based on rapeseed oil methyl ester (RME) and FAME. Between 1991 and 1997 Austria, France, Czech Republic, Sweden, Germany and Italy all adopted national biodiesel specifications.⁷ The lack of bioethanol standards in the 1990s was partly due to the high interest in diesel, which was - and still is - the main light transport fuel in Europe. This resulted in more pronounced interest for biodiesel, which could potentially reduce Europe's dependency on diesel imports (Kutas *et al*, 2007).⁸

Building upon fragmented national initiatives, Parliament and Council adopted the first EU-level legislation in 1998, harmonizing technical standards for transport fuels. This initiative was the Fuel Quality Directive 98/70/EC, which also included specifications for biofuel blending. Other major markets were

also making progress. The United States adopted a nationwide biodiesel standard in the same year, and Brazil started a biodiesel program in 2003.⁹

2.2 Between 2003 and 2009: European policies for biofuels

The year of 2003 is a turning point in EU policies on biofuels. While important technologies such as flex-fuel engines were entering the market, three key legislative instruments were created which established a formal biofuels policy at EU level.¹⁰

In March 2003, Parliament and Council adopted the directive 2003/17/EC, amending the 1998 fuel quality directive by essentially

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including the blending of biofuels with conventional fuels up to a ceiling of 5% per volume for both ethanol and biodiesel (EC, 2003a; Schnepf, 2006). Later, in May 2003, a major biofuels directive was adopted (2003/30/EC). Although non-mandatory, the directive pushed for the introduction of biofuels, setting EU targets for the first time. The initial target was set at 2% share (in energy content) for all petrol and diesel for transport in the EU by 2005, to be increased

4 Quotas limited the amount of biodiesel eligible for tax reductions and exemptions. See Kutas *et al* (2007, p. 16)

5 COM(1992) 36

6 Reduced to 10% in 1996.

7 Austria (1991 – ON C 1190); France (1993 – by decree and later NF EN 590); Czech Republic (1994 – CSC 65507); Germany (1994 – DIN V 51606); Sweden (1996 – SS 15 54 36) and Italy (UNI 10635).

8 The regulatory focus on biodiesel during the 1990s is also partly due to the more complex nature of this chemical, which is a composite of many different organic molecules, when compared to ethanol, which is homogenous.

9 US law D-6751-02. Brazil tried vegetable oil as alternative fuel already in 1975 in the Pro-Oleo program, but this was not successful due to lack of cost-efficient technologies at the time. See Soares (2007)

10 The first flex-fuel vehicles were introduced on a commercial basis in Brazil in 2003. For an overview of the Brazilian ethanol program, which worked as a test lab for many policies and technologies supporting biofuels, see Hira and Oliveira (2009).

stepwise towards a reference goal of 5.75% by 2010 (EC, 2003b).

In order to achieve the proposed target introduced by the biofuels directive, the Council adopted a third measure in October 2003, namely the directive on energy taxation (2003/96/EC) providing member states with regulatory discretion to use tax policy, pending EC approval, to foster the penetration of biofuels in their markets (EC, 2003c). By 2007, sixteen EU member states had applied for permission to introduce tax relief for biofuels, the majority in the form of tax exemptions proportional to blending levels (Kutas *et al.*, 2007 p. 19).

Still in 2003, the EU adopted a reform of its Common Agricultural Policy, which decoupled support payments from specific crops, and adopted a special energy crop subsidy of €45/ha up to a limit of 1.5 million ha. The support was later increased to 2 million ha, which effectively meant a maximum available subsidy of €90 million for energy crops in the EU (OECD, 2004).

In compliance with the biofuels directive, both the United Kingdom and Sweden adopted national laws stimulating renewable fuels for transport by 2005.¹¹ The adoption of renewable fuel obligations in Europe came in parallel with the entering into force of the Kyoto protocol, driving optimism for renewable energy worldwide. Other major markets also introduced renewable fuel mandates in 2005, such as the enactment of the Renewable Fuel Standard (RFS1) in the United States.

It became increasingly clear that sourcing large part of the required feedstock to meet the expected demand for biofuels within the EU borders would be no easy or cheap task. In late 2005, the Commission adopted a communication on biomass action plans which primarily focused on surveying bioenergy potentials among EU member states for solid and liquid

11 Renewable Transport Fuel Obligation (RTFO) based on the UK Energy Act of 2004, and the Swedish National Climate Policy in Global Cooperation Bill.

biofuels.¹² Shortly thereafter, in 2006, the European Commission published a communication specifically announcing its strategy for biofuels, which contained a clear emphasis on technological innovation and promotion of energy security, complementing the well-known environmental goals of the policy (EC, 2006). Henceforth, envisioned second-generation biofuels would be much more dependent on lignocellulosic sources (e.g. wood) than conventional starch, vegetable oil and sugar-based biofuels.

Trade-offs with other commodities were partially addressed by the sugar sector reform in 2006, which reduced 36% in direct support previously provided for sugar production, as well as eliminated interventionary purchases and quota buybacks.¹³ This reduced incentive for channeling agricultural feedstock into sugar, thus making bioethanol production more attractive.

In early 2007, the European Commission attempted to harmonize the multiple fronts of its conventional and renewable energy initiatives. The result was a communication entitled *An Energy Policy for Europe*, which was the basis for major regulatory initiatives in the subsequent years.¹⁴ Both communications on the biofuels (2006) and energy (2007) strategies served for preparation of formal directives, aimed at unifying diverse aspects of renewable and efficient energy promotion in Europe.¹⁵

In January 2008, the EC finally put forward its proposals for legislation on climate and energy, known for its 20-20-20 targets of 20% renewable energy, 20% increased energy efficiency and 20% less GHG emissions by 2020, as measured from the levels of 1990.¹⁶ A mandatory 10% biofuel target for the transport sector was part of the text in the initial directive proposal.

12 COM (2005) 628 final.

13 European Commission press-release IP/06/1591.

14 COM (2007) 1 final.

15 Reference to the European Climate Package proposed by the EC in January 2008.

16 The EU Climate and Energy Package. Available at: http://ec.europa.eu/clima/policies/brief/eu/package_en.htm

However, during the decision-making process undertaken between the European Parliament and the Council, the term *biofuels* was replaced by *renewable energy in transport*, broadening the scope of technologies which could be used for the 10% mandatory target in 2020. The change, adopted in the final text of December 2008, was based on perceived risks particularly those related to increased biofuels production. Risks perceived include the potential of biofuel production compromising affordable food supply due to the competition for land and water, and actual GHG reductions due to potential indirect land use change, as well as social conditions in agricultural areas of developing countries. The change from a 10% *biofuels* to a 10% *renewable energy* target can also be understood as being motivated by innovation theory perspectives, which suggests policy makers should refrain from picking technology winners without knowing innovation paths of competing options such as electricity and hydrogen (Jacobsson et al, 2009; Pacini and Strapasson, 2012).

Labour issues were especially sensitive, and were also brought by the European Parliament during the appraisal of the directive proposal in 2008. Since the EU has in principle no power to regulate labor, health and remuneration conditions outside its borders, a compromise has been achieved in the final text as to require external supplying countries to be signatories of the conventions of the International Labour Organization, with verification to be made via an initial report to be presented in 2012. The European Parliament and Council reached broad consensus in December of 2008, and the final directive text was formally adopted in April 2009 (as 2009/28/EC).

3. The 2009 renewable energy sources directive (RED) – consolidation of EU common goals

A new chapter of the European biofuels policy was started in early 2009 with the introduction of the Renewable Energy Directive, or RESD (2009/28/EC). The new directive did not only focus on biofuels, but rather on a broad legal instrument for the promotion of renewable energy in Europe. Unlike the biofuels directive

from 2003, the new directive was adopted in a context of large use of biofuels albeit short from meeting the targets set in 2003. The total biofuel consumption in 2009 represented 4% of the transport fuel pool, or 12.1 Mtoe.

A new fuel quality directive (2009/30/EC) was published shortly after the RED. It updated the 1999 and 2003 fuel quality directives in the sense of increasing the biodiesel (FAME) cap to B7 (7% biodiesel) blends, while also calling for a standard for B10. The directive effectively changed gasoline specifications, allowing an increase from 2.7% to 3.7% in oxygen content (in weight), meaning a potential increase from 5% to 10% ethanol blends or 15% to 22% in Bio-ETBE blends (Sabic, 2010). A set of sustainability criteria for biofuels were also introduced.

The RED came into being partly due to the perception that the 2003 biofuels directive was not implemented correctly (Ninni and Lanzini, 2010). Failure to meet the voluntary targets of the 2003 biofuels directive contributed to the introduction of a mandatory target for renewable energy in transport in the new directive of 2009. **Figure 1** shows the difference between actual consumption and the targets for biofuels initially set by the 2003 directive.

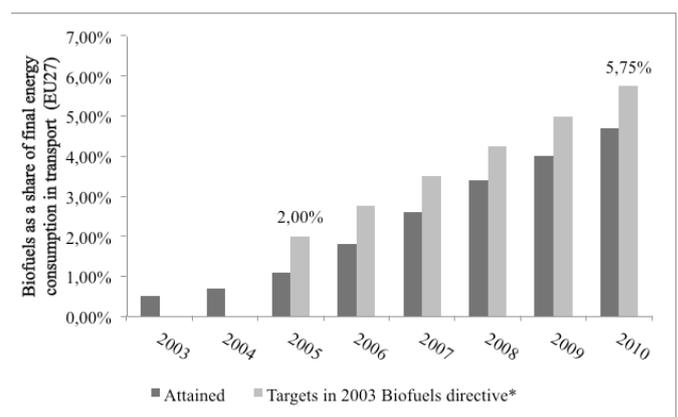


Figure 1. Actual biofuels consumption compared to targets set in directive 2003/30/EC. *Targets between 2005 and 2010 represent a linear interpolation; only 2005 and 2010 had policy-backed indicative targets of 2% and 5.75% respectively.

Source: based on data from EurOberver (2010).

The RED directive incorporated two previous directives, namely 2001/77/EC (on renewable

electricity) and 2003/30/EC (on biofuels) into a single and more ambitious instrument. A mandatory target of 10% renewable energy by 2020 was set specifically for the transport sector. This corresponds to 10% of the total energy consumed in transport, but only petrol, diesel and biofuels consumed in road, rail and electricity are taken into account (RED Art. 3, §4).¹⁷ Advanced biofuels (i.e. based on cellulosic or lignocellulosic non-food material), as well as biofuels made from waste and residues count double towards the 10% national renewable energy obligations in the transport sector, on an energy basis (RED Art. 21 §2; Hodson et al,

mandatory 10% share of renewable energy in transport seems to contradict the ideal of flexibility, the EC position, as expressed in the Renewable Energy Roadmap from 2006, was that investment security needed to be explicitly promoted in transport, the low-performing sector of renewable energy (EC, 2006, p.10; Hodson et al, 2010 p. 174).

EU member states had very different shares of renewable electricity and heating in their energy matrixes, but their starting points were rather similar in transport. As noted by Hodson et al (2010, p. 174-175), the share of RE in transport was well below 10% in all EU countries when the directive was adopted in 2009, even for leading countries such as Germany and Sweden. While member states could set voluntary targets higher than 10%, carbon offset costs via renewables in transport tend to be higher than in other sectors, indicating a potential lack of interest in pursuing larger shares than the legal mandate (McKinsey, 2010). This led to the perception that a flat 10% share of renewable energy in transport was appropriate for all member states irrespective of their starting points.

While the RED adoption meant a strong promotion of biofuels, the year of 2009 saw the revision of the Common Agricultural Policy (CAP "health check") in which subsidies for energy crops were removed.¹⁸ The effect of this is debatable, given the dual-purpose (i.e. food and fuel) nature of predominant feedstocks used within the EU, such as cereals and oil seeds.

Another important motivation behind the RED directive was the need to respond to the debate on sustainability, which gained significant strength in Europe during the last decade. Since biofuels can be produced in numerous ways and in different countries, higher demand could also generate negative impacts, exacerbate land conflicts and competition with food crops, or even increase greenhouse gas emissions due to indirect land use change. Under the assumption that biofuels would still make the bulk towards the

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2010, p. 217; GAIN, 2010, p. 6)

According to Hodson et al (2010, p. 69) the move from indicative sectoral targets (for renewable electricity in 2001 and biofuels in 2003) into legally binding overall targets for renewable energy (20% in average) and transport (10% in all member states) by 2020 marked the essence of the RED. In this way, the directive sought to provide investment security and flexibility in order to increase the share of renewables in Europe. Though the inclusion of a

¹⁷ It is important to note that at least three large sectors of energy use in transport are not included in the calculation of the 10% denominator: jet fuel, fuel oil (bunker fuel for shipping) and biofuels used for air and waterway transport. As pointed out by Hodson et al (2010), this makes the eligible denominator smaller and the 10% target more attainable.

¹⁸ Council regulations 72, 73 and 74/2009.

Year	Biodiesel			Bioethanol			Other biofuels*		
	Production	Consumption	Prod/Cons ratio	Production	Consumption	Prod/Cons ratio	Production	Consumption	Prod/Cons ratio
2006	4205	4005	1.05	772	863	0.89	662	649	1.02
2007	4913	5921	0.83	885	1175	0.75	632	725	0.87
2008	6669	8291	0.80	1153	1556	0.74	342	342	1.00

Table 1. Production, consumption and self-sufficiency ratios of biofuels in Europe 2007-2011 (in ktoe) * Includes pure vegetable oil and biogas.

Source: Compiled from EurObserv'er biofuel barometers (2007-2011).

10% renewable energy target for transport in 2020, a sustainability scheme was then included in the directive in an attempt to reduce risks associated to a higher biofuel demand in Europe.^{19 20}

3.1 Improving information: National Renewable Energy Action Plans

From the 2006 communication *A Biofuels Policy for Europe*, until after the adoption of the RED directive in 2009, the balance between indigenous capacity and the need for imports permeated the discussion on biofuel usage in Europe. While Europe managed to have a net surplus of biodiesel in 2006, between 2007 and 2008 imports were needed to meet about 18% of the total consumption. The reliance on foreign bioethanol is more severe, with dependency rates approaching 26% in 2008. The increase in dependency rates suggest growing opportunities for developing countries to supply the increasing biofuel demand in Europe. Interestingly, there is substantial idle production capacity for ethanol in Europe denoting transitional barriers, market failures or lack of competitiveness (ePure, 2011). Table 1 depicts the self-sufficiency ratios for most used biofuels.

The RED directive required European member states to prepare action plans (NREAPs),

including an assessment of their renewable energy capacities and strategies to meet requirements defined in the directive. The plans set out national targets for the share of renewables to be used in various sectors (transport, electricity, heating and cooling), also taking into account the effects of other policy measures such as energy efficiency and multi-level cooperation between authorities. These followed a standardized template, which sought to improve information, benchmarking, as well as reduce heterogeneity in reporting of national renewable energy potentials (ECN, 2011).

The NREAPs provide information on biofuel production potentials identified and strategies being devised at member state level, thus providing better basis for forecasting biofuel developments beyond a simply adaptive extrapolation of past trends in the EU. The national action plans surveyed natural resource endowments, investment trends and policy strategies in order to present numbers based on national realities, bridging the information deficit of previous years.

In line with the call for renewable energy in transport by 2020, as set by RED, the NREAPs surveyed the EU27 potentials for 5 types of renewable energy options in transport: renewable electricity, hydrogen, biodiesel, bioethanol and other biofuels. While renewable electricity has visible participation mainly in rail transport, the participation of electricity in road transport has so far been very limited. An European Commission white paper published

19 Arguments for the EC expectation that biofuels will cover a significant part of the renewable energy mix in transport can be found at COM (2006) 34, p. 3. This could be revised in the coming years since the EU transport roadmap released in March 2011 foresees a greater emphasis on electric vehicles. See EC (2011c).

20 See COM (2006) 848 p. 10.

in 2011 outlined a roadmap to a single European Transport Area, including the goal of no more conventionally-fuelled vehicles in cities by 2050 (EC, 2011c). While this goal might well include a large share of electric vehicles, the long time-horizons make it difficult to predict which technologies will contribute towards this objective. As of 2011 and up to 2020, the largest share of renewable energy in transport is expected to be derived from bioliquids such as biodiesel, bioethanol and other biofuels (e.g. biogas and vegetable oil) respectively (see **Figure 2**).

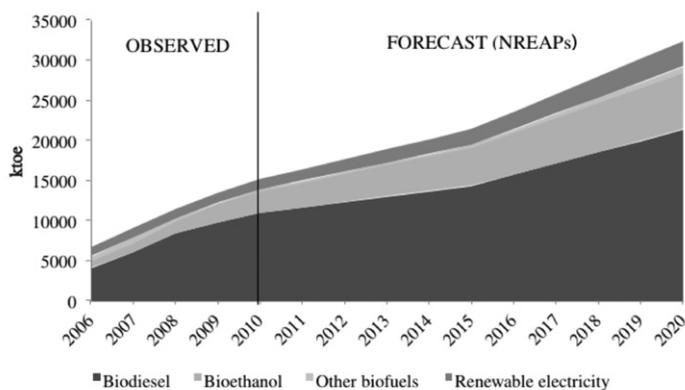


Figure 2. Biofuel consumption in the EU27 between 2006-2010 and prospects until 2020, by type of fuel.

Data sources: *EurObserv´er* (2010) and National Renewable Energy Action Plans – NREAPs (ECN, 2011).

Data from the NREAPs suggest a continued dominance of biodiesel as the main renewable fuel in transport. There is, however, an expected increase in the shares of ethanol, electricity and other biofuels (including biogas) in the renewable energy contributions to transport by 2020.

While the term “renewable energy” used in the RED allowed for electricity and hydrogen to compete with biofuels in order to fulfill the 10% consumption target by 2020, the development of these two is expected to be fairly slow in the short term. Hodson et al (2010, p. 175) identify some of the technology barriers behind the low expectations for hydrogen in transport by 2020. These include issues of technological and cost-efficiency nature related to the production, transportation and usage of

hydrogen in vehicles. The same can be said about renewable electricity for road transport, which in spite of a strategy push embodied in the SET plan from 2009, still has quite limited penetration in the market (SETIS, 2011). There are, however, expectations for a higher growth rate for renewable electricity in road vehicles after 2020 (Kendall, 2008).

Figure 3 illustrates growth trends in renewable energy for European transport based on recent data from the NREAPs published in March 2011. Other biofuels include biogas and vegetable oil, with the latter being partially responsible for negative growth of this category between 2008 and 2009, due to a phase-out of an excise tax exception in Germany (EC, 2011d). Notably, the growth rates for biofuels have been modest in the past few years but still bioethanol and biodiesel stand out. The forecast indicates however belief in a more even distribution in the future.

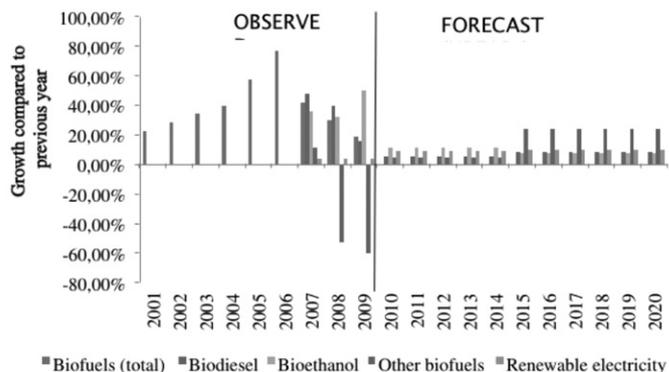


Figure 3. Past and expected yearly growth rates in the usage of different renewable energy technologies for transport.

Data sources: *EurObserv´er Biofuels Barometer* 2010 for actual observations prior to 2010. Forecasts based on National Renewable Energy Action Plans (NREAPs) from ECN (2010). Note: Exact definitions depend on specific national reporting, see (EC, 2011a). Hydrogen not figured in data as its growth rate (and absolute usage) ranked zero for all EU27 member states.

3.2 Sustainability Scheme for biofuels

During the development of the RED, a strong debate on biofuels sustainability gained steam, reaching a much politicized tone in Europe by

early 2008 (EC, 2007; Londo and Deurwaarder, 2007; EurActiv, 2007). As the production of biofuels can potentially harm the environment and social systems in various ways, the inclusion of a sustainability scheme for the production and usage of biofuels became one of the most debated features of the RED. While sustainability can be defined in a multitude of ways, the EC had to balance different approaches and come up with a scheme that was both effective and practical to implement.

The RED directive was not the only legal instrument to introduce the sustainability criteria for biofuels in the EU. Technical aspects of biofuel blending were addressed by the revised Fuel Quality Directive (EC, 2009b), which also included the sustainability scheme in its text published on April 23rd, 2009. Internationally, technical standards for biofuels were explored via a tripartite document between the EU, US and Brazil (Brazil, EU and US, 2007). However, many doubts remained on methodologies for the calculation of greenhouse gas balances of biofuel production and usage, as well as of rebound effects brought by indirect land use change (Pimentel, 2004; Fehrenbach *et al.*, 2008; Khatiwada *et al.*, 2012).²¹

In mid-2007, the EC launched a public consultation to gather views on how to optimally design a sustainability scheme for biofuels, receiving 251 responses.²² In addition to the public consultation, in late 2007 and early 2008, the Commission was flooded with requests for meetings from lobby organizations and government representations based in Brussels, all seeking to influence the upcoming directive and understand the risks and oppor-

tunities inherent to a sustainability scheme for biofuels. Direct meetings were held with representatives from Brazil, Malaysia and Mozambique, as potential exporters of biofuels to EU markets.²³

Environmental and social aspects in third countries were also raised as potential risks of a deliberate promotion of biofuels at large scale in Europe (Eikhout, 2008; Hall *et al.*, 2009; Di Lucia, 2010). While a higher demand for biofuels could act as a development driver and boost income in rural areas, there were fears that biofuels would crowd-out native vegetation and species, conflict with land and labor rights, as well as reduce incentives for food-oriented plantations in various countries. The debate led the European Commission to design its own sustainability scheme for biofuels, the observance of which is mandatory for EU countries to be able to count such fuels towards renewable energy targets set in the RED of 2009.

The core of the EU biofuels sustainability criteria – also reflected in similar initiatives by the US EPA – was a minimum greenhouse gas performance and land-use criteria, applicable irrespective of origin (EPA, 2009).²⁴ For biofuel producers inside the EU, there was also the requirement of cross-compliance with the CAP requirements (Art. 17 §6). Based on the adopted sustainability scheme for biofuels, member states can only count certified sustainable biofuels for the mandatory 10% share of renewable energy in the transport sector. Failure to comply with the sustainability criteria does not prohibit member states to use non-certified biofuels. However, biofuels that fail to fulfil the sustainability criteria do not count towards national targets of renewable energy obligations. In addition, biofuels that do not meet the sustainability criteria will not be entitled to financial support from consumption schemes (Hodson *et al.*, 2010 p. 180).

21 Indirect land use change (iLUC) results from increased demand for land for energy crop production. The indirect effects are caused by changes in prices of crops, land, labour, capital, leading to changes of production, consumption and trade patterns. This may result in carbon stock changes, increased carbon emissions, and loss of diversity. iLUC can occur with significant time lags and can be distributed through trade of agricultural commodities and biofuels. It should be noted that such indirect effects may occur with essentially all types of land use and not only those associated with biofuels.

22 http://ec.europa.eu/energy/renewables/consultations/2007_06_18_biofuels_en.htm

23 Source: DG ENER officials.

24 The minimum GHG savings required is related to the date when production sites start their operation. See Hodson *et al.* (2010, p. 182).

In a nutshell, the EU criteria mandates that biofuels:

- Should deliver a minimum of 35% savings in greenhouse gas emissions, calculated on a lifecycle basis, when compared to their fossil-equivalent. These requirements are elevated to 50% after 2017 and 60% after 2018.
- Cannot be produced in areas of high biodiversity.
- Cannot be produced in untouched forests, areas of protection and highly biodiverse grasslands.²⁵
- Should not be sourced from areas with high carbon stocks, wetlands and continuous forests.
- Must be produced under work conditions which observe the Conventions of the International Labour Organization

The sustainability criteria were amended by the European Parliament and Council in 2008 with changes including the requirement of periodic reporting on labour conditions according to Conventions of the International Labour Organization and on the impacts of biofuel demand on food prices and land rights, especially in what regards developing countries.

3.3 Sustainability certification

While there was consensus on the need for sustainability in biofuels (Lewandowski and Faaji, 2006), the production and usage of biofuels is a complex system, which can be subdivided in several steps. These include cultivation, harvesting, transport, storage, processing and distribution to fuel blenders and final users. Any effort seeking sustainability requires information from all these steps in the production chain. Details on certification procedures and costs were largely unknown by the time the RED was adopted in April 2009, but policy makers and private agents at member state level in the EU had 20 months to comply with the directive.

²⁵ An EC decision on the criteria and ranges which define highly biodiverse grasslands is still pending after a public consultation carried out between December 2009 and January 2010. See: http://ec.europa.eu/energy/renewables/consultations/2010_02_08_biodiverse_grassland_en.htm

The EC had different possibilities when it contemplated a system for sustainability information in chains of custody. The Commission impact assessment which accompanied the RED proposal contained three options for regulating the chain of custody of biofuels, namely *track and trace*, *book and claim* and *mass balance* (EC, 2008b; Hodson et al, 2010 p. 201).

Track and trace is a path of identity preservation, where all shipments claiming biofuels sustainability need to be physically separate from other biofuels in each step of the production chain. This system results in high costs given the logistics of duplicating containers along the chain, and was thus not endorsed by the EC.²⁶

A *book and claim* system requires no physical link between production of biofuels which comply with the sustainability criteria and a claim of compliance (Hodson et al, 2010 p 201). Under this system, operators register production of sustainable biofuels (thus booking this into a central registry), for which they receive a tradable certificate. Operators at the end of the chain need to hand over a certificate for each unit of biofuel they sell as sustainable. In this system, certificates are traded in the market and there is no physical requirement that biofuels used meet any sustainability criteria, given they are matched with a certificate proving the same amount of sustainable biofuel has been produced – and presumably consumed elsewhere.

Finally, a *mass balance* system is one in which a mix of sustainable and non-sustainable biofuels can take place. Each container must be accompanied by information on the quantity of biofuels which conform to the sustainability criteria. Changes in the contents of the containers must then be matched by an adjustment on the percentage of sustainable biofuels which remain as part of the whole. By establishing a flexible form of physical tracking, mass balance is more rigorous than a book and

²⁶ A Track and trace mechanism is the rule on genetically modified organisms (GMOs) in the European Union. GMOs are shipped in separate containers from conventional organisms as cross-contamination is undesired.

claim approach, but less so than a full-identity preservation approach.

The European Commission opted for a mass balance system for biofuels certification and tracking in the chains of custody. Reasons for this choice included the need to change behavior of market actors and provide price premiums for sustainable biofuels. According to the EC, this was better safeguarded through physical tracking of shipments (EC, 2009a, Recital 76 and §18). The directive also argues against a very stringent system of track and trace due to risks of unreasonable burden on the industry. The practical guidelines for market operators were published by the EC in 2010, and member states were charged with the task to verify compliance and promote audits (EC, 2010; Hodson et al, 2010 pp. 202-203).

The broad methodological scope and fact that the EU took on the task of designing a sustainability criteria instead of using market agents (e.g. private, ISOs) has led to the development of a large number of parallel sustainability certification schemes for biofuels. Desplechin (2010) pointed 27 different biofuel sustainability schemes in early 2010. In fact, the RED delegated the certification process itself to private agents, charging EU member states with the responsibility of monitoring the system. Member states were required to source information and audit local biofuel producers and operators. The RED opened three options for market agents to obtain certification of sustainable biofuels: (1) via voluntary schemes for producers irrespective of origin; (2) through agreements with third countries; and (3) via agreements with EU member states.

Voluntary schemes include industry, NGOs and governmental schemes which, unlike the mandatory "floor" set by the RED, are of voluntary compliance by operators. Examples include the Roundtable on Sustainable Biofuels (RSB), Roundtable on sustainable Palm Oil (RSPO) and Bonsucro.²⁷ The EC can examine

voluntary schemes and decide – via comitology process – that a voluntary scheme is at least as stringent as the requirements of the RED (EC, 2009a Art. 18 § 4). EU member states can support and promote voluntary schemes via national agencies, but they cannot require mandatory compliance to sustainability requirements that are more stringent than those in the Directive. In July 2011, seven voluntary certification schemes were recognized by the EU as adequately covering the requirements in the RED.²⁸ Alternatively, market operators in third countries can obtain sustainability certification if their governments reach an agreement with the EC, again based on proof of attaining the same requirements as the minimum sustainability requirements for biofuels laid at RED.

The comparative costs of the three certification options remains somewhat unclear. While some biofuel supplying countries will likely have institutional and scientific capacity to obtain bilateral certification with the EC such as Brazil, other emerging biofuel producers in developing regions will lack regional information on GHG lifecycles, land-use patterns and carbon stocks of arable land, all important for obtaining sustainability certification (Khatiwada et al, 2012). Production of such information (and subsequent scientific validation) might represent a large financial and temporal burden – delaying access to EU markets and harming competitiveness. However, biofuel trading groups such as Greenergy and Abengoa are already funding the certification of biofuels from partners in developing countries to guarantee the availability of suppliers able to access the EU market. This could be an indication that the cost barrier may not be as significant as anticipated.

The 2009 RED consolidated the EU common goals on renewable energy, and promoted significant change in the framework for biofuels when compared to the 2003 directive. This policy shift can be seen as a reflection of increas-

27 See: RSB: <http://rsb.epfl.ch/>; RSPO: <http://www.rspo.org/> and Bonsucro: <http://www.bonsucro.com/>

28 See: http://ec.europa.eu/energy/renewables/biofuels/sustainability_schemes_en.htm

ing understanding about the complexities involved in the expansion of biofuel production and use, and the opportunities and constraints for the specific case of the EU. The next section attempts to create forecasts for biofuel participation in the EU27, based on historical trends of biofuel usage in the EU as well as directions likely to be taken with the new policy developments embodied in the RED.

4. Biofuels in the EU: Where to?

This section attempts to forecast future directions for biofuel usage in Europe. For this purpose, we do not only seek best-fit extrapolations

It is not clear whether the costs of suffering an infringement procedure outpace the “direct savings” of noncompliance with the directive

tions based on past trends. Since future adoption of biofuels will depend on innovation and system shifts, this section incorporates information from regulatory changes introduced by the RED in 2009. Ultimately, forecasts and growth rates of biofuel consumption can serve as a tool to improve understanding about potential policy impacts, and indicate policy adjustments.

4.1 Targets and trajectories for biofuel usage

Since 2003 there has been a continuum of targets for biofuel usage in Europe. Firstly, the 2003 directive introduced an indicative (non-binding) target of 5.75% to be met specifically with biofuels by 2010. Later, when EU member states appeared to be lagging behind, a policy revamp in the form of a renewable energy directive introduced a mandatory goal of 10%

renewable energy in European transport, this time without picking technology options. At the same time, member states were required to survey their local markets and policies, producing action plans which serve to consolidate implementation of the renewable energy directive until 2020. This led to 27 individual submissions which constitute the NREAPs report published in 2011 (ECN, 2011). It is clear from the report that biofuels are expected to continue making the bulk of renewables in transport until 2020.

According to Hodson *et al* (2010 p. 62-64), it was not enough for the Commission to be able to impose sanctions on member states that fail to achieve their national targets after 2020. It was deemed necessary to give the Commission the power to initiate legal action against member states which were not on track to meet their targets before 2020. For this reason, an indicative trajectory was adopted based on the total goal of 20% renewables (all forms) by 2020, consisting of 25% by 2011, 35% by 2013, 45% by 2015/16 and 65% by 2017/18 (using averages for the two-year periods). The indicative trajectory - while a potential trigger for legal action - is only indicative of a country's performance and not specific for the transport sector (EC, 2009a, Annex 1b).²⁹

A non-binding trajectory would potentially let member states underperform without penalties. Thus, the trajectory can play an important role since the Commission has authority to start an infringement procedure against a member state that is lagging behind and failing to streamline administrative procedures. It is not clear, however, whether the costs of suffering an infringement procedure outpace the “direct savings” of noncompliance with the RED targets.

²⁹ The progress slope for renewable energy was a matter of debate in the European Parliament. The ITRE committee voted for binding interim targets, accompanied by direct penalty mechanisms (Claude Thurmes report, 2008/0016(COD)). Direct penalties were also strongly supported by an EREC position paper of May 2008.

4.2 Forecasting scenarios

The exponential growth in biofuels usage during the years between 2003 and 2009 suggested that biofuel production and usage could achieve very large levels, possibly substituting for a large amount of fossil fuels used in world transport. Both McKinsey (2007) and Matthews (2007) illustrate this optimism. Exponential growth in biofuels took place in Brazil and the US, and that trend was somehow expected to take place also in the EU after the RED. However, conjunctural factors such as the financial crisis of 2008-2009 curtailed energy demand and reduced the pace of biofuels usage in Europe. A clear situation of *adaptive vs rational* expectations then emerged for biofuels in the EU. Contrary to the adaptive expectation view, which would mean continuity in past growth trends, the production and usage of biofuels fell short of anything exponential in the years after 2009. Instead, the rational expectations embodied in the National Renewable Energy Action Plans (NREAPs) showed signs of more modest expectations for biofuels demand in European member states up to 2020.

Taking into account the biofuels regulatory framework prevailing in the EU in 2011, how can we conceptualize the future directions for biofuels in Europe? To tackle this question, this section adopts a modeling exercise which aims to present alternative development scenarios based on both the extrapolation of past trends and expectations about how the share of biofuels in transport might evolve in the EU27 until 2020. Data sources used for this exercise include EUROSTAT, all EurObserver biofuel barometers between 2007 and 2011, as well as the NREAPs report from the Energy Centre of the Netherlands (ECN, 2011).

Different regression curves are plotted searching for the best fit with observed data for biofuel consumption in the EU27 between 2003 and 2010. Forecasts are made until 2020 in three fundamental ways:

- A simple adaptive-expectations forecast based on the best-fitting regression curve matching past observations of biofuel consumption in the EU27;

- A reference forecast indicating how consumption might behave conditioned to a best-fitting curve of past observations, as well as a 10% share of biofuels in 2020 (corresponding to the scenario proposed by the initial EC proposal for biofuels only by 2020)
- A rational-expectations forecast which includes information contained in the newly published NREAPs.

In order to create the initial adaptive forecasts, different regression approaches were implemented in MATLAB seeking a best-fit curve matching the empirical share of biofuel participation (in energy terms) in the EU27 transport between 2003 and 2010. Nine projections were selected: (1) exponential; (2) power; (3) polynomial; (4) cubic; (5) square, (6) logarithmic; (7) linear; (8) logistic; and (9) logistic adjusted for a 10% biofuels share in 2020. The specifications of the equations and calculated parameters for each of the regression types are given in **Table 2**. A graphical representation of the curves can be seen in Figure 4.

The selection of the best-fit regression method is based on a quantification of dispersion compared to observed data. For this purpose, we use RMSE (Root Mean Square Error), which consists of the square root of the average of the squares of the deviations between real and forecasted values of aggregate biofuel consumption. RMSE can be formally defined as:

$$RMSE = \sqrt{\frac{\sum_{i=1}^N (Forecasted\ consumption - Observed\ consumption)^2}{N}}$$

Where N is the number of observations available (i.e. 8 values for share of biofuel consumption in the EU27 between 2003 and 2010). Additionally, the coefficient of determination (R^2) provides a measure of how well future outcomes are likely to be predicted by each regression type.

Regression	Equation	Equation (after regression)	RMSE	R ²
A - Exponential	$Y = k e^{(mx)}$	$Y = 0.1969 e^{(-0.4991x)}$	0.368	0.978
B - Power	$Y = k x^{(m)}$	$Y = 0.0485 x^{(-1.9921)}$	0.102	0.986
C - Polynomial Grade 4	$Y = a + b_1x + b_2x^2 + b_3x^3 + b_4x^4$	$Y = 3.5857 - 2.3343x + 0.5623x^2 - 0.0464x^3 + 0.0015x^4$	0.051	0.999
D - Cubic	$Y = a + b_1x + b_2x^2 + b_3x^3$	$Y = 1.7193 - 0.9570x + 0.2067x^2 - 0.008x^3$	0.054	0.999
E - Square	$Y = a + b_1x + b_2x^2$	$Y = -0.0032 - 0.0135x + 0.0501x^2$	0.089	0.996
F - Logarithmic	$Y = a + m \ln(x)$	$Y = 0.0150 + 3.6016 \ln(x)$	0.487	0.892
G - Linear	$Y = a + bx$	$Y = -1.8576 + 0.6381x$	0.246	0.972
H - Logistic	$Y = a/(1+b*e^{-cx})$	$Y = 6.74/(1+61.16*e^{-0.5003x})$	0.069	0.996
I - Logistic10	$Y = a/(1+b*e^{-cx})$	$Y = 10.1934/(1+54.7222*e^{-0.394x})$	0.114	0.998

Table 2. Equation specifications of different types of forecasts for share of biofuels in the EU27.

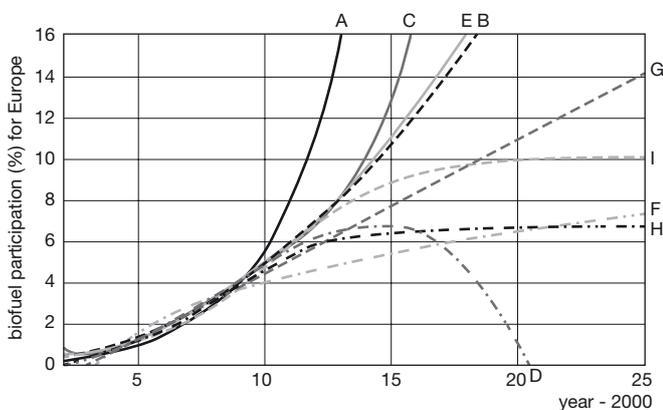


Figure 4. Different types of adaptive forecasts based on past shares of biofuels in the EU27, including logistic forecast adapted to a 10% biofuel share in 2020 (curve I).

Based on the best-fitting criteria of RMSE and R², it can be noted from results in Table 2 that curves D – Cubic, C – Polynomial Grade 4, H – Logistic and I – Logistic10 displayed the best results. However, the graphic visualization suggests some of these curves are not good forecasting candidates.

While D (Cubic) showed the best fitting results, its adaptive extrapolation from past data implies a contraction in terms of the share of biofuels being aimed at, a saturation near 2014 and decline to zero by 2020. While this would be plausible in case of the introduction of a radically new energy technology in transport, the short time-horizon analyzed makes this scenario improbable.

The adaptive curve C – Polynomial Grade 4 shows a good fitting with past observations, but displays a somehow explosive growth in the biofuel share, far beyond 16% already by 2016. This is highly unlikely given the many constraints that the expansion of biofuel production and trade needs to face in the short run, related costs, as well as the lack of European mandates for renewables in transport beyond the 10% set for 2020.

This leaves two logistic curves as interesting candidates for forecasting the EU market until 2020. **Figures 5 and 6** illustrate these two: a simple adaptive forecast based on the best-fitting logistic curve matching past observations of biofuel consumption in the EU27 (Figure 5); and a similar logistic curve, but adjusted to meet a 10% share for biofuels by 2020 (Figure 6).

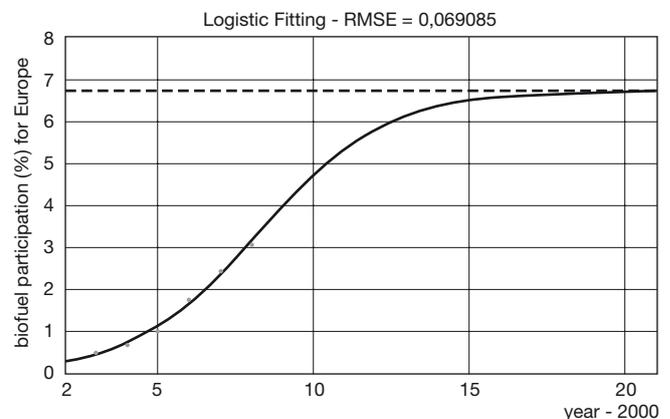


Figure 5. Simple adaptive logistic forecast fitted to past data on the share of biofuels in EU transport between 2003 and 2010.

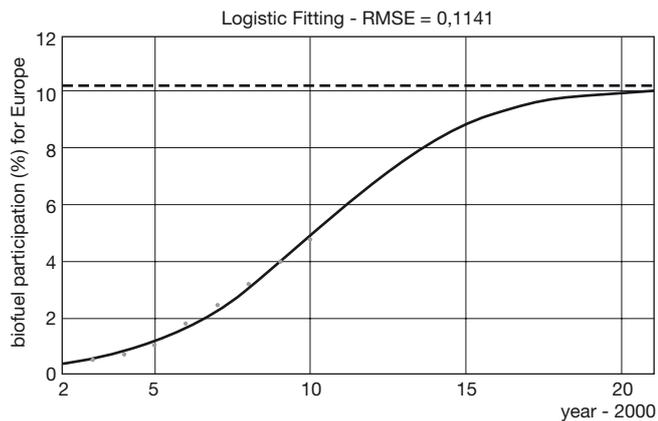


Figure 6. Adjusted adaptive logistic forecast, fitted to past data on the share of biofuels in EU transport between 2003 and 2010, as well as to a hypothetical 10% share of biofuels by 2020.

A comparison of both can be seen in **Figure 7**. It can be noticed that a simple best-fitting logistic extrapolation of past trends suggests a much lower share of biofuel consumption in the EU27 by 2020 (6.7%) compared to another best-fitting logistic curve adjusted to match 10% by 2020. This corroborates the perception that the 2003 biofuel directive by itself would not have been effective enough to bring higher shares of renewables to EU transport, partially validating the effort behind the policy reformulation via the RED in 2009.

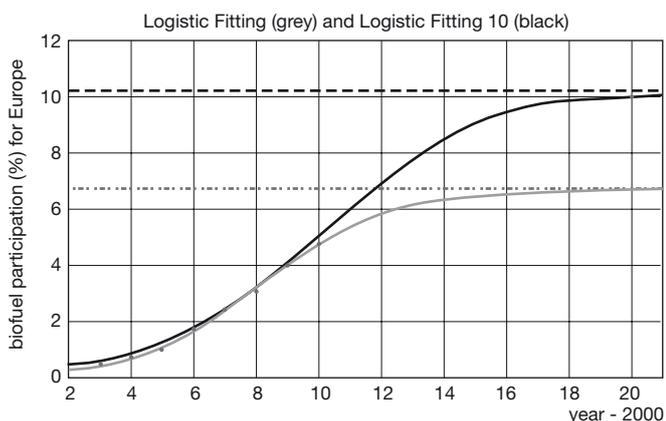


Figure 7. Comparison between logistic forecasts (simple best-fit and adjusted to a 10% biofuels share by 2020)

Logistic trends are plausible for two reasons. The first relates to the constraints on the amount of sustainable biofuels that can be effectively supplied. When eligible production factors (e.g. areas of non-highly biodiverse

grasslands, rainfed land, certified mills, etc.) approach full mobilization, the amount of sustainable biofuels produced could be reduced, de-accelerating growth. The second reason relates to the potential lack of interest from fuel retailers to go beyond the 10% mandate, in case biofuel prices (per unit of energy) continue to be higher than conventional gasoline and diesel.

On the other hand, logistic trends have a characteristic which might not adequately represent how biofuels will expand in the EU until 2020. Such forecasts imply a fast growth in biofuel shares between 2010 and 2015, with reduced growth between 2015 and 2020. A logistic development means the main trust for biofuel adoption would come in the initial periods, with growth in biofuel shares decreasing and stabilizing in 2020. In the plausible case that corporate investments and national policies take some time to result in higher biofuel usage, the incorporation of such fuels would accelerate in the later years (i.e. 2015-2020). This would render the logistic forecast no longer adequate.

Interestingly, the NREAPs report indicate what member states expect as the result from their policies and actions to promote biofuels. This is used here to produce a third forecast. In aggregate terms for the EU27, the NREAPs report indicated a 6.2% biofuel share in 2015 and a 9.3% share in 2020.³⁰ Contrasting to the logistic models, this third forecast contemplates the possibility that biofuel use might accelerate from 2015 onwards. This third forecast was modeled in MATLAB to condition a polynomial curve to both the real observations available until 2010, as well as the 2015 and 2020 values inferred from the NREAPs report (6.2% and 9.3% respectively). The resulting curve is shown in **Figure 8**.

³⁰ The NREAPs report considered a penetration of 1% renewable electricity in transport by 2020. According to that projection, biofuels will not be the only contributor to the 10% target of renewables in transport by 2020, but will still comprise 9.3% of the total (ECN, 2011 p. 239).

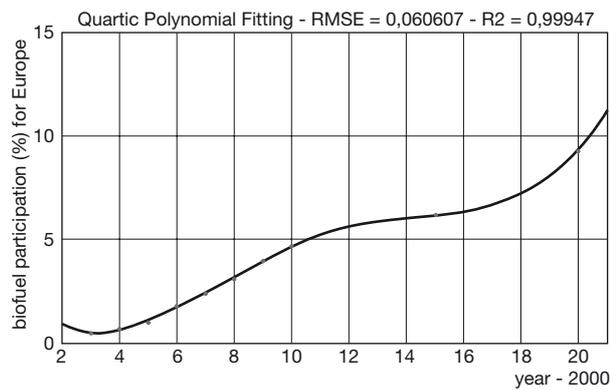


Figure 8. Rational quartic polynomial forecast based on past adoption of biofuels in the EU, adjusted to information contained in the NREAPs report (ECN, 2011).

Interestingly, when the polynomial curve is adjusted to match the forecasted values for 2015 and 2020, it also displayed an excellent fit for the observed data in the past (2003-2010), with a RMSE of 0.06 and an R^2 of 0.9947. Until 2020 this trend could be adequate if the production costs for 2nd generation biofuel technology are reduced and new types of biomass become eligible for biofuel production. It could also represent an increase in interest for biofuels in a post-2015 period, possibly due to higher oil prices or expansion of carbon-pricing mechanisms. After 2020, however, the growth turns explosive, reducing the trustworthiness of the forecast. The polynomial trajectory is also interesting because it reflects the already-mentioned discussions which took place during the RED co-decision process between the European Parliament and the Council in 2008, when a trajectory for the adoption of renewables was being debated. The message from those discussions is that policies and incentives – and the RED itself – should be adjusted based on the evolution of the biofuel adoption trend and underlying aspects.

A combination of all three projections is in **Figure 9**.

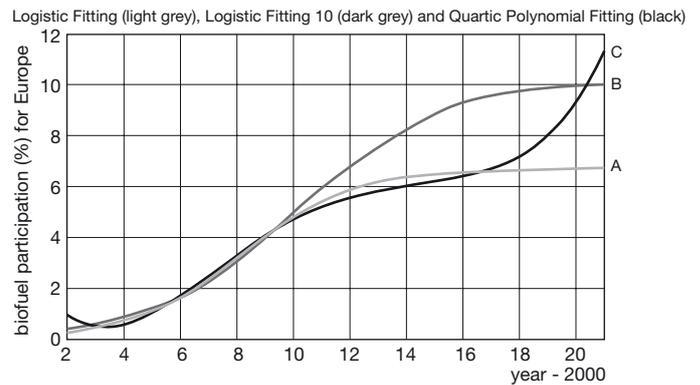


Figure 9. Comparison of forecasts representing adaptive expectations (A - Logistic and B - Logistic fitting 10% by 2020) as well as rational expectations (C - quartic polynomial adjusted to NREAPs predictions).

By deducing the derivate of the curves in Figure 9 for each year between 2010 and 2020, yearly growth rates of biofuel participation are estimated for biofuels in the EU based on each of the projections (logistic, logistic10 and polynomial). Results are presented in **Table 3**.

Inherently to any forecast, it is difficult to foresee a priori which trajectory biofuels will take in Europe until 2020, since the actual trajectory will depend on prices, technology, as well as policy developments which could alter the expectations in the NREAPs. Still, this analysis presents possible trajectories towards 2020, which could be useful for policy makers at EU and member state levels to access the speed of biofuel adoption, as well as compare that with the speed of competing technologies once better data is available.

Conclusion

The European directives 2003/30/EC and 2009/28/EC marked the consolidation of EU policies for biofuels. Through these directives, biofuels are now dealt with at the EU level, having evolved from previously scattered national initiatives. In addition, after 2003, the European Union has made clear efforts to coordinate its biofuel policies with other initiatives related to climate change, energy security, sustainability and development (EC, 2008a, EC, 2011b).

Year	LOGISTIC		LOGISTIC10		Polynomial (NREAPs)	
	% usage	Growth*	% usage	Growth*	% usage	Growth*
2011	5.40%	12.97%	5.93%	20.04%	5.17%	11.67%
2012	5.86%	8.52%	6.87%	15.85%	5.57%	7.74%
2013	6.17%	5.29%	7.69%	11.94%	5.86%	5.21%
2014	6.39%	3.57%	8.35%	8.58%	6.06%	3.41%
2015	6.52%	2.03%	8.88%	6.35%	6.21%	2.48%
2016	6.61%	1.38%	9.27%	4.39%	6.39%	2.90%
2017	6.66%	0.76%	9.55%	3.02%	6.67%	4.38%
2018	6.69%	0.45%	9.75%	2.09%	7.17%	7.50%
2019	6.71%	0.30%	9.89%	1.44%	7.99%	11.44%
2020	6.72%	0.15%	9.99%	1.01%	9.30%	16.40%

Table 3: Forecasts for the share of biofuels and yearly growth in the EU27, for different projection types. *growth calculated based on the increase from the previous year.

By setting an indicative consumption target of 5.75% biofuels in road transport by 2010, the 2003 directive attempted to secure a market for development of biofuel capacities. However, as most EU member states fell short of meeting this target, a new approach was necessary. Climate change, energy security issues and the expectation of growing biofuel imports from developing countries required restructuring of the European strategy for biofuels. Binding targets for renewable energy and sustainability requirements for biofuels were identified as crucial steps for a second EU-wide directive seeking more stringent rules for compliance. The introduction of sustainability criteria for biofuels in 2009 appeared to be a game changer, with signs of policy convergence from other major players such as Brazil and the United States.

The EU biofuel policy as it currently stands was never the fruit of a single directive, but the result of an evolutionary process from number of initiatives in different sectors. In addition to the formal directives in 2003 and 2009, the CAP, trade regimen (tariffs), technical fuel standards, sugar subsidies, public opinion, oil prices and technology progress all played a key role in shaping the present European stand on transport biofuels, as well as their actual level of insertion in the market.

Together with a definition of trajectories (speeds) for the introduction of renewables and potential sanctions, EU biofuel policies were made more stringent. In 2011, the National Renewable Energy Action Plans (NREAPs) tackled one of the weaknesses of the 2003 and 2009 biofuels directives – the lack of a stronger debate about expected future directions of biofuels in the EU compared to other energy technology options. While the 10% renewable energy target for transport in 2020 considers all sorts of renewables, the action plans published by EU countries in March 2011 further elaborated, and indicated low expected shares of electricity and biogas in transport until 2020, giving argument to the already-expected dominance of liquid biofuels.

The analytical exercise carried out in this paper contributes with insights about potential directions for the EU biofuel policy. The exercise helps frame the debate about future developments, and identify eventual policy adjustments that are needed to achieve successful incorporation of sustainably-produced biofuels. The MATLAB model, using both adaptive and rational expectations based on observed levels of biofuel adoption, as well as future trends, builds upon information in the NREAPs, which in turn are directly related to

policy implementation efforts in the member states.

What can the policy trajectory of biofuels in the EU tell us so far? This may entail some reflection. For one thing, it echoes a major effort of multiple actors. In policy terms it is something quite unique in its ambition level. And it has progressed despite the need to accommodate many different interests. The drive of energy security has been really strong and also the EU climate policy leadership. As most countries were still in ground zero when biofuel policies were launched in 2003 and

On 17/10/2012 the Commission published a proposal to limit global land conversion for biofuel production, in order to stimulate the development of alternative biofuels from non-food feedstock, like waste or straw, which emit substantially less greenhouse gases than fossil fuels and do not directly interfere with global food production. The use of food-based biofuels to meet the 10% renewable energy target of the Renewable Energy Directive will be limited to 5%. (Note by the editor)

(reinforced) in 2009, perhaps that has been an advantage while trying to find a common agenda. There was here an empty space to engage scientists, engineering companies, consultants, etc. in the buildup of a new industry. On the negative side, it can be said that despite the policies and efforts for technological innovation in a broad set of energy solutions, biofuels were what actually took off as they were what markets were ready to respond to.

It is far too early to say that there is a consolidated EU biofuels policy in place, as any forecast must be seen with reservations. The push for biofuels is still likely to be a moving target, as even the RED acknowledges the possibility for the Commission to suggest future amendments. Many uncertainties still rove the issue of biofuels sustainability, such as indirect land use change factors in emissions accountancy, the industry's sensitivity to

certification requirements, developments in oil prices as well as broader social acceptance as utilization rates grow. The promotion of biofuels in Europe is expected to continue taking shape of a myriad of efforts into the future.

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