REPORT f3 2013:15

POLICY INSTRUMENTS DIRECTED AT RENEWABLE TRANSPORTATION FUELS

– AN INTERNATIONAL COMPARISON

Report from an f3 project

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PREFACE

This report is the result of a cooperation project within the Swedish Knowledge Centre for Renewable Transportation Fuels (f3). The f3 Centre is a nationwide centre, which through cooperation and a systems approach contributes to the development of sustainable fossil-free fuels for transportation. The centre is financed by the Swedish Energy Agency, the Region Västra Götaland and the f3 Partners, including universities, research institutes, and industry (see www.f3centre.se).

This report shoud be cited as:

Grönkvist, S., Peck, P., Silveira, S., Åkerman, J., Larsson, M., and Khedkar, P. (2013) *Policy Instruments Directed at Renewable Transportation Fuels – An International Comparison.* Report No 2013:15, f3 The Swedish Knowledge Centre for Renewable Transportation Fuels, Sweden. Available at www.f3centre.se.

SUMMARY

The production of transportation fuels from renewable primary energy sources requires ongoing support if it is to reach commercial maturity. Worldwide, the most common types of support are politically derived 'policy instruments'. A variety of such instruments have been and are applied in differing contexts in different parts of the world; in this project we describe and dissect policy instruments that have been used in Brazil, the EU (with prime focus on Germany), and the US. As the political economy of biofuels these jurisdictions has evolved over past decades, and policy interventions have also changed, the analysis focuses on key points of change or major market inflections. Emphasis was placed on the following aspects of enquiry in particular:

- underlying motivations for policy interventions, how were they formulated, and how outcomes align with the initial objectives;
- how instruments supported the biofuels sector(s) in the short and longer terms;
- lessons of relevance to the promotion of renewable biofuels in Sweden.

This work is to contribute to the formulation of more efficient policy instruments in Sweden that better account for dynamic issues tied to feedstock, climate, technological and industrial development, infrastructure, regulations, and long-term political intent. It departs with a view that although production, infrastructure, and markets for biofuels in Sweden are of significant scale, they are still in an early stage of their development potential – and that biofuels policy must reflect this.

During the study period, the Swedish government proposed a new 'hybrid' quota system for low-level blended biofuels. However, pure and high-level blended biofuels outside the quota system and retaining tax exemptions. This has affected the deductions drawn for the Swedish way forward regarding biofuel-related policy instruments. Further, two important Swedish policy goals affect biofuel futures: zero net 2050 greenhouse gas emissions, and a fossil independent 2030 transport sector. While transportation biofuels will be part of the toolbox to reach both these goals, lack of clarity regarding their application to biofuels (particularly for the latter) make many questions regarding future policy instruments difficult to answer definitively.

Analysis of the three cases provided a range of contrasting insights regarding factors important for a positive developnment; such factors generally fall within three thematic areas:

- synergies by design, multi-sectoral or cross-sectoral benefits, and delivery of other social or economic 'goods';
- policy support stability but 'flexibility' over relatively long market development periods, with support for both infrastructure investments as well as development of fuel markets, production logistics and technologies;
- trade-offs between effective/efficient quota systems that mainly support low-level blends and the combination of policy instruments necessary for high-level blend chains.

<u>Synergies by design and multi-sectoral benefits:</u> Synergistic effects stimulate biofuels and increased overall benefit accrues if several sectors gain from the development. Cases highlight a number of areas where biofuels development can be utilised to strengthen and diversify incumbent

sectors while delivering socio-economic benefits in other areas (e.g. fiscal deficit and oil dependence reduction, agricultural and transport sector stimulation, energy-sector development).

Multifaceted policy support and longer-term stability: Cases highlight the benefits of diversified policy mixes that provide relatively stable support. Key stability parameters observed included multiple and flexible support mechanisms, lengthy time horizons for change, and guaranteed market spaces for both fuel supply chains and fuel demand. Ongoing support matched by steady sector growth was mapped for Brazil and the US over more than 30-years. Policy support in these countries helped develop industry confidence, legitimacy, and private sector investment. In contrast, German experiences with rapid policy shifts in systems with high subsidy dependence caused immediate solvency problems and flow-on effects such as marked increases in investor doubt and increased investment risk premiums.

Trade-offs between quota systems for low-level blends and policy instruments that support high-level blends: Contrasting experiences with policies supporting high or low level blends point to a number of policy trade-offs. In Brazil, mid-high level blends have been supported by a mandatory quota system in combination with other initiatives such as subsidy support for a large scale flexi-fuel vehicle programme. Such interventions have resulted in large market shares for renewable fuels. In contrast, while successful in the development of a huge domestic market for ethanol at blends of up to 10%, frameworks in the US have not been conducive to the development of markets and infrastructure for high-blend biofuels. These remain marginal and the US already faces ‘blend wall’ challenges, where the absence of extensive infrastructure and vehicles for high level blends constrains biofuels to 10% of the fuel mix. While quota based systems dominating in the EU can apparently deliver low-share targets for biofuels in total fuel mix, evidence is found that this may not set up the system that is required to deliver much higher penetration of fossil free fuels. High-blend penetration is an endeavour requiring considerable time and investment to develop and be accepted by the market.

Another lesson to be learned from experiences in USA is that the fulfilment of a mandatory market-volumes or ‘quotas’ does not occur automatically if the techno-economic systems required for production are not adequately mature. The mandated volumes for cellulosic ethanol is an example when difficulties related to the development of the production has led to a situation when mandated volumes are unlikely to be fulfilled.

That targeted efforts to achieve multi-sectoral benefits has proved to be important for the development of biofuel-chains elsewhere is very relevant for Swedish ways forward. Although some synergies between sectors are inevitable – as at least production, transportation, and distribution must be involved for a full biofuel chains, there are many other opportunities for synergies in Sweden. One vital component is the well-developed infrastructure for district heating that offers systemic advantages for integrated second generation biofuel production processes, particularly those that release large amounts of waste heat. Currently, there may also be a relatively positive business climate for integration of secondnd generation biofuel production with the Nordic forest industry, as it offers diversification opportunities to ameliorate decreased profitability in core business areas.

Considering the design of the Swedish hybrid quota system, the Swedish government seems to have taken note of fallout to events such as the rapid change from tax exemptions to a quota-based system in Germany. Some of the promising second generation pathways in Sweden, such as the DME and second-generation biogas, are still granted full tax exemptions. This is instrumental for the continued development of these options and an example of stable policy support as well as a trade-off between a quota system that secures low-level blends and a continued support for the pursuit of the high-level blends necessary to achieve the high ambitions for biofuels in the Swedish transport sector.

However, these ambitions, together with the activities most likely required to fulfil the targets with second-generation fuels will lead to a situation where capital costs are expected to become a more significant part of the total production cost. As such, it seems logical that the hybrid quota system will be insufficient. There will be a need for increased support for both R&D and for capital investment programmes. Target-specific policy instruments are also more effective to fulfil goals such as energy self-sufficiency and rural development than quota systems and tax exemptions.

SAMMANFATTNING

Produktionen av förnybara drivmedel kräver generellt olika former av stöd för att nå kommersiell mognad. Den mest väletablerade och omfattande typen av stöd utgörs av politiska styrmedel som kan understödja och driva utvecklingen i en riktning och fart som marknadskrafter av egen kraft inte förmår. Runt om i världen används en mångfald av olika styrmedel riktade mot förnybara drivmedel och i denna rapport beskrivs de som använts i Brasilien, EU (med huvudsaklig inriktning på Tyskland) och USA. I rapporten analyseras hur användningen och utformningen av styrmedel har förändrats under de senaste decennierna. Särskild vikt har lagts vid följande aspekter:

- Syften med styrmedlen, hur dessa utformades och hur resultatet av tillämpningen förhåller sig till de ursprungliga motiven
- Hur väl styrmedlen fungerat för att stödja utvecklingen av förnybara drivmedel i förhållande till konventionella drivmedel
- Relevanta lärdomar för utformningen av stöd för biodrivmedel i Sverige

Rapporten kan underlätta utformningen av mer effektiva styrmedel i Sverige som tar hänsyn till de nationella förutsättningarna gällande råvaror, klimat, teknisk och industriell utvecklingsnivå, infrastruktur, regelverk och långsiktiga politiska målsättningar. Utgångspunkten är att den svenska produktionen, infrastrukturen och marknaden för förnybara drivmedel fortfarande är relativt outvecklad och att styrmedlen måste anpassas till det.

Under arbetet med rapporten föreslog den svenska regeringen ett nytt kvotpliktsystem för biodrivmedel, inom vilket rena och höginblandade biodrivmedel fortsatt i hög grad ska skattebefrias. På så sätt är det en hybrid mellan ett kvotpliktssystem och ett skattelättnadssystem. Det nya förslaget har påverkat de slutsatser som dragits om Sveriges framtida styrmedel för förny-bara drivmedel. Resonemangen har till stor del utgått från två politiska målsättningar hos den svenska regeringen: inga nettoutsläpp av växthusgaser år 2050, och en fossiloberoende transportsektor år 2030. Förnybara drivmedel kommer att utgöra ett viktigt verktyg för att nå båda dessa mål, särskilt det andra. Då den exakta innebörden av respektive mål inte är helt helt fastställt ännu, återstår dock många frågor att besvara gällande styrmedlens roll.

Analysen av de tre regionernas styrmedel gav insikter inom följande tre tematiska områden om vad som kan gynna utvecklingen av biodrivmedel i transportsektorn:

- Biodrivmedelssektorns förmåga att generera synergier som sträcker sig över och mellan sektorer samt andra sociala och ekonomiska fördelar utanför den egna sektorn.
- Styrmedlens långsiktiga stabilitet i kombination med en flexibilitet i förhållande till nya marknadsförutsättningar, samt styrmedlens förmåga att generera stöd till samtliga delar i kedjan från produktion till användning.
- En avvägd balans mellan effektiva och ändamålsenliga kvotpliktssystem för låginblandade biodrivmedel å ena sidan, och den kombination av styrmedel som behövs för att utveckla samtliga delar i produktions- till användarkedjan för höginblandade och rena biodrivmedel å andra sidan.

Intra- och intersektorella synergier: En biodrivmedelsutveckling som involverar olika samhälleliga sektorer och genererar enskilda såväl som gemensamma fördelar är positiv för utvecklingen av biodrivmedelssektorn. I rapporten diskuteras olika fall som visar att utvecklingen av biodrivmedel kan användas för att stärka och utveckla existerande sektorer med direkt koppling till biodrivmedelskedjan, men även generera positiva effekter inom andra områden. Exempel på det är en förbättrad handelsbalans, ökat energioberoende och en utveckling av energisektorn.

Långsiktig stabilitet i kombination med flexibilitet: Rapporten visar genom flera exempel på vikten av långsiktigt verkande styrmedel. Viktiga parametrar är en mångfald av relativt flexibla stödsystem, långsiktighet gällande förändringar, samt marknader som garanterar avsättning. I Brasilien och USA har regelbundet stöd kombinerat med stabil tillväxt inom sektorn pågått under 30 år, vilket delvis kan förklaras med att industrin känt tillit till stödsystemen samt fått ett ökat självförtroende. I Tyskland har däremot en snabb förändring från skattelättnader till kvotplikt medfört stora ekonomiska problem i en industri som varit mycket beroende av stödsystemen. Detta kan delvis förklaras med att risktilläggen för investeringar i industrin har ökat i samband med att tilliten till styrmedlen har minskat.

Balans mellan skattelättnader och kvotplikt: Erfarenheter från tillämpningar av styrmedel riktade mot låg- respektive höginblandade biodrivmedel visar på både väntade och oväntade utfall. I Brasilien har utvecklingen för mellan- och höginblandade biodrivmedel drivits på av en kombination av kvotplikt och program som stödjer fordon som klarar flera bränslen. Här har alltså kvotplikt fungerat för mellan- och höginblandade biodrivmedel. I USA har däremot styrmedlen i huvudsak inte varit inriktade mot marknader och infrastruktur för höginblandade biodrivmedel eftersom man tillämpat ett med kvotplikt närbesläktat volympliktsystem. Därför har en gräns för andelen biodrivmedel i den totala drivmedelskonsumtionen uppnåtts, då transportsektorn som helhet inte anpassats för mer än 10% biodrivmedel. Liknande erfarenheter finns också inom EU; kvotplikt har visat sig kunna uppfylla mål med relativt låga andelar biodrivmedel i den totala drivmedelskonsumtionen, men kvotplikten har också visat sig vara otillräcklig som understöd för den utveckling av infrastruktur, fordon och marknad som behövs för att möjliggöra högre marknadsandelar.

En annan lärdom från USA är att regelverk om en viss volym specificerat biodrivmedel inte uppfylls om de tekno-ekonomiska förutsättningarna utvecklats till en viss nivå. De fastlagda volymerna för cellulosaetanol kommer troligtvis inte att kunna uppnås eftersom den tekniska utvecklingsnivån ännu inte nått kommersiell mognad.

Att styrmedel som genererar intersektorella synergier visat sig vara effektiva för att utveckla de olika delarna i kedjan produktion till användning av biodrivmedel, är relevant för framtida utformning av styrmedel i Sverige. Vissa typer av multisektorella synergier är oundvikliga eftersom produktion, transport och distribution är delar av alla biodrivmedelskedjor. Bland övriga möjliga multisektorella synergier i Sverige, kan nämnas potentialen hos den överskottsvärme som i stort sett alla produktionsprocesser för andra generationens biodrivmedel genrererar, och som kan utnyttjas för produktion av fjärrvärme. Det finns också förutsättningar att integrera biodrivmedelsproduktion med skogsindustrins processer, idag är de kanske större än någonsin eftersom biodrivmedelsproduktion skulle kunna förbättra en sviktande lönsamhet inom kärnverksamheter.

Utformningen av det svenska hybridkvotpliktsystemet för biodrivmedel indikerar att man har tagit lärdom av effekterna av en övergång från ett skattelättnadssystem till ett kvotpliktssystem i Tyskland. En viktig del i detta är att vissa av de utvecklingsprogram som pågår för andra generationens drivmedel i Sverige gäller rena biodrivmedel, exempelvis DME och andra generationens biogas. Dessa kommer fortsättningsvis att ges skattelättnader, vilket är en förutsättning för en långsiktigt stabil utveckling av biodrivmedel i stor skala. Det är också ett exempel på en avvägning mellan behovet av dels kvotpliktsystemet som säkerställer låginblandning i alla drivmedel, dels den kontinuiteten för att utvecklingen av produktion, infrastruktur, fordon och marknander för höginblandade och rena biodrivmedel. Det senare är en förutsättning för högre framtida målsättningar gällande förnybara drivmedel i den svenska transportsektorn.

Dock kommer målsättningar om en hög andel förnybara drivmedel i transportsektorn i framtiden, i kombination med att en hög andel i realititen kräver andra generationens biodrivmedel, att leda till ett läge där kapitalkostnadernas andel av specifika produktionskostnader ökar. Med utgångspunkt i detta verkar det inte troligt att det svenska hybridkvotpliktssystemet kommer att vara tillräckligt som enda styrmedel för att nå mål med en hög andel förnybara drivmedel i transportsektorn. Sannolikt kommer det att uppstå ett behov av ökade anslag till FoU samt olika typer av investeringsprogram. Sådana specifika styrmedel är också mer effektiva för att uppnå målsättningar om ökad självförsörjningsgrad och landsbygdsutveckling än generella styrmedel som kvotplikter och skattelättnader.

CONTENTS

1 INTRODUCTION

Policies to control the supply and use of energy carriers have been applied for decades. Two milestones in the development of energy policies were the two oil crises of 1973 and 1979 that were followed by political programmes with the ultimate intention to reduce oil dependence. Countries with large oil import reliance were severely affected by the two oil price shocks, and were especially motivated to consider different sources of energy. More recently, the debate surrounding peak oil and efforts to reduce greenhouse gas emissions have favoured a shift away from fossil energy carriers, particularly after the signature of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992.

Struggles to reduce the dependence on imported energy carriers and to mitigate climate change will in many cases lead to measures that may reduce the total use of fossil fuels. However, the picture is more complex than so. For countries with large domestic primary energy reserves, efforts to increase energy autonomy may lead to a shift from one fossil energy carrier to another. Similarly, measures to abate CO_2 emissions can take the form of fossil fuel-switching – the shifts from coal, or lignite, to natural gas for power production being leading examples. Major substitutions between different energy carriers can also be caused by a combination of technical breakthroughs – these also stimulated by national efforts towards increased energy self-sufficiency. A recent example of this is the dramatic increase of natural gas on the expense of coal to the US power sector that has taken place since 2008. This shift is explained by the change in the relative price of natural gas to coal caused by the rapid increase in US shale gas production (Yanagisawa, 2013). The development in Europe has since 2010 been the reverse, i.e. the consumption of coal for power production has increased while natural gas has decreased. This development is largely due to the market in the US where the surplus of coal created by shale gas expansion is exported to Europe (ibid.). A policy instrument that may have neutralised the development Europe is the EU ETS (European Union emissions trading scheme), but the on-going economic crisis, which in turn has led to a dramatic decrease in the EUA (European Union emission allowances) price since 2008 (Climate Brief, 2012), has rendered this tool ineffective.

For countries with large domestic primary energy reserves, there are many cases where energy policies have not focused on reducing the use of fossil fuels – quite the contrary. The International Energy Agency has estimated that global subsidies[1] for fossil fuels amounted to $409 billion in 2010 while the subsidies directed at renewable fuels were estimated to $66 billion during the same year (IEA, 2011). Globally, the subsidies to fossil fuels outweigh the subsidies to renewable fuels by a factor of more than six. Thus, incumbent energy subsidy regimes are more likely to increase the use of fossil fuels rather than the opposite. If electricity-related subsidies are removed from these figures, fossil fuels received $287 billion and renewable fuels $22 billion in 2010 (ibid.). Here the relationship is even more pronounced, since subsidies directed at fossil fuels are 13 times higher than the subsidies directed at renewables. It is important to point out that the countries that subsidise fossil fuels are not the same as the ones that subsidise renewable fuels. The subsidies directed at fossil fuels are most prevalent in oil and gas rich countries, with the highest total subsi-

[1] Subsidy is in the IEA report defined as "any government action directed primary at the energy sector that lowers the cost of energy production, raises the price received by the energy producers or lowers the price paid by energy consumers".

dies being found in Iran, Saudi Arabia, and Russia. The largest subsidies towards renewables are found in the USA and the European Union (ibid.).

The main focus in this report is to present the development of biofuel[2] production and use in three leading jurisdictions (Brazil, EU, and USA), and to analyse how different policy instruments have influenced this development. The production and use of alternative transportation fuels derived from renewable energy sources has been dependent on support to reach commercial maturity and the variety of political initiatives that deliver such support are commonly referred to as policy instruments. There are several reasons why political support has been required; these include that inter alia: the production costs for renewable transportation fuels tend to be higher than for the corresponding fossil fuel; the use of renewable fuels frequently requires adaptation of infrastructure for distribution; and that new types of end-use technologies need to be adopted. The cases depicted in this report seek to provide illustrative examples where policy instruments have been most successful in promoting biofuels.

We review instruments directed at renewable transportation fuels[3] that have been used in the European Union, USA, and Brazil. The analysis works from the point of departure that policy instruments may be classified as economic, administrative, informative, and as support to research and development. The focus in this study will be on the first two. The effects of policy instruments are dependent upon a variety of different circumstances and the outcome of one policy instrument that has been successful in one context may be markedly different in another context. Nevertheless, the experience gained from one set of circumstances is usually useful, not least as a way of preventing or preparing for what was unintended outcomes in the first use. Our intention is to extract lessons from previous experiences that are of relevance to the Swedish context.

The renewable transportation fuels that have reached production volumes of a magnitude that enable an impact on the world market for transportation fuels are currently ethanol and biodiesel. The production of ethanol for transportation emerged in Brazil in the 1970s and remained in essence and entirely Brazilian concern until the mid-1990s, see Figure 1. On the other hand, global biodiesel production has mainly been concentrated to Europe where production accelerated markedly in the 1990s – and where it remains the largest at the global level, see Figure 2. The figures for global renewable transportation fuel production presented below may be compared to the total oil-derived final energy consumption for transport, which was 25 534 TWh in 2010 (IEA, Key World Energy Statistics 2012)[4]. This indicates that the shares of ethanol and biodiesel in world transportation fuel consumption remain modest – i.e. approximately 2.2% and 0.6% respectively.

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[2] Biofuel is used to denote liquid or gaseous transportation fuels derived from biomass.

[3] Renewable transportation fuels and biofuels are commonly interchangeable words, but the provious may also include some fuels such as hydrogen that could be derived from e.g. renewable electricity production.

[4] This figure includes all oil-derived fuels used in the transportation sector, i.e. also fuels used in aviation and marine transportation.

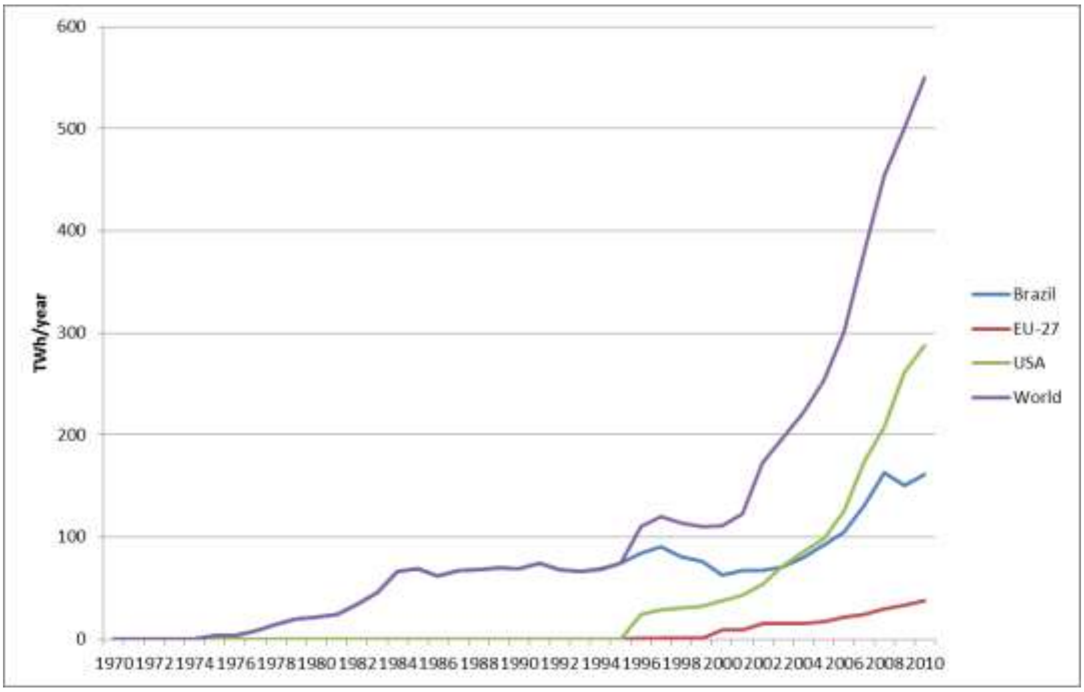

Figure 1. Ethanol production in Brazil, EU-27, USA, and globally (FAO, 2012a).

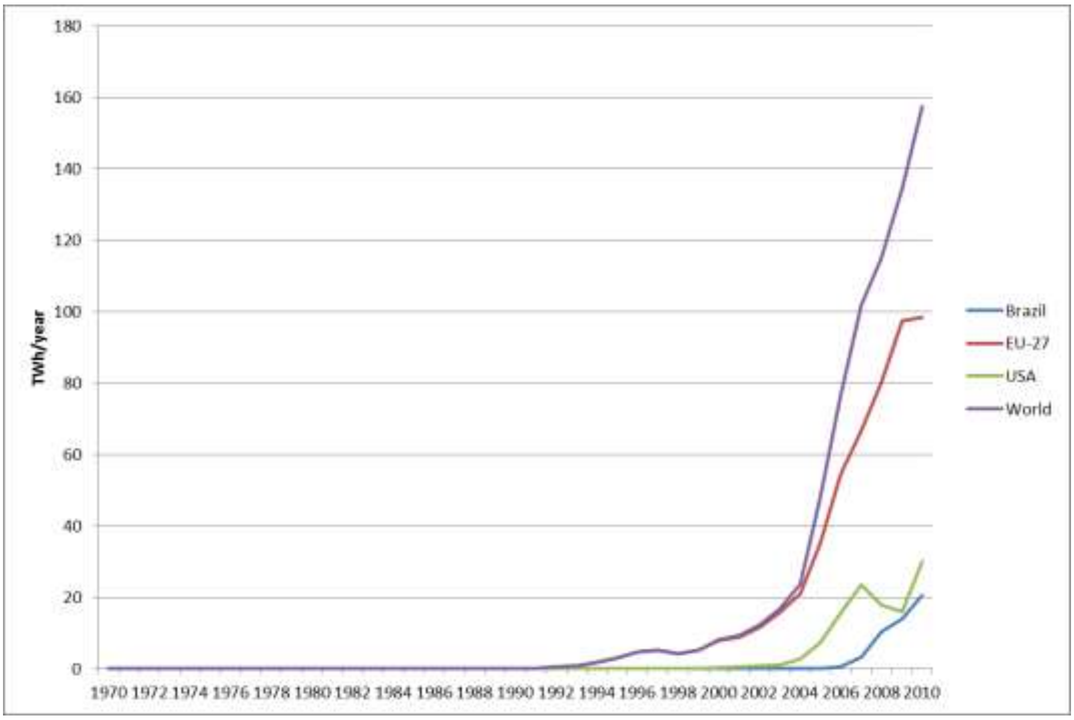

Figure 2. Biodiesel production in Brazil, EU-27, USA, and globally (FAO, 2012a).

The motivation for the selection of Brazil, the EU and the U.S. for deeper analysis in this report is mainly their global dominance considering renewable transportation fuels (see Figure 1 and Figure 2). Of the countries in the European Union, Germany has been studied in more detail – this because it has been the leading country in the EU, and even globally, with regard to production and consumption of biodiesel. In 2011, the German production volumes amounted to almost 30 TWh of the circa 91 TWh biodiesel that was produced in the European Union (European Biodiesel Board, 2013).

Biogas is produced in almost all countries in the European Union. It is produced in considerable volumes in Germany, the United Kingdom, and Italy in particular (EurObserv'ER, 2012). However, to enable use in vehicles, the biogas needs to be upgraded and upgraded biogas is still only produced in modest volumes. In Sweden, however, the use of biogas for transportation has reached quite meaningful volumes in comparison with other biofuels, see Figure 3. Over a ten years period, the production of upgraded biogas in Sweden has grown from negligible volumes to some 0.7 TWh in 2011. Even if the amount of biogas used for transportation in 2011 remains relatively modest, it should be noted that the entire use is from domestic production, while the domestic production of ethanol and biodiesel amounted to approximately 45% and 55% of the total use in 2011 (Hansson and Grahn, 2013). This could also serve as an indication of how the markets for the different biofuels are evolving: the biogas market tends to be local, the biodiesel market is mostly regional (within the EU), and the ethanol market is already international is its character.

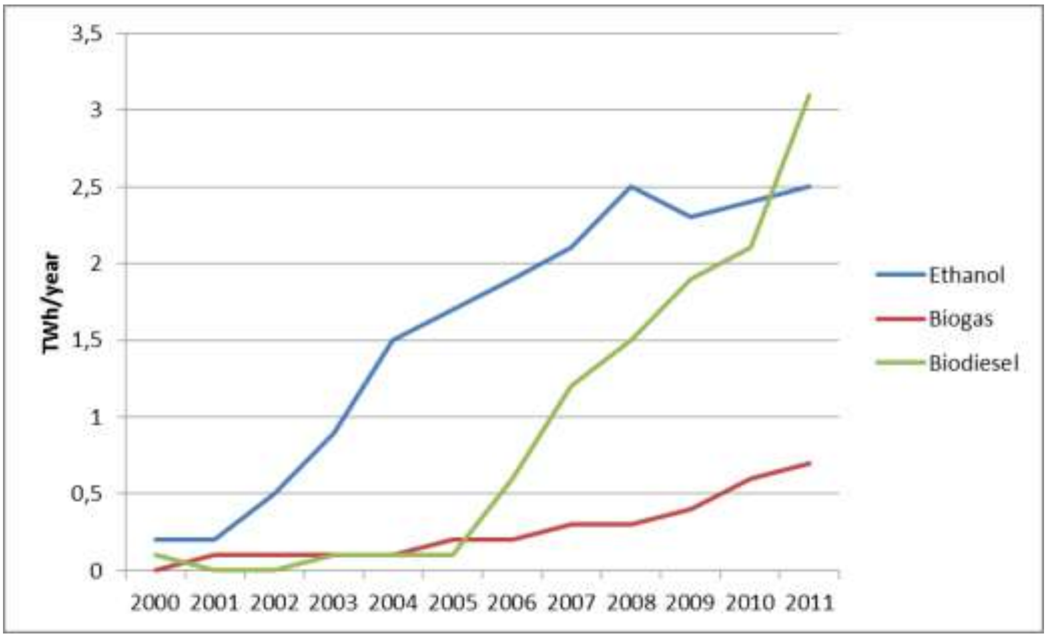

Figure 3. Use of biofuels for transportation in Sweden (Swedish Energy Agency, 2012a).

The development of biofuel production, as visualized in Figure 1 and Figure 2 have led to a prominent and, at times, divisive discourse regarding the impact on food supplies and price volatility on livestock during recent years. The cause being that feedstock for the so-called first generation biofuels, are to a large extent edible resources like maize (corn), sugarcane, wheat, rapeseed, palm oil, etc. The Food and Agriculture Organization of the United Nations (FAO) estimated that half of Brazil's sugarcane and 37% of the coarse grain production in the USA went to ethanol production in 2012, while 80% of the vegetable oil production in the EU was used for biodiesel production (FAO, 2012b). However, the nature of market interactions between biofuel and food productions is definitely not crystal clear and is influenced by a range of factors. For example, higher demand and prices on agricultural commodities also help stimulate overall higher production levels. A consequence of the discussion about the competition with food production and other unintended effects with biofuel production, such as low positive total effects on climate change mitigation due to indirect land-use change impacts, is that the European Commission proposed to limit the amount of renewable biofuels from first generation to 5% (energy content), i.e. half of the 10% renewable energy target for the transport sector by 2020 (European Commission, 2012a). As of mid-2013, this limit is still under debate.

1.1 OBJECTIVES OF THE PROJECT

This report provides a synthesis of policy instruments used in different country contexts to promote renewable transportation fuels. The regions/countries in focus are Brazil, EU, and USA, since they reflect the present penetration of biofuels seen from both national and international perspectives. Emphasis is put on the following questions:

- What motivated the policy instruments, how were they formed and what impacts did they have in relation to the initial objectives of the country?
- How well has the policy instruments worked to support the development for renewable transportation fuels in comparison with traditional fuels, both in the short and long terms?
- What lessons can be extracted that are relevant to continue promoting renewable biofuels in the Swedish context?

With these questions in focus, the ultimate objective is to discuss and hopefully devise efficient policy instruments that can be applied in Sweden considering feedstocks, climate, technological development, industrial infrastructure, industrial development, regulatory framework, and common long-term political intentions. Presently, the policy instruments ought to reflect that the production, infrastructure, and market for biofuels in Sweden are under development. Over time, as commercial maturity is reached for differing fuels or technology platforms, the policy focus will need to shift towards improved efficiency along supply-chains and increased competitiveness in relation to other transportation fuels.

1.2 METHODOLOGY

This study has been predominantly based upon desk-top research conducted at the four participating departments (three at KTH and one at Lund University). A wide range of literature addressing the historical development of biofuel-related policy instruments in the studied juridictions was drawn upon. Dominant information sources utilised were in the following general order of preference:

- peer-reviewed articles;
- reports and statistics gathered by governmental, or quasi-governmental institutions (e.g. the European Commission, the Swedish Energy Agency, the US Department of Agriculture, etc.);
- reports from multi-lateral organisations (e.g. International Energy Agency, United Nations bodies, etc .);
- reports, policy briefs etc. from industry groups or representative organisations (e.g. bodies representing petroleum, biofuel, vehicle manufacturing, forestry, agricultural sectors);
- media articles;
- web available branch organisation, lobby group and NGO materials.

Despite the notably differing contexts for each country case, analysis for each case was structured following three common investigative themes in line with the overall objectives:

1. the underlying motivations for policy interventions, their formulation, and how outcomes aligned with initial policy objectives;
2. how the instruments supported the biofuels sector(s) in the short and longer terms;
3. what lessons can be considered of relevance to the promotion of renewable biofuels in Sweden.

Where possible, a longitudinal perspective was applied to each case, where the chronological development of both the policy field and the market were presented. The latter part of the work involved a cross-case by case analysis that sought to draw forward common themes from the differing countries and their policy mixes. This analysis delivered the synthesis for the 'international' to the Swedish context.

1.3 STRUCTURE OF THIS REPORT

In Chapter 2, some basic features, categorisation and effectiveness of policy instruments used to control the production and consumption of energy carriers are presented and discussed. This is followed by a historical overview of how policy instruments have been used to shape the development of biofuel markets in Brazil, the EU and the US. In the EU, Germany has been selected for a more detailed description, due to the considerable penetration of biodiesel. Some issues of importance from the three chapters with historical overview are discussed in Chapter 6. Chapter 7 then provides a summary of the current and suggested changes of the Swedish policy instruments used to promote renewable transportation fuels and the findings. The last chapter discusses policy instruments linked to a Swedish context, including an overview of current political intentions and suggested changes of the Swedish legislation, a scenario discussion of how different options would affect the aims considering biofuels, and a discussion about the possibilities to integrate biofuel production within the Swedish forest industry. Finally, findings from this report are used to discuss the future role of policy instruments in the support of biofuels in Sweden.

1.4 CLASSIFICATION OF BIOFUELS

As gaseous and liquid fuels from biomass used for transportation (termed biofuels in this report), may be produced from different feedstocks, may have different production routes, and may be different products, a clear categorisation is useful. A common way to classify biofuels is in accordance with the feedstock used for the production.

Most of the biofuels in use today are produced from feedstock that could be used for food production, such as ethanol used from sugarcane, corn, wheat, or sugar beets – or biodiesel produced from edible vegetable oils extracted from rapeseed, soybeans, or oil palms. These biofuels are generally termed first generation biofuels or conventional biofuels. Biogas produced by anaerobic digestion of biological waste materials also frequently falls within this category, even if the feedstock is neither edible nor in competition with food markets. This paradox only helps highlight that there is no universally accepted definitions of biofuel "generations".

The feedstocks for second generation – or advanced[5] – biofuels are lignocellulosic materials, such as, wood, agricultural residues, black liquor (from kraft pulp processes), and so forth. At the time of writing, second generation biofuels are as a general rule not produced at commercial scale. This stated, there are a limited number of exceptions. Biodiesel produced by hydrotreatment of vegetal oils (e.g. tall oil, a by-product from kraft pulp production being one leading feedstock), is produced in commercial scale as well as frequently being recognised as second generation. Ethanol produced by hydrolysis of cellulosic biomass, then fermentation is another that almost has reached commercial scale – with one plant having been commissioned in Italy, and several approaching production status in the USA, see Chapter 5. Hydrotreated vegetable oils (HVOs) have properties that make them essentially interchangeable with conventional diesel[6], which is not the case with fatty acid methyl esters (FAME) that represents the vast majority of the biodiesels in use today. FAME can be blended up to certain levels with conventional diesel and still used in conventional diesel vehicles, but dedicated engines are required when it is used at higher concentrations such as B85 or in the pure form B100. In this report as in many others, the word biodiesel will be used to denote FAME unless otherwise noted.

Third generation renewable fuels for transportation are even less well-defined than first or second generation biofuels. The term renewable fuel is used instead of biofuel since is it not even certain that such fuels will be derived from biomass. What is common for the third generation renewable fuels is that they are further away from commercial application than second generation biofuels and encompass fully synthetic fuels produced from a variety of reactions and/or renewable electricity (Mosheni et al., 2012) as well as fuels derived from algae (Dragone et al., 2010).

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[5] Note that this is European nomenclature and that in the US the term “advanced” is also used to descibe some first generation biofuels that are held to deliver high GHG savings. However, in this report the term will only be used in that way in specific US related sections – and there is clearly explained.

[6] Some the HVOs produced commersially do not have the same cold properties as conventional diesel while others work well in winter grade diesel as well.

2 POLICY INSTRUMENTS

Energy-related policy instruments have been used for very long periods of time in industrialized societies, but the purposes have changed over time. Globally, the first and second oil crises with their onsets in 1973 and 1979 respectively, had great impact on how the supply of primary energy could be viewed. In Sweden, these had a major influence on a process that, with some lag, led to a transformation of the country's energy system over the decades that followed, see Figure 4. As major examples of policy instruments used in Sweden, an overview of the Swedish energy and carbon dioxide taxes directed at oil products for diffeent uses is provided in Figure 5.

The Swedish nuclear power programme started in the mid 1940s (Jonter, 1999) and power was delivered from the beginning of the 1970s. This paved the way for much of the change that was possible in the period up until the mid 1980s when all Swedish nuclear reactors had been commissioned. Despite its great importance to the Swedish energy mix, nuclear power is definitely not the full answer to the dramatic change in primary energy supply for the country and much has been achieved by interventions such as the aforementioned taxation of fossil fuels. This stated, the analysis of direct and indirect effects of the rather dramatic changes in taxation directed at oil products as presented in Figure 5 is beyond the scope of this report. However, even in the absence of a detailed analysis, it is not a bold assumption that the taxes have had a strong impact on the 46% decrease in Swedish oil consumption between 1970 and 2010 – Figure 4 displaying this decrease is provided as an indication of what can be achieved with policy instruments. Sweden's energy mix also shows that change can be achieved in a mature industrialized economy while maintaining almost constant levels of economic growth.

During the 1970s, Sweden competed with Denmark and Singapore for the dubious honour of having the largest imports of oil and oil products per capita worldwide. Today however, Sweden no longer holds such a position – despite the lack of domestic oil resources (BP, 2012; World Bank, 2013)[7]. The promotion of biomass use in the energy utility sector and the introduction of a high tax pressure on fossil fuels in non-industrial applications have been key strategies pursued within the change. Despite that fact that taxation burdens on oil consumption have been comparable or even higher in the transportation sector compared to other sectors, a marked shift away from oil-derived fuels has not occurred within the transport sector, see Figure 6. One plausible explanation for this discrepancy is that few technical alternatives have been available and this has led to far lower price elasticity for oil products in the transportation sector than in the energy, industry, and residential sectors.

[7] A combination of figures from these sources are used.

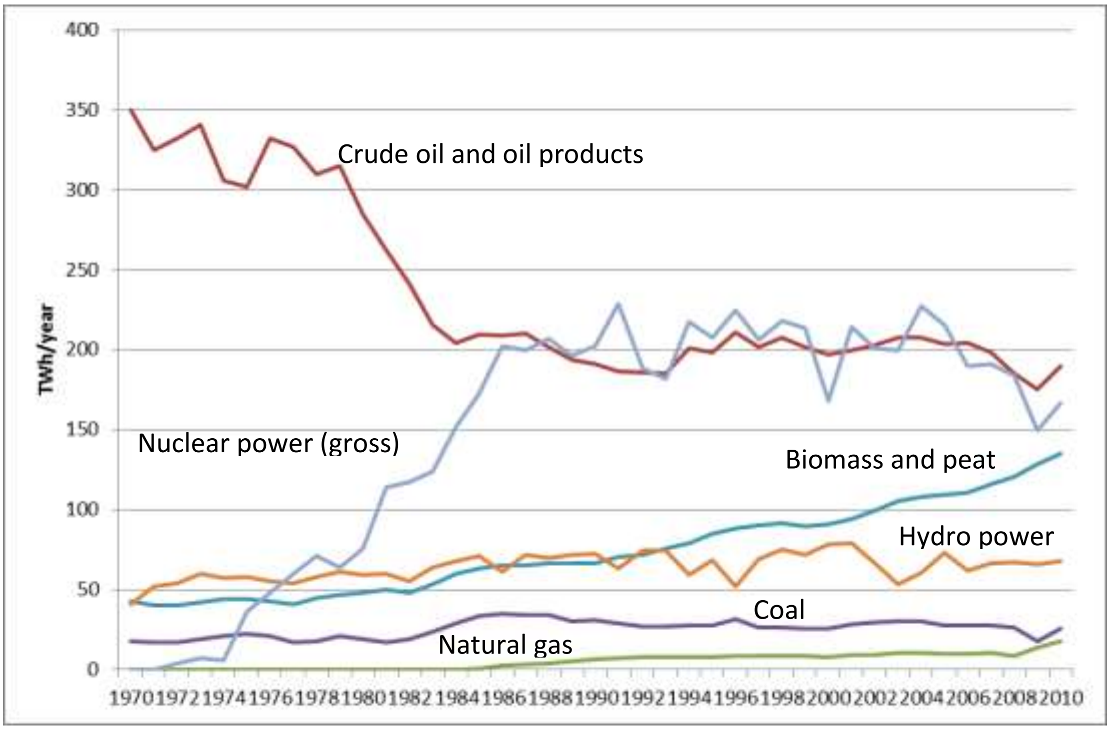

Figure 4. Primary energy supply to Sweden from 1970 to 2010 (data from the Swedish Energy Agency 2012a).

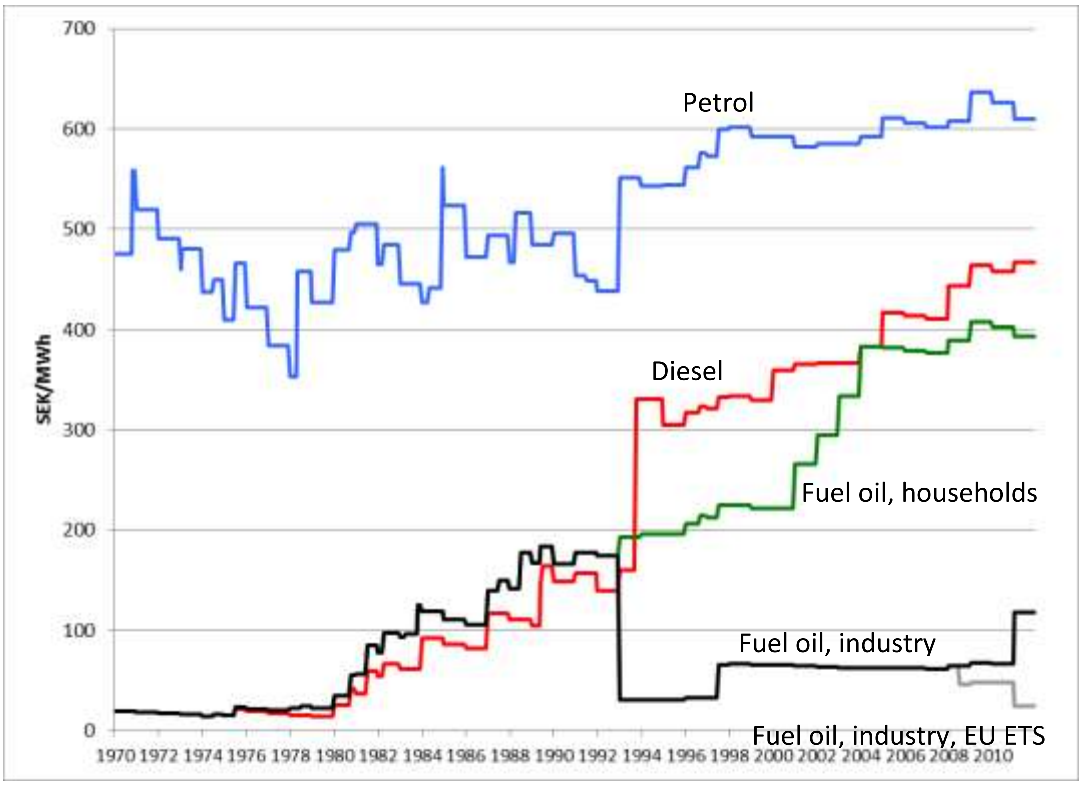

Figure 5. Summary of taxes for oil products in Sweden 1970-2011. (The Swedish Tax Agency, 2013; Statistics Sweden, 2013; Dahlberg, 2013). Notes:

i. Energy taxes, carbon dioxide taxes, and special fuel taxes are included while Value added taxes (VAT) and sulphur taxes are excluded. The taxes are adjusted for inflation to 2012 year´s prices using consumer price indices from Statistics Sweden.

ii. The specific energy content of diesel and fuel oil is set to 9.8 MWh/m^3 (LHV) while the specific energy content of petrol is set to 9.1 MWh/m^3 (LHV).

iii. The tax level for petrol is for unleaded petrol from 1986 to 1994, for unleaded environmental class 2 from 1995 to 1999, and for environmental class 1 from 2000 to 2011.

iv. The tax level for diesel in transport is for light fuel oil (Eo1) from 1970 to 1974, for light diesel from 1975 to 1990, for diesel environmental class 2 from 1991 to 1994, and for diesel environmental class 1 from 1995 to 2011.

v. The tax level for fuel oil for households is for environmental class 2 from 1970 to 1974, for all fuel oil except diesel from 1975 to 1990, for fuel oil environmental class 3 from 1991 to 1994, and for coloured fuel oil from 1995 to 2011.

vi. From 1 January 1993, there are general tax exemptions for fuel oil used for industrial production. Prior to and after this date, the tax levels for industrial production are subject to limits for energy intensive companies that not are displayed in the diagram.

vii. From 1 July 2008, there are differentiations in the tax exemption levels for industrial companies within the European Union Emissions Trading Scheme (EU ETS) compared to companies outside the EU ETS.

viii. The high increase in the taxation of diesel in 1993 was introduced at the same time as the removal of the kilometre-tax for diesel vehicles.

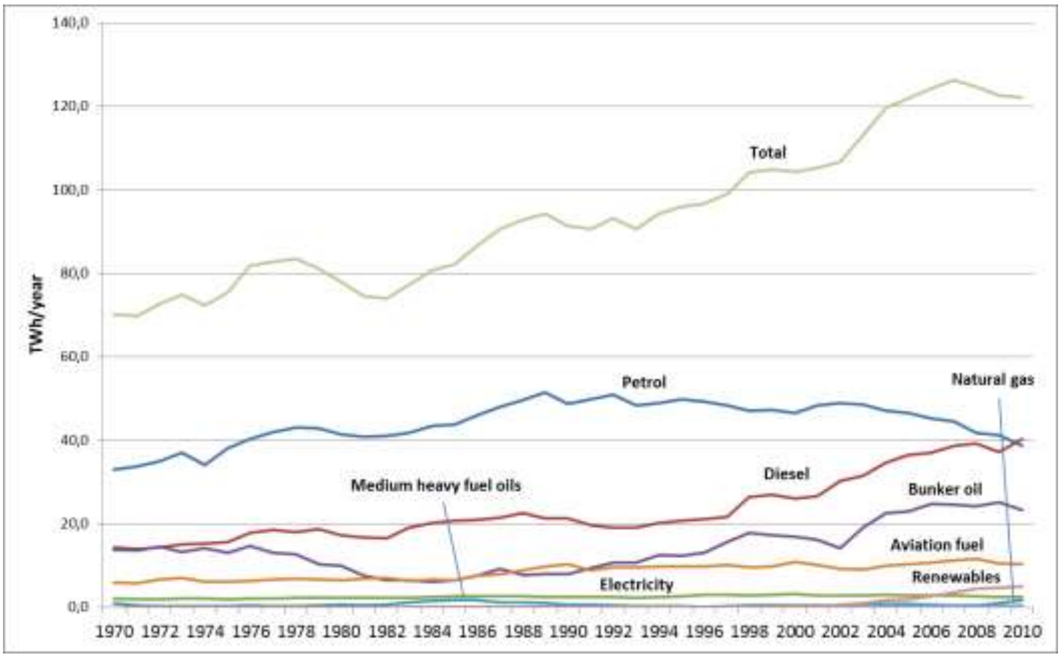

Figure 6. Final energy supply to the transportation sector in Sweden from 1970 to 2010 (data from the Swedish Energy Agency, 2012a)

2.1 CHARACTERIZATION OF DIFFERENT POLICY INSTRUMENTS

There are several ways by which policy instruments may be categorised, one being the nature of the policy instrument itself as provided within the classification of policy instruments directed at transportation fuels below:

Administrative (command and control mechanisms)

- Mandatory quotas (e.g. a certain share of the consumed fuel should be renewable)
- Mandatory blending standards (e.g. the fuel should contain a certain concentration of the renewable fuel)
- Mandatory volumes (e.g. a specific quantity of renewable fuel or fuels should be sold)
- Mandatory demands for vehicles with regard to fuel type or emission standards
- Mandatory infrastructure (for fuel suppliers)
- Import restrictions

Financial (economic)

- Taxes
- Subsidies, which may be of a variety of forms, e.g.:
    - Tax exemptions for fuels
    - Direct financial support to fuel production
    - Investment support to producers, infrastructure, vehicles, etc.
    - Market based incentives (tradable certificates)
    - Tax-switching
    - Favourable loans or loan guarantees
    - Liability reduction (common for nuclear power)
- Public procurement

Support to research and development (R&D)

- R&D support may be provided to any part in the chain from agricultural tests and laboratory tests of different fuels, to full scale demonstration plants

Information

- Information programmes are often performed in combination with or as a result of financial instruments, e.g. a tax incentive may be referred to as an environmental tax and this may in itself work as an environmental campaign.

Another way of categorizing policy instruments is in accordance with the link in a supply and demand chain to which they are directed. For biofuels this may be towards the supply or the demand side, but this may be further divided in, for example, the terrestrial production, the chemical conversion and upgrading, the infrastructure for supply, the private or professional consumer, or the vehicle producer.

2.1.1 Intentions with policy instruments

The intended outcomes of different energy-related policy instruments differ depending on the time and country/region where they are implemented. Taxes have been used for energy carriers as long as there has been significant trade in societies, but the intentions have shifted from being purely fiscal, to purposes such as increased energy independence or the abatement of greenhouse gas emissions. Other external effects that may be provided by policy instruments directed at energy carriers can include the development of domestic industries, stimulation of rural economies or development, and poverty alleviation.

For renewable transportation fuels, the initial production costs have been too high for a spontaneous development of the industry and support has been required. Biofuel support has commonly taken the form of subsidies or mandatory targets – the first, in contrast to taxes – are typically costly for the state. As biofuel industries develop, there will hopefully be possibilities to abandon the help from subsidies and to let the biofuels compete freely on the markets for transportation fuels. However, in the European Union, it remains difficult to see that the industry for renewable transportation fuels can achieve independence from policy support anywhere in the near future. As this report outlines, there are also examples of when an emerging industry has been damaged when supportive policy instruments have been removed or shifted, see Section 4.3.

There are also economic policy instruments that neither result in incomes nor costs for the state – at least not through direct effects: green tax-switching policies, i.e. to decrease the burden on activities that are less environmentally damaging while increasing it on more environmentally harmful is one such system; the Swedish system for the reduction of nitrous oxide emissions is another. In the latter system, polluters with higher specific emissions pay to polluters with lower specific emissions, while the state sets the total limits. Some systems with tradable emission certificates, mandatory blending standards, or mandatory quotas may also have this effect. However, indirect effects may have effects on the tax losses in these cases as well[8].

[8] An example of this is a blending standard makes the price for a fuel more expensive and thus decreases the consumption – this in turn resulting in lower tax incomes for the state.

2.1.2 General effectiveness of different policy instruments

Some of the features with different policy instruments have already been mentioned above, i.e. whether they directly generate income or cost to the state. There are many other general features of different policy instruments and some of these will briefly be touched upon here.

The term effectiveness is here used in a broader sense, i.e. related to how well a certain measure works in achieving the objectives of a specified policy intervention or suite of interventions. When the terms cost effective or cost effectiveness are used, the cost for achieving these outcomes are also clearly part of the consideration. Thus such terms are intended to capture the concept that the unit costs of producing well-defined outcomes are (relatively) low in comparison to other options. This utilisation is thus intended to be closely related to the concept of 'productive efficiency' in policy-making, where the most productively efficient outcome is that which uses the least cost input mix required to produce a given output of any good or service.[9]

Investment support programmes must in many cases be combined with other support systems if the variable costs are too high to be covered by the revenue, i.e. when the contribution margin is negative. This is in many cases true for biofuels, at least in the European Union. The economic support may thus be in the form of direct financial support to the production, tax exemptions, or mandatory quotas that establish a sufficient market price for the producer on a secondary market. Generally, the policy instruments that are directed at inputs or outputs of the production, may it be electricity, feedstock, or biofuel, are for the society in general more cost-effective to achieve a certain goal in comparison with investment support systems. The reason for this is that the actors targeted by the policy interventions have the possibility to adjust over time and to react by performing the most cost efficient measures first, or in the order that suits them. Hence, variable policy instruments[10] generally provide stimulation for technical development. Variable cross-sectoral policy instruments, such as taxes or production support will in many cases bring about similar marginal effects to all actors within a field and this is cost-effective for the society. It is difficult to achieve such an effect with investment support programmes. Nevertheless, to create a system with e.g. the same energy taxes for all sectors in society will often be hard to establish. This as the competition on an international market may set constraints on the possible tax levels put on sectors that compete internationally while similar constraints not exist for sectors that not face international competition. An illustrative example of this is found in Sweden where the energy and CO_2 taxes are significantly lower for industrial production in comparison the taxes for households and the transport sector, see Figure 5. The designs of the energy and CO_2 taxes and possible tax exemptions for the Swedish energy utility sector have historically been relatively complex and are difficult to plot in a similar way. However, a general trend has been that fuels used for district heating production are taxed significantly higher than fuels use for electricity production; the rational being that district heating not is competing on an international market while electricity sometimes is[11]. Even if this demonstrates the problems of creating variable cross-sectoral policy instruments in reality, the variable policy instruments often provide similar marginal effects within certain sectors and even this is

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[9] This definition has been drawn from a discussion document produced by the Government of Australia. See http://www.pc.gov.au/__data/assets/pdf_file/0003/123357/efficiency-effectiveness.pdf.

[10] The term variable policy instruments is here used in analogy with e.g. variable costs, i.e. it represents a cost or income that is proportional to inputs and outputs to e.g. an energy conversion process.

[11] There are also other reasons behind the lower taxes on fuels used for electricity production, e.g. to keep electricity prices on a lower level since electrity prices affect all other sectors in society including the export industry.

almost impossible to achieve with investment programmes[12]. Another disadvantage with investment programmes is that the frequent application of investment programmes may induce investors to delay (otherwise economically rational) investments in the anticipation of another investment programme.

With this said about the problems with investment support programmes, there are also benefits in comparison with variable policy instruments. One being that, for long-term investments, such as energy conversion facilities of different kinds, investment programmes may provide more certainty for the investment than tax exemptions and direct production support – especially as these may change during the lifespan of the process or there may be a perceived risk that they will change. Such policy volatility is actually one of the well-known problems with variable policy instruments, as this brings about higher risks for the investor. In an analysis of the effect of support systems for biofuels in the European Union, Nanni (2010) put forward that stability regarding the policy instruments seem to be important to increase biofuel supply – a finding again aligning with mainstream business views that environmental policy stability increases business confidence (c.f. Porter and van den Linde, 1995).

[12] One exeption might be if a new sector is established and all entities will receive similar investment supports.

3 POLICIES FOR DEVELOPING BIOFUELS IN BRAZIL

3.1 FROM DEVELOPING COUNTRY TO LEADING ECONOMY

In the past decades, Brazil has moved from a position among developing countries to a key position as a BRIC[13] country, member of the G20[14], and the sixth largest economy in the world[15]. A number of efforts lay behind this rapid transformation, including industrialization since the 1930s, modernization of agriculture started mainly after the 1960s, and stronger integration of the country with the global economy mainly after the 1990s. Political stability and economic growth has led to significant poverty reduction particularly in the last decade (OECD, 2011). The transformation of the Brazilian energy system has also served as an important pillar in the economic development achieved.

In energy terms, Brazil has gone from large dependency on traditional biomass to a diversified and modern energy matrix within less than half a century. Figure 7 shows the development of the Brazilian energy matrix between 1940 and 2010. More than half of Brazil's energy supply still came from traditional biomass in the early 1970s, mainly in the form of firewood and charcoal. At that time, sugarcane-based bioenergy was limited to internal uses of residues in the sugar production. Oil surpassed biomass in 1973 and became gradually more important in parallel with the expansion of infrastructure for road transport. Hydropower became the backbone of the Brazilian electricity system, and as much as 74% of the country's electricity is still generated in hydropower plants (EPE, 2011a). Brazil is rapidly approaching universal electricity coverage (MME, 2012; Gomez and Silveira, 2011). The use of gas has become more significant in the last decade and the country has evolved from a net importer of oil, to self-sufficiency. Brazil now is expected to become the 5th largest oil producer in the world within this decade gives Brazil a strategic position in relation to global energy security.[16]

Brazil's energy consumption increased several times in the last few decades. Today, the country's energy matrix relies largely on modern energy systems based on renewable sources. The large use of renewables differentiates the Brazilian energy matrix from most countries. Although Brazil did not avoid an increase in oil demand – the result of the rapid expansion of its economy and the development priorities chosen, it has managed to modernize the energy sector and diversify the energy sources of the country in innovative ways. This has led to reduction in the country's relative dependency on oil, improved security of supply, and new opportunities to develop a green economy. Biofuels have played a key role in this process.

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[13] BRIC is an acronym referring to the countries of Brazil, Russia, India and China, which are considered as being in an advanced economic development.

[14] G20 Refers to the group of 20 major economies: 19 countries plus the European Union. Together, the G-20 economies comprise more than 80 percent of the global gross national product (GNP).

[15] http://www.bbc.co.uk/news/business-17272716

[16] The Economist, 5 Nov., 2011. Filling up the future, available at http://www.economist.com/node/21536570

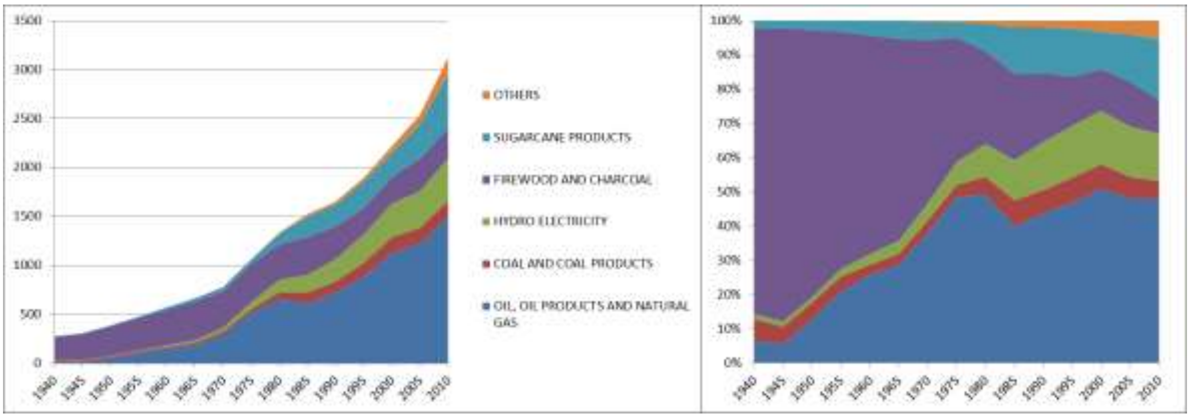

Figure 7. Development of the Brazilian primary energy supply matrix 1940-2010, in TWh (EPE, 2011a).

The purpose of this chapter is to evaluate the policies that supported the development of biofuels in Brazil. Deployment of biofuels in the form of ethanol and biodiesel has put Brazil at the forefront of the international energy and climate debate, particularly when it comes to substituting oil in transport. The ethanol development in Brazil is known for being the most successful of the global attempts to substitute oil in transport, both in relation to scope and scale. There are thus valuable insights that can be provided by examination of policy elements that contributed to this development.

The material presented here is drawn from scientific literature, official data provided in Brazilian consolidated energy balances (EPE, 2011a) and other Brazilian statistics (IBGE), information provided by business associations' reports, and is combined with research and extensive on-the-ground experience of the authors with bioenergy in Brazil. The Brazilian energy expansion plan PDE 2020 and conjuncture analysis made by EPE were considered (2011b; 2011c). Also on-going international processes, particularly the negotiations under the climate convention (United Nations Framework Convention on Climate Change, UNFCCC) and formation of biofuel markets are taken into account. The chapter ends with reflections about the present and future development of biofuels in Brazil, and the importance of the Brazilian experience for other countries as well as for climate change mitigation at large.

3.2 FROM TRADITIONAL FUELWOOD TO MODERN BIOENERGY

The oil price shocks of the 1970s served as incentive to the development of domestic energy alternatives in Brazil. Oil prices increased fourfold in 1973 – a time when Brazil's oil import dependence was around 70%, putting considerable pressure on the Brazilian economy. Higher oil prices and the ensuing higher energy import costs, strongly (negatively) affected the Brazilian trade balance. This led to increased borrowing, economic recession, high inflation, and a serious debt crisis in the 1980s.

Brazil's strategies for the development of energy supply after the 1970s included investment in oil prospecting and research, deployment of the country's hydropower potential, and development of alternative energy sources such as ethanol from sugarcane. Despite these efforts, oil import dependence continued to increase reaching 85% in 1980 (EPE, 2011a). Between 1980 and 2005, Brazil managed to reverse the situation, developed its bioenergy potential and became an oil exporter. Brazil reached net oil exporter status in 2006 and is now heading towards becoming a major oil exporter. In 2010, the Brazilian energy import dependence amounted to 7.8%, mostly in the form of imported coal for metallurgical uses and a small amount of electricity (IBGE, 2011).

There has been a revolutionary change in the role played by biomass in Brazil in terms of energy sources, carriers, and end-use technologies. Sugarcane-based energy has grown as a result of the ethanol programme launched in the mid-1970s aimed at gasoline substitution. It subsequently became an important development engine in the Brazilian economy. Meanwhile, the use of firewood has decreased in importance in line with the penetration of LPG in domestic markets for cooking, and urbanization. Charcoal remains important for metallurgical industries despite some shift towards imported coal. In absolute terms, the use of firewood and charcoal decreased by 18% between 1970 and 2010, while the sugarcane-based energy increased many times over.

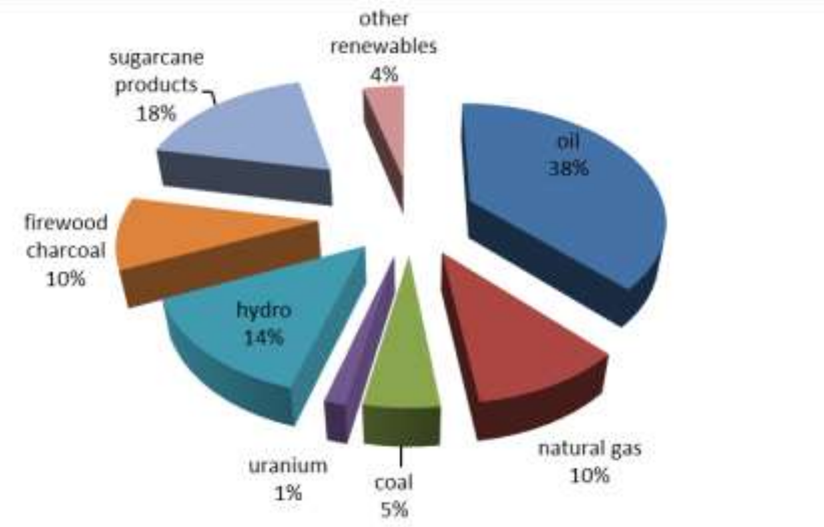

Figure 8. Primary energy supply in Brazil, by source 2010 (EPE, 2011a).

Brazil had a total primary energy supply of 3128 TWh in 2010. Figure 8 shows the total primary energy supply by source. Biomass corresponded to 28% of the total energy supply, being the second largest energy source in the country after oil. Two thirds of that, or 18% of the total supply, was sugarcane based. This can be taken as an indicator of the modernization of the bioenergy segment in Brazil, since most of the ethanol production and use in the country is connected to rather modern supply and use chains from agriculture to industrial processing, all the way to fuel distribution and utilisation. More recently, Brazil has been developing biodiesel production, an industry that is also based on modern technologies and applications.

In the next section, we briefly describe Brazil's efforts to develop alternative transport fuels, i.e. ethanol and biodiesel. While this is not an exhaustive description, it provides an overview of how Brazil has systematically explored biomass as a modern energy alternative in the country and how this has served the objectives of sustainable development. The policies used to promote biofuels are highlighted.

3.3 THE DEVELOPMENT OF ETHANOL FUEL FOR TRANSPORT

As was the case in most oil-dependent countries when oil prices climbed in the 1970s, Brazil had to search for new energy sources, and the country particularly needed to reduce its dependence on imported oil. Sugar production was well-established in the country –actually being Brazil's oldest industry. However, despite its export capacity, the industry was still rather traditional and had low agricultural productivity. Brazil had previous experience using ethanol in transport, particularly from the world war periods. This had demonstrated the viability of the fuel in the national context. Using the existing agricultural structure and the potential for coordination of sugar and ethanol production, a set of supply and demand measures were put in place to boost this industrial sector. It was held to make sense in the context of rising oil prices, the rapidly growing car ownership in the country, increasing transportation needs, ambitions to develop both agriculture and industry, and the need to generate jobs and economic development. In addition, sugar prices declined significantly in 1974 and this served to motivate and mobilize producers to modernize the industry and develop new products.

The Brazilian ethanol programme Proalcohol was launched in 1975 with the objective to reduce oil dependency, promote the development of ethanol fuel and strengthen the sugarcane and sugar-producing sector (GoB, 1975). It included both expansion of sugarcane production and distilleries, as well as development and modernization of the whole supply chain from agriculture to distribution. Initially, manioc was also contemplated as a potential ethanol crop, but sugarcane crops and sugar production offered a synergy of higher economic value, and formed the basis of modernization in agriculture and the sugar industry (Moreira and Goldemberg, 1999; Hira and Oliveira, 2009). The ethanol programme triggered the industry leading to rapid expansion of sugar-ethanol production.

The Brazilian move was radical and the results came relatively fast. There was significant improvement in yields on the agricultural side and design of distilleries, and successful expansion of the distribution infrastructure throughout the country (Valdez, 2011). The expansion of sugarcane has been constant since 1975, albeit much slower between 1985 and 2000, see Figure 9. In the first ten years of the Proalcohol programme, the production increased threefold. Sugarcane-based energy increased by 120% in the first five years of the programme, and then doubled between 1980 and 1985.

Since 2000, the area planted with sugarcane almost doubled, see Figure 9. In 2010, the area harvested reached 9.0 million hectares, while production reached 717 million tonnes (IBGE, 2011). Yields increased by 30% between 1990 and 2010, reaching 80 ton/ha on average. In the Southeast region, however, yields have reached considerably higher levels. The expansion is now taking place more rapidly in other states than Sao Paulo, the traditional geographical focus of the sugar-ethanol industry in Brazil. Sugarcane amounts to 18.4% of the agricultural production value in Brazil, only second to soybeans which amounted to 24.2% of the total value[17] in 2012.

[17] IBGE, www.ibge.gov.br

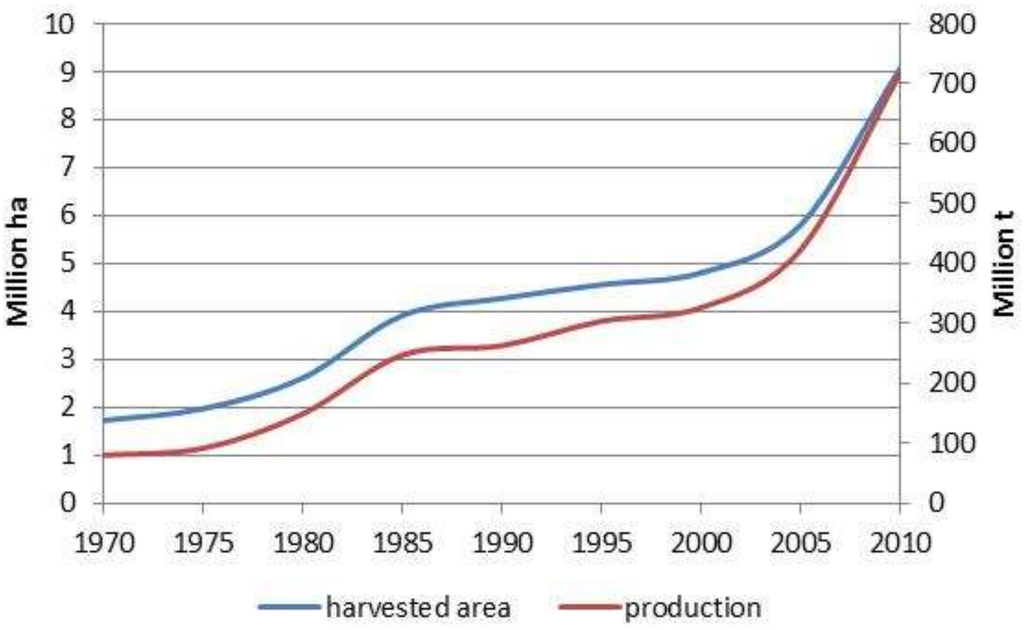

Figure 9. Sugarcane production expansion in Brazil 1970-2010 – harvested area in million hectares and production in million tonnes (IBGE, 2011).

The rapid fall in oil prices in the second half of the 1980s exerted considerable pressure on the Brazilian ethanol programme. This was a time of very high inflation in Brazil. The government had difficulties justifying the focus on fuel shift at a time when oil prices were dropping and the climate change debate had minimal status in political discourse. There was not yet broad common understanding about the multiple benefits of the sugar-industry for the country. At the same time, the Brazilian economy was being gradually opened, and ethanol-related policies moved towards removing price regulations and the incentives previously provided to the sector. As a consequence, research and development on sugarcane production slowed down, while producers shifted to sugar, where prices had recovered and better return in export markets could be obtained. The situation undermined consumer confidence and led to the collapse of the market for ethanol cars. After 1988, sales of ethanol cars dropped very fast and, by 1989, only 13% of the cars sold were ethanol driven. Shortage of ethanol in the pumps required that both ethanol and methanol were imported in the early 1990s, upsetting consumers and compromising the development of ethanol markets (Rosillo-Calle and Cortez, 1998).

However, some important positive effects came out from the challenges of the late 1980s. In particular, the efforts made by producers to adapt to the new policy and market context led to significant efficiency improvements and increased robustness in the ethanol industry. The average ethanol production cost declined twice as fast in the late 1980s compared with the previous ten years (Goldemberg et al., 2004; Moreira and Goldemberg, 1999). The high blend of ethanol in gasoline guaranteed a market which, given that gasoline demand still expanded, offered potential to absorb production. Nevertheless, production increased much slower in this period than before. It was the introduction of the flex-fuel technology in 2003 that boosted a new phase in favour of ethanol markets.

With a well-established infrastructure for ethanol distribution, and flexibility for consumers to choose their fuel, flex-fuel cars gained new sales and market share very quickly. When introduced in 2003, flex-fuel cars comprised only 3.5% of the new car sales. In 2010, flex-fuel cars had reached 95% share of new car sales in Brazil. [18] Today, 57% of the Brazilian fleet of light vehicles is composed of flex-fuel vehicles (UNICA, 2012). The production of ethanol has doubled since the introduction of flex-fuel cars and is now at 28 billion litres of ethanol per year (EPE, 2011c). The 18% of Brazilian energy needs that sugarcane provides is approximately equivalent to the amount of energy used in Sweden as a whole.

The policies put in place since the creation of the Proalcohol programme included incentives to expand ethanol production, mandatory targets for ethanol mix in the gasoline[19], agreements with car manufacturers to produce ethanol-cars, procurement to create government owned/operated car fleets driven by ethanol, and research and development to improve crops and yields of sugarcane and investment grants. Brazil's experience with biofuel market development has continued for almost 40 years and the policies applied and incentives provided have changed over time in response to both internal and external conditions.

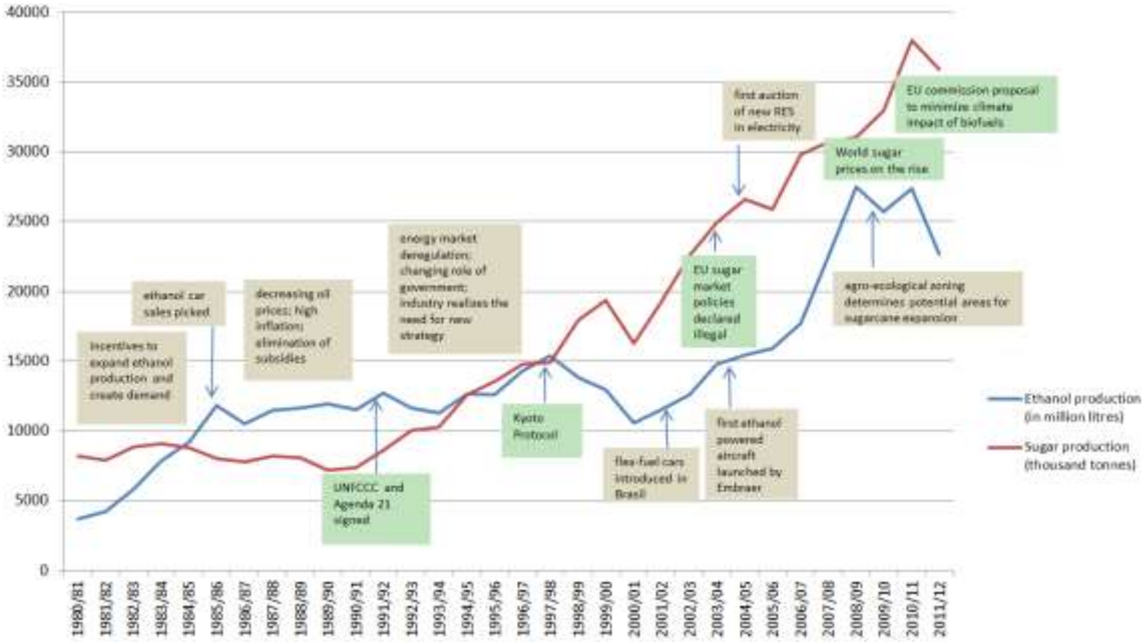

Figure 10. Sugarcane and ethanol production in Brazil 1980-2012 (UNICA, 2011).

Figure 10 shows the development of ethanol and sugar production between 1980 and 2012. Most mills still produce both sugar and ethanol and tend to adjust the share of the two products in response to market conditions. More recently, some new distilleries only produce ethanol. Notably, the market for sugar has grown continuously and has become particularly attractive since prices started rising again in 2005. Brazil has 20% of the global sugar production and 40% of global sales, thus sugar prices often reflect Brazilian production costs. The evolution of ethanol production in

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[18] Government policies have played an important role increasing Brazil's flexi-fuel vehicle fleet. Automobile manufacturers were granted tax breaks to produce cars that run on hydrous ethanol: in 2004-08, taxes were 6-7 percent lower for flexi-fuel vehicles (the so called IPI tax) than on gasoline cars, and since December 2008, new flexi-fuel cars with engine displacement of 1000 cc or less have been exempted from the IPI tax. Moreover subsidized credit (estimated at $330 million in 2007) has been made available to car manufacturers for operational and R&D activities to help increase flexi-fuel vehicle fleets (see: Valdez, 2011).

[19] Proálcool set the mandated blend to 11 percent in 1976. The blend has fluctuated between 11 and 25 percent since then, with the government adjusting the mix requirement according to supply and demand conditions. In January 2010, the blend level was set at 20 percent, down from 25 percent, as a result of falling ethanol stocks (see: Valdez, 2011).

past decades denotes larger volatility, which in turn, reflects policies and uncertainties related to the new market formation. In the second half of the 1980s when oil prices went down, ethanol production grew slowly in line with the demand for gasoline that already then contained significant amounts of ethanol mixture. Since the turn of the millenium, and particularly after the introduction of the flex-fuel car, ethanol production has more than doubled. Lately, the continued growth of internal demand for ethanol, development of export markets and availability of cheap credit is boosting a new wave of expansion in ethanol production. However, increasing labour costs, bottlenecks in transport, storage and logistics, and climatic conditions have somewhat affected the development of production and attractiveness of ethanol fuel in the last few years.

Besides sugar and biofuel for transport, another important contribution of sugarcane to the overall energy supply in Brazil refers to the generation of heat and power using sugarcane residues. Traditionally, bagasse was used to generate heat and power and meet internal process needs. In 2009, however, sugar-ethanol producers delivered almost 6 TWh of power to the grid. The opening of electricity markets together with government efforts to diversify sources of electricity generation in the country have provided incentives to upgrade cogeneration facilities using bagasse (Khatiwada et al, 2012a). The CDM (Clean Development Mechanism under the Kyoto Protocol) also helped boost investments on efficiency improvements since bioelectricity has been eligible to generate tradable certificates. In fact, this type of projects represent one third of the CDM renewable energy projects realized in Brazil. Today, sugar-ethanol mills retain 6% of the installed capacity for electricity generation in the country (ANEEL, 2012). This means that total efficiency of the Brazilian sugar-ethanol mills can still increase significantly in the short term if bagasse and leaves of the sugarcane are more effectively used for electricity production. In the medium and long term, the production of second and third generation biofuels promise even larger potential for efficiency improvements.

Scientists calculate that sugarcane ethanol contributes considerably to climate change mitigation, reaching more than 60% GHG emissions reduction when compared with gasoline (Wang et al, 2012; Meira Filho and Macedo, 2008). However, different LCA methodologies indicate quite different results and indicate that further refinement is required if the benefits of biofuels are be properly addressed (Khatiwada et al., 2012b). Since the introduction of the flex-fuel vehicles in 2003, it is estimated that more than 128 million tonnes of carbon dioxide have been avoided in Brazil (one litre of ethanol in a flex-fuel engine is considered equivalent to a reduction of 1.7 kg of carbon dioxide). The large use of ethanol has been estimated to reduce the equivalent of 10% of the country's total emissions in 2006, indicating the large climate benefits of this fuel substitution (Meira, Filho and Macedo, 2008).[20] Increased climate benefits are expected as the production increases further and fuel substitution procedes both nationally and internationally due to the formation of global ethanol markets. Despite international concern about the competition between food and fuel (Rosillo-Calle and Johnson, 2010), Brazilian food production has increased continuously side by side with the expansion of sugarcane for sugar and ethanol along the past decades, see Figure 10. Brazil remains one of the largest exporters of food. To a great extent, the productivity gains accrued from the modernization of the agriculture have benefited both food and fuel pro-

[20] The reader should note that the authors of this report have assumed that these figures (pre-2008), and later similar figures reported in reports used in this study such as Valdez (2011), do not include LUC emissions. Deeper examination of this issue lies beyond the scope of the report for simple reasons of complexity.

duction. Meanwhile, deforestation has been reduced sharply in the last fifteen years. Although still a problem, it is presently at half of the deforestation level observed in the early 1990s (Silveira, 2012).

EPE (2011c) projects continued expansion of sugarcane planted areas and production capacity in the present. Further efficiency improvements are expected along the supply chain, including increasing production of bioelectricity and possibly also the implementation of second generation biofuel production. In this manner, ethanol will likely remain a competitive option in the market. As a result of the agro-ecological zoning developed by the Brazilian government in 2009, it is not possible to plant sugarcane in the sensitive biomes of the Amazon and Pantanal (wetlands in the center-western part of Brazil). Neither is sugarcane expansion allowed in areas where there is native vegetation, for example in the cerrado. However, there are some 65 million hectares or arable land that can be used for sugarcane expansion (Leite et al, 2009).

In summary, the Brazilian sugar-ethanol industry has been supported by a number of different policy instruments in the last four decades, but the development has also been facilitated by a number of initiatives lanched by the industry itself. It is obvious that strategies to develop ethanol fuel have shifted in accordance with national priorities and exogenous impulses received from global agendas and markets. It is worth noticing how the development of agriculture has been a major pillar in the development of the sugar-ethanol industry in Brazil long before the establishment of the Proalcohol programme in the 1970s. In the 1980s, the government guided and participated directly in the development, bringing together stakeholders, making agreements with car manufacturers and providing credit for industrial development. By the mid-80s, the instruments in use became inadequate to address falling oil prices and market competition. For some time, the government shifted attention away from the ethanol industry which was forced to review its structure and strategies, and work to improve efficiency. As the global climate agenda gained momentum in the 1990s, the Brazilian ethanol industry was ready for a new expansion phase. The government now took a different role, focusing on the development of infrastructure to improve market logistics, demand creation, and investment provision, as well as to regulate stocks, market flows and labour issues. Since 2005, both federal and state governments have constantly strengthened scientific research to prepare the industry for yet a new cycle of innovative expansion in the next decade. The sugar-ethanol is seen as a strategic industry for the country’s development.

3.4 THE DEVELOPMENT OF BIODIESEL PRODUCTION

Although the use of vegetable oils in engines dates from the experiments made by Rudolf Diesel already in 1900, Expedito Parente, a Brazilian researcher, was the first to patent biodiesel in the world as late as 1980. In Brazil, the first attempts to use vegetable oils in transport date from the 1940s. Vegetable oils had been used in emergency situations, but were not considered suitable as heavy vehicle fuels, in contrast with biodiesel which can be mixed with the fossil diesel in varied proportions (Yusuf et al, 2011). Many research institutes tested biodiesel production from different plants in the 1950s. More recently, biodiesel has attracted global interest and many countries are investing in research in this field. Brazil has held an intermediary position in this context, but is reviewing strategies given the recent success of the national biodiesel programme and potential for market development.

The Brazilian National Energy Commission created the Pro-Oleo programme in 1980, initially aiming at 30% fossil diesel substitution (Pousa et al, 2011). Such as in the case of the Proalcohol, the Pro-Oleo programme also included research efforts, including the development of technologies for biodiesel production, and engines, which were performed in cooperation with motor manufacturers in the country. However, the biodiesel programme did not achieve the same government engagement and public support as the alcohol programme. Eventually, production costs were judged too high to be competitive, and the programme was abandoned already in the mid-1980s when oil prices fell.

At the end of the twentieth century, the issue of biodiesel was on the government's agenda once again and, in 2002, a biodiesel programme was launched aimed at the substitution of 5% of the fossil diesel consumed in the country by 2013. The production of biodiesel started in 2005 when also a mixture of 2% (volume) biodiesel was authorized. Later, the mix became mandatory, and was successively raised to 5%. The idea was to use diverse feedstock depending on the vocation of each region. This contrasted with the single feedstock used for ethanol. Figure 11 shows the rapid development of biodiesel production in Brazil which reached 2.4 billion litres in 2010, thus allowing the 5% mix of biodiesel in the total diesel consumption of the country, and meeting the mandatory target long before the target year (EPE, 2011a). Meanwhile, the installed capacity is already at the order of 6 billion litres and the government is being asked to set new targets and authorize increases in the mix, initially to 7% and gradually up to 20% (IPEA, 2012).

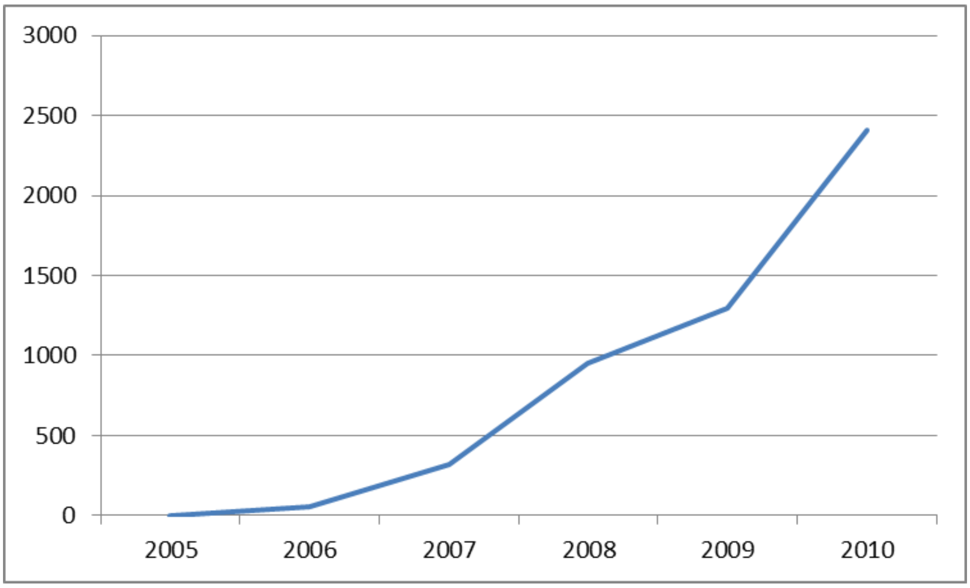

Figure 11. Biodiesel production in Brazil 2005-2010 – in 10^6 litres (IBGE, 2011).

Notably, Brazil was able to establish production to meet a 5% biodiesel mixture in only 5 years. There is here a clear distinction from the efforts made in the 1980s and the successful policies implemented in the past few years. First, there is now a broad international interest in the development of biofuels for transport as many countries face challenges posed by high oil prices and climate change mitigation challenges. Second, Brazil had a long and successful experience developing the ethanol industry when the recent biodiesel programme was launched. This includes the modernization achieved in agriculture, and technological development favoured by R&D, both very important for a competitive biodiesel production.

One point to note, however, is that the biodiesel programme was launched to be more socially inclusive and diverse than the ethanol programme. Given the variety of species that can be used for biodiesel production in Brazil, a central idea was to build upon regional vocations and promote different species. However, although the production goals and the fuel mixture were reached, the dominance of two major sources indicates that more attention is needed if the distributive social and regional benefits are to be fully explored. Most of the production came from soybeans (85%) and a small part from meat fats (13%) in 2010, indicating that the most established and export-oriented segment of the Brazilian agribusiness (soybeans) was able to very rapidly capitalize on the synergies that market incentives for the biodiesel programme made possible. Notably, this has resulted in significant participation of international capital in the development of biodiesel production, and higher capital concentration than in the ethanol sector (IPEA, 2012).

The social certification system created early in the programme to favour small producers has had limited impact. Only some 109,000 families have benefited directly from the programme in southern regions, while the target was 245,000 families with particular focus on the Northeast (IPEA, 2012). This goes hand in hand with the fact that soybean plantations are often large scale and regionally concentrated. As a result, the biodiesel production is mainly concentrated in four states of the centre-south regions following on the location of the soybean plantations. For other crops to become more important, technological improvements are needed to establish cost-efficient industrial processes for inputs other than soybeans. Since at least 70% of the production costs of the biodiesel are in the oil source, there is need for coordinating R&D efforts with distributive policies to achieve the full social benefits of the biodiesel development.

Given the rapid development of the biodiesel industry, idle capacity awaiting new legal frameworks to increase production, and on-going discussions about a new regulatory framework for the sector, it is surprising that the government's ten year plan for the energy sector indicates no expectation to increase the percentage of biodiesel mix in the near future. This is justified by the fact that input prices are expected to increase in the next years, putting biodiesel in strong competition with other end-uses for relevant crops. In the ten year plan report, EPE (2011b) indicates an increase from 2.4 billion litres in 2010 to 3.8 billion litres in 2020, which is needed to continue fulfilling the compulsory mix of 5% biodiesel. This is a very conservative view given that installed capacity already allows production of 6 billion litres and the industry is putting pressure on the government to increase the compulsory mix. In any case, a new legal framework for biodiesel is needed to strengthen the social and regional development dimensions of the programme, as well as research and technological innovation in the sector.

3.5 BIOFUELS – OPPORTUNITIES FOR SUSTAINABLE DEVELOPMENT

Changes in the Brazilian energy matrix in the past decades reflect not only diversification of energy sources and technologies, but also the shift from traditional to modern bioenergy, and the increasing integration of energy in development strategies. In fact, biofuels have become an important development engine in Brazil. Synergies have been established between energy and agriculture in particular, but research policies have also been increasingly important in the process. Through national mobilization of multiple stakeholders, and the capacity to define goals, catalyse industries, market forces and investments, together with coordinated efforts on the supply and demand sides, and R&D, Brazil achieved success with the ethanol programme. Furthermore, the country has capitalized on this experience and established biodiesel production and markets within a short period of time, see Table 1.

Today, Brazil is the world leader in the production and use of sugarcane ethanol. The positive results of the efforts made have been gradually recognized internationally, not least due to the climate change mitigation benefits achieved. The benefits of a more sustainable energy path are also strongly felt in the Brazilian economy, and this is triggering new efforts to continue on track. A study by Weidenmier, Davis and Aliaga-Diaz (2008) found empirical evidence that diversification of energy supply resulted in large macroeconomic benefits to Brazil. According to their study, the GDP was almost 35% higher in 2008 compared to 1980 due to reduction of oil imports, increased domestic oil production and development of sugarcane ethanol. In addition, diversification of the energy system helped reduce business-cycle volatility, particularly in the past decade when the reduction was in the range of 14 to 22%. Three quarters of the welfare benefits are related to reduced oil imports and development of national oil production. However, sugarcane ethanol had a major role in the other share of the benefits particularly as it protected the economy from oil price shocks.

The sugar-ethanol industry in Brazil has evolved into a modern industry, now also with participation of international capital and interests. The Brazilian sugar-ethanol industry is a strong actor in the fuel markets of Brazil and also in the global arena, pushing for the formation of global ethanol markets. Investment in ethanol and other biofuels is increasing in Asia and Africa, as oil-importing countries recognize the strategic value of diversifying into biofuels to address energy insecurity, stimulate agro-industrial development and mitigate climate change (Batidzirai and Johnson, 2012).

The Brazilian experience shows that a lot can be realized at national level, and the modern bioenergy transition achieved in a few decades only. As international competition intensifies, it will be important to devise new strategic policy frameworks to guarantee continued leadership in the ethanol segment (Souza and Macedo, 2011). Likewise, sectoral and innovative policies will be needed in the other bioenergy segments to fully explore their national and global benefits.

An important lesson from the Brazilian experiences is that the transition towards biofuels cannot be achieved within the context of the energy sector alone. In fact, a significant amount of synergies need to be created across economic sectors and governance levels. In Brazil, broad integration was orchestrated encompassing agriculture, transport and the energy sector. National mobilization of public and private stakeholders, the definition of goals and policies to catalyse investments, market creation and provision of additional infrastructure have been essential in the process, see Table 1.

Coordinated efforts were made on both the supply and demand sides, supported by R&D, and pushed by strong interest groups who embraced the new fuels, technology options and markets. Short-term variation in exogenous factors affecting policy choices (e.g. oil prices) have been counteracted by the long-term commitments of multiple stakeholders and served as incentive to improve efficiency and consolidate the biofuel sector. This systemic approach in policies is, in fact, receiving increasing attention also in the technological innovation literature (Wieczorek and Hekkert, 2012). In the search for renewable energy substitution pathways and increased energy efficiency, a cross-sectoral system approach has proved to be a requirement due to the character of the resource base, the opportunities for developing multiple products and energy services in integrated processes, and the requirements for cost efficiency and competitiveness in the various sources from which biomass is derived.

Specific technology options and strategic policies had an important role in orchestrating the biofuel transition in Brazil, but the key factor for modern bioenergy in the country is associated with the alignment of old established structures and interest groups in agriculture with industrial actors and policy-makers at national and sub-national scales. Long term commitments created the virtuous cycle of private and public investment in both infrastructure and institutions, which provided the basis for the up-scaling phase of successful technology deployment and the movement from niche market to mainstream technology and fuel option, which is the case of ethanol in Brazil today.

Still, many challenges lie ahead. The future development of bioenergy is not given. Beaten unsustainable paths, established infrastructure and economic interests, lack of systemic political and cross-sectoral support, the conflict of fuel versus food, and public opinion are some of the barriers to be addressed in Brazil and in the world at large. Planning for social, economic, spatial and environmental balance simultaneously will be crucial for correcting distorted processes of environmental degradation, capitalizing on the bioenergy benefits and potential sector synergies, turning the present dynamics into processes of sustainable development.

Table 1. Characteristics and actors involved in ethanol and biodiesel segments in Brazil in past decades.

BRAZIL	Starting point/existing platforms	Triggers for development of the industry	Technologies, infrastructure, investment needs	Interest groups	Opposition	Characteristic of policies	
						Earlier	*More recently*
Ethanol 1975 – present	Extensive sugar-cane plantations and sugar production (important export product).	Low sugar prices; opportunity to expand and modernize sugarcane production. Opportunity to link agriculture modernization and energy policy to reduce oil imports and dependency; oil prices.	Technology improvements in agricultural production; investment in sugar/ethanol plants; logistics in transport, storage and distribution; new technology for ethanol vehicles.	Sugar producers aiming at expansion and modernization, targeted ethanol as complementary to sugar (e.g. ethanol). Car producers: opportunity to develop new products for growing Brazilian market. Researchers aimed at improved agricultural productivity.	Initially, none. Ethanol was to displace oil, which was imported. Lately, environmental NGOs, (particularly international); food security professionals and politicians worried about competition with food production. Agri-business in new ethanol producing countries fearing competition. Oil and gas industry.	Multi-sectoral and development oriented; strategic; strong coalition of public and private interests; long-term and constantly reviewed and adapted; job creation.	Strategic and growth oriented; monitoring role in a broader development and energy security context; link between national and international efforts to shift energy systems towards renewables and mitigate climate change.
Biodiesel 2002 – present	Modernized agriculture sector; successful experience with establishment of ethanol industry; large markets for diesel; some diesel import dependency.	Increasing recognition of biofuels role in promoting sustainable development; global climate change agenda; national social agenda.	Investment in biodiesel plants; certification schemes for social sustainability in biodiesel production.	Agriculture sector particularly soybean producers; industrial groups focused on biofuel production.	Initially, none. Lately, national opposition groups worried about the domination of large-scale industry, and failure of programme to address social inclusion as envisaged.	Replication of success case with ethanol though now with strong dimension of social inclusion.	Caution in the expansion of targets.

4 EUROPEAN UNION

4.1 INTRODUCTION

This chapter provides an overview of policy instruments applied in the EU and how they have affected biofuel markets and trade with biofuels. The analysis also looks into the more specific case of biodiesel in Germany, and examines the experiences of the policies applied there. A discussion is then provided of the pros and cons of the policy instruments applied in the EU and Germany. The chapter closes with a brief elaboration of how the EU target of 10% biofuels in transport until 2020 may be met.

4.2 EUROPEAN UNION

EU policy on biofuels has been driven by energy security and climate mitigation considerations. While energy security was originally the key driver in the 1990s, see for instance the Green Paper "Towards a European strategy for the security of energy supply" (Commission of the European Communities, 2000), focus has gradually shifted towards mitigation of climate change. Considerations of rural development have also constituted a substantial driver throughout.

As the biofuel market is still dominated by 1st generation fuels, mainly ethanol and biodiesel, the Common Agricultural Policy (CAP) has important implications. The CAP was created in 1962 and is one of the oldest policies of the European Union[21]. It has historically been revised to account for fluctuations in the global food market, but other factors have also affected it. The Mac-Sharry CAP reform was introduced in 1992 to handle the food surplus at that time. The main component was to set aside land for non-food purposes, and that has become a strong driver for biofuel production. As a consequence of recent high food prices (particularly in 2007/8), CAP set-aside provisions were again revised and presently it is not mandatory to set aside land (Council of the European Union, 2009).

In the Directive 2003/30/EC (European Parliament and of the Council, 2003) a target of 5.75% (energy content) biofuels in transport by 2010 was set as an indicative target. The actual development is shown in Figure 12. Although the target was not met, the share for renewable transport fuels in the EU has increased from 1.9% to 4.7% between 2006 and 2010 (Eurostat, 2012).

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[21] The CAP was created by the six member countries of the European Economic Community (EEC) in 1962.

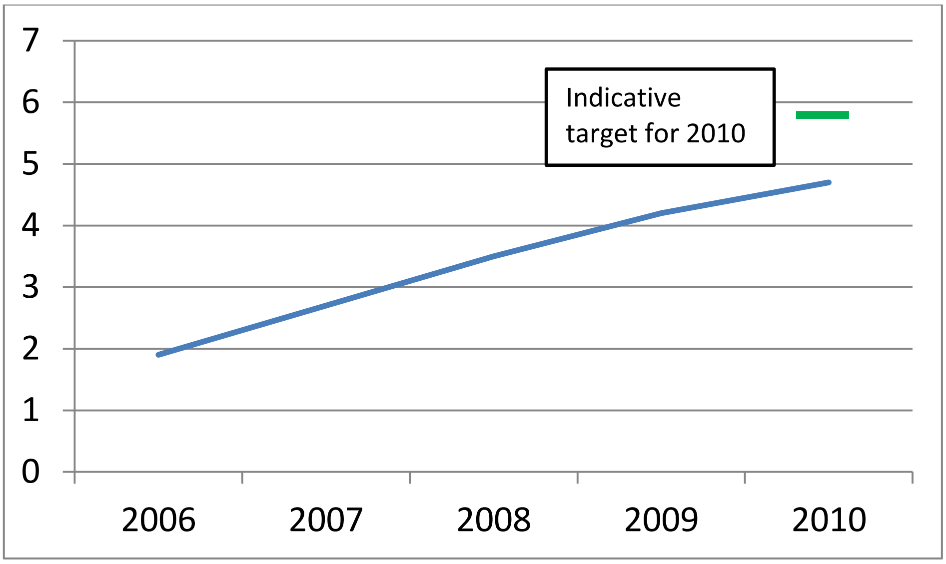

Figure 12. Share of renewable fuels in transport in EU-27 (energy content) in relation to target for 2010 (Eurostat, 2012).

In March 2007 the EU "Energy and climate package" was passed in the European Council (European Commission, 2013). The package included the following targets:

- 20% reduction of GHG by 2020
- 20% renewables on average in gross energy supply in the EU by 2020
- 20% energy efficiency improvement by 2020

In 2009 the European Parliament approved Directive 2009/28/EC, also referred to as the Renewable Energy Directive or "RED" (European Parliament and the Council, 2009a). The RED states that all member states should reach a share for biofuels in transport (excluding aviation and sea transport) of at least 10% by 2020. The contribution from fuels based on waste, residues, non-food cellulosic material and lingo-cellulosic material shall be counted as twice that of other biofuels. Renewable electricity used by electric road vehicles shall be multiplied with a factor of 2.5. However, for rail vehicles no such factor is applicable. The share for renewable electricity (of the total electricity use of a vehicle) may be calculated either as the EU-average or as the actual share in the country in question. A minimum calculated 35% reduction of greenhouse gases (GHG) for approved biofuels during their life-cycle is required. To calculate the GHG reduction, either default values or the actual values according to a formula in Annex V of the Directive may be used. The minimum required calculated reduction is to be raised to 50% by 2017.

In October 2012, the European Commission launched a proposal for an amendment of the Renewable Energy Directive revision (European Commission, 2012a). With reference to the risk for negative indirect Land-Use Change (iLUC) effects, the Commission proposed a cap for food-based biofuels at 5% of total fuels (energy content), thus steering the market towards the development of second and third generation biofuels, i.e. those based on non-food feedstocks. There are also other revised incentives in that direction. Transport biofuels produced from, for instance, straw, bark, branches, tall oil pitch[22], and animal manure are to be counted as four times their energy content in the new proposal, compared to only two times according to the Renewable Energy Directive. Further, requirements on GHG savings are strengthened. While previously a 60% calculated reduction was required in installations with production start after 1 January 2017, the new proposal requires a 60% calculated reduction in installations with production start after 1 July, 2014.

The proposal also contains a strengthening of the requirements regarding GHG reductions for biofuels on a life-cycle basis. These requirements may be compared to typical GHG savings mentioned in the Renewable Energy Directive, see Table 2. It is evident that many existing biofuel production paths will be difficult to reconcile with the proposal.

Table 2. Typical GHG savings from biofuel production chains (European Parliament and the Council, 2009a).

Biofuel	Typical GHG savings
Rapeseed biodiesel	45%
Soy bean biodiesel	40%
Sun flower biodiesel	58%
Palm oil biodiesel (process not specified)	36%
Palm oil biodiesel (methane capture at mill)	62%
Corn ethanol	56%
Sugar beet ethanol	61%
Sugar cane ethanol	71%
Waste vegetable or animal oil biodiesel	88%

Member states have mainly used two types of policy instruments in order to achieve EU-wide and national targets. These are tax exemptions and mandatory quotas for fuel providers. All member states with substantial biofuel shares have or have had tax exemptions in place. Tax exemptions have been regulated by the Directive 2003/96/EC (Council of the European Union, 2003) on Energy taxation, which is now (2013) under revision.

About 20% of biofuels for transport that were used in the EU in 2011 were imported. There is also some export from the EU, but in essence this is negligible. A difference in production costs among regions is obviously a key determinant for trade patterns, but import tariffs are also important. One reason behind the 50% increase in import of Brazilian ethanol in 2008 seems to have been that importing companies discovered that ethanol blended with some petrol could be classified as a chemical product instead of a fuel product. It could then qualify for a lower 6.5% duty (corresponding to about 30-40 Euro per cubic metre) instead of the duty for denatured ethanol of 102 Euro per cubic metre. When sugar prices increased in 2009, almost all of the import from Brazil was replaced by import from the US in only two years (Flach et al., 2012). The import from the US was also supported by a US tax credit of 45 cent/gallon (Cohen, 2013).

[22] A non-volatile fraction from tall oil destillation.

In October 2011 the EU Customs Code Committee approved a proposal to end the loophole stating that all blends of ethanol and petrol with ethanol contents above 70% should be subject to the duty rate 102 Euro per cubic metre (Flach et al., 2012). This regulation became valid from 3 April, 2012. In addition, and spurred by the European biofuels industry, the EU in February 2013 put in place a regulation including an anti-dumping duty on agricultural ethanol imported from the US. The duty is 62.3 Euro per tonne, which corresponds to 79 Euro per cubic metre (Council of the European Union, 2013).

The import of biodiesel has been small but increased from 60 to 2113 thousand tonnes between 2006 and 2010 (Flach et al., 2012). For 2009, 18% of the biodiesel consumed in the EU in 2009 was imported (ibid.) and biodiesel from Argentina represented almost half of the import to the EU during this year.

There are also other EU policies that have an indirect but substantial impact on biofuel markets, both the total volume and the composition. One such policy is the emission standards set for new passenger cars (European Parliament and the Council, 2009b). It states that average emissions of new passenger cars should not exceed 130 g CO_2/km by 2015 and 95 g CO_2/km by 2020. The target for 2015 will be met relatively easily, but the 2020 target will be more challenging. In meeting these emissions standards diesel cars will have an advantage over petrol cars, due to the higher inherent energy efficiency of diesel engines. Different kinds of electrification will also be increasingly important. The increasing general use of medium distillates such as diesel and aviation fuels will provide a further incentive to focus on substitutes for fossil diesel.

4.3 GERMANY

Germany reached a share of 7.2% (energy content) biofuels of total road transport fuels in 2007, a share that in 2009 had decreased to 5.5%. Of the transport biofuels used in 2009, 77% was biodiesel (mainly produced from rapeseed), 20% was ethanol and 3% was vegetable oil (Rauch and Thöne, 2012). The shares for biomethane and second-generation biofuels were negligible. The development of the German biodiesel market is shown in Figure 13.

Germany was in 2009 the biggest producer of biodiesel in the EU accounting for a share of 28% (Rauch and Thöne, 2012). Most of the biofuel sold in Germany was produced domestically.

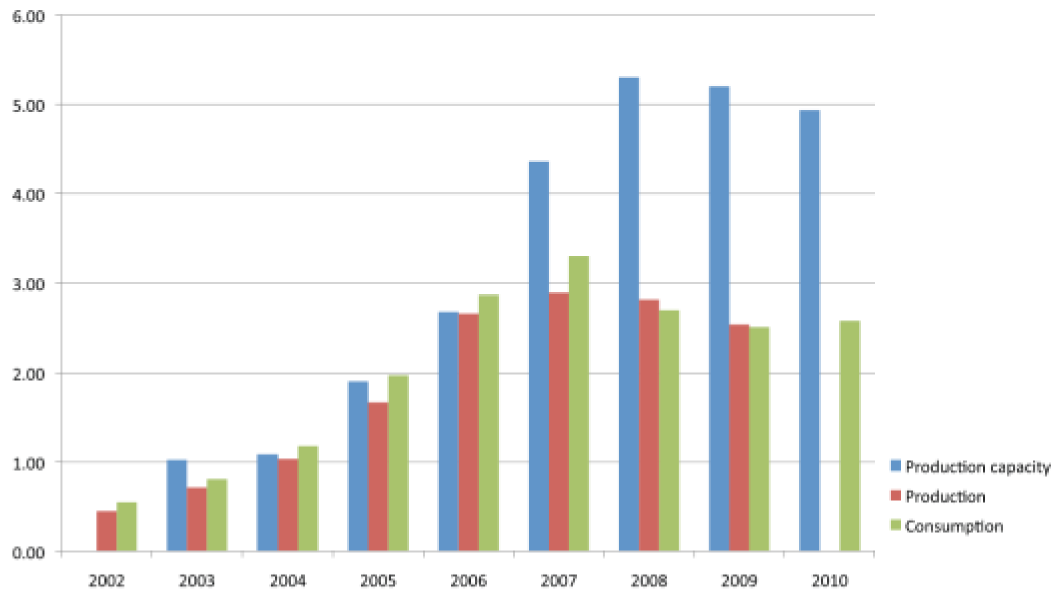

Figure 13. German biodiesel market in million tonnes (Rauch and Thöne, 2012).

A driver for introducing biofuels in Germany has been climate concern, but the importance of energy security and rural development concerns have also weighed strongly – particularly in the early 2000s. A powerful actor has been the ministry of consumer protection, food and agriculture, from 2001 to 2005 led by Renate Künast of the Green Party. From this side it is clear that concern for development of rural areas in former East Germany was a significant driving force (Thuijl and Deurwaarder, 2006). Many car manufacturers in Germany have allowed fuel containing 100% biodiesel B100 for some of their cars, but recently interest among manufacturers have shifted towards the truck market. The Association of the German Petroleum Industry has been against tax exemptions for first generation biofuels, such as biodiesel (Bomb et al, 2007).

In 1995, the first commercial production of biodiesel started. Leaded petrol was abolished in 1996 and this provided an opportunity for biodiesel as free tanks then became available at filling stations. Within a couple of months more than 600 filling stations marketed pure biodiesel, none of which belonged to the major oil companies (Thuijl and Deurwaarder, 2006). In these early days, the focus was on pure biodiesel (B100). In 2004 a blended fuel with 5% biodiesel (B5) was authorized and from 2009 the maximum allowed blend was increased to 7% (B7) (Rauch and Thöne, 2012).

The main driver for biodiesel in Germany until 2007 was excise duty exemption. Originally it only applied to pure biodiesel, but from 2004 it also applied for low-level blends (Bomb et al., 2007). In combination with increasing oil prices in 2004-2006, these policy initiatives triggered a wave of new investments in the biodiesel industry.

A key concern for the German government then became the rapidly increasing tax losses due to the tax exemptions for biofuels. The tax losses reached an all-time high at 2.14 billion Euros in 2006. As a response a quota system was launched on January 1, 2007. This caused tax losses to diminish to less than 0.1 billion Euro in 2010 (Rauch and Thöne, 2012). In this quota system there is one quota for diesel substitutes, one quota for petrol substitutes and one total quota. The development of these quotas is shown in Table 3. A total quota was introduced in 2009. The quota for diesel has been the same since 2007 while the quota for petrol has been raised from the start at 1.2% in 2007. This has caused stagnation in biodiesel consumption while ethanol consumption has increased rapidly, from negligible in 2003 to nearly 1.2 million tonnes in 2010 (ibid.). While more than 80% of biodiesel consumption was produced domestically in 2010, the corresponding figure for ethanol was around 50%.

Table 3. German quota system (FNR, 2011, cited in Rauch and Thöne, 2012)

Year	Quota: diesel	Quota: petrol	Total quota
2007	4.40 %	1.20 %	
2008		2.00 %	
2009		2.80 %	5.25 %
2010			6.25 %
2011			
2012			
2013			
2014	4.40 %	2.80 %	6.25 %
2015	Decarbonisation 3.0 %		
2017	Decarbonisation 4.5 %		
2020	Decarbonisation 7.0 %		

The general rule in the German quota system is that biofuels used within the quotas are levied with the same taxes as fossil fuels. Biogas, E85 and second generation biofuels are eligible for full tax exemption until 2015, but presently these fuels represent a negligible share in the German market (Rauch and Thöne, 2012). Pure biodiesel and vegetable oil have also continued to have tax exemptions efter the introduction of the quota system, but this has gradually been phased out between 2007 and 2013. The excise rates (cent/litre) for these fuels were 9.00 in 2007, 14.90 in 2008, 18.30 in 2009, 18.60 between 2010 and 2012 and from 2013 onwards 45.03 (Rauch and Thöne, 2012).

From 2015 the quotas will be calculated according to GHG reductions on a life-cycle basis instead of energy content as is now the case. The decarbonisation target for the total fuel mix used in road transport (fossil and renewable fuels) will be 3% for 2015 and 7% for 2020. The latter is calculated to correspond to approximately a 12% energy share for biofuels (ibid.).

An effect of the new system launched in January 2007 was that the gap between production capacity and actual production of biodiesel rapidly increased, see Figure 13. Between 2006 and 2008 production capacity almost doubled – due to projects “in pipeline” – while production increased by less than 10% (the dedicated biodiesel quota remained the same from 2007). That is, capacity use fell from nearly 100% to around 50% in only two years. This overcapacity had also been contributed to by public co-funding of biodiesel plants. The consequence was that a number of companies became insolvent from 2008 and onwards (ibid.). The production capacity of these companies together amounted to more than 1.3 million tonnes, which may be compared with total production of around 3 million tonnes in the peak year 2006. However, not all these biodiesel plants were closed down. More than 400,000 tonnes of annual production capacity were taken over by other companies (Rauch and Thöne, 2012). It was also the case that many companies that managed to avoid insolvency had ceased production at some of their plants.

Another interesting effect of the policies of 2007 was a radical shift from pure biofuel (B100) to blends. In 2006 two thirds of biodiesel production was used in the form of B100. Only four years later this share had diminished to 11% (ibid.). A related development is that the number of filling stations for B100 has diminished from 1900 to less than 200. There are thus strong indications that the market for pure biodiesel was very fragile – as the first steps away from tax exemption had such a dramatic effect.

In Figure 14 some key policies affecting biodiesel consumption in Germany are shown in relation to actual consumption. While other factors such as oil price, economic cycles and public opinions also affect the consumption of biodiesel, some conclusions may still be drawn. The impact of the quota system introduced in January 2007, which imposed a constant 4.4% quota for biodiesel between 2007 and 2014, is rather clear. The market share for biodiesel was above 5% in 2007, but then fell back. In the quota system there is a total quota that is higher than the sum of the specific quotas for biodiesel and petrol substitutes (see Table 3 above), but biodiesel did not appear to be competitive enough to fill that quota. Rather, it was imported ethanol that increased rapidly between 2007 and 2010.

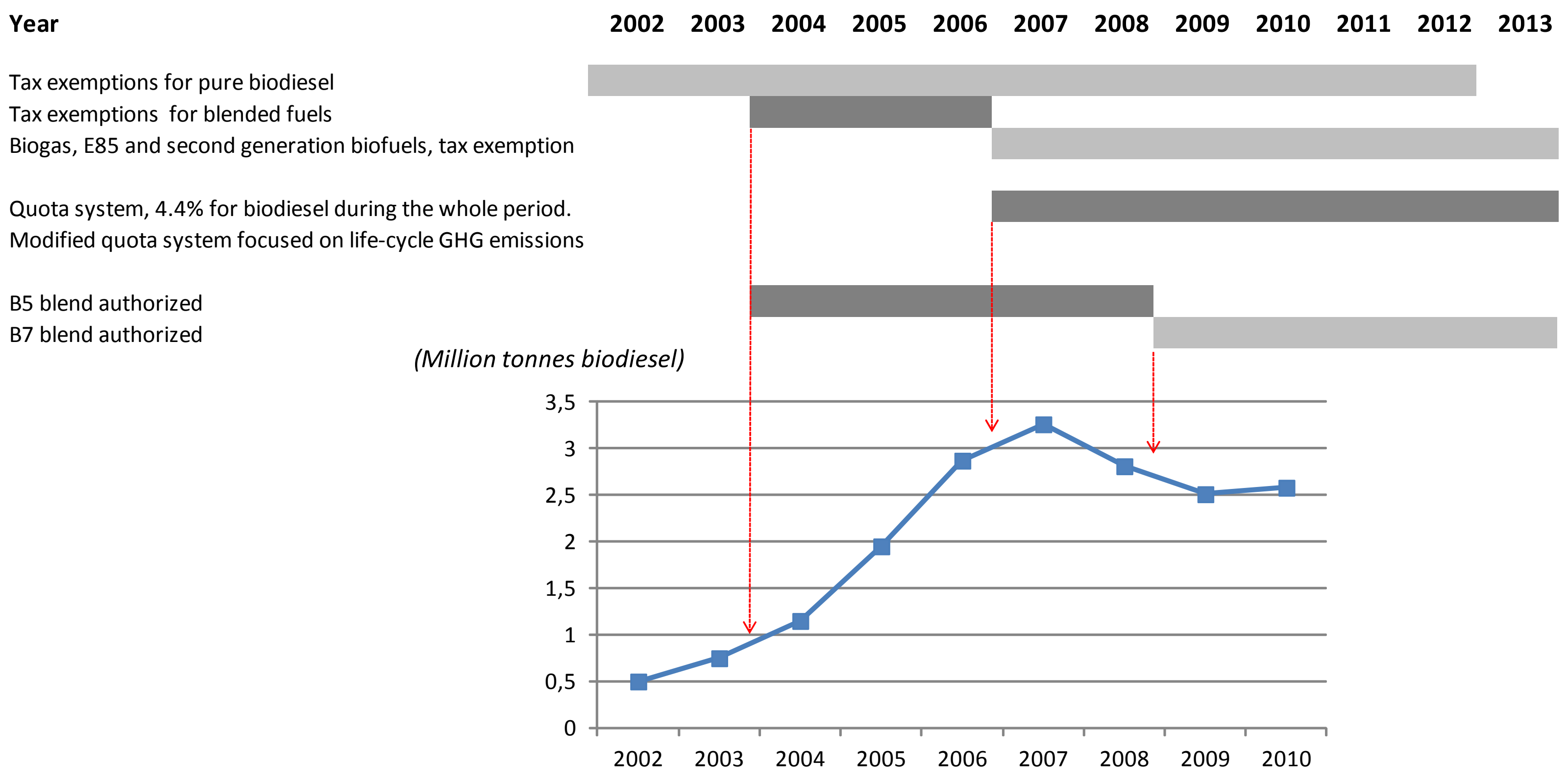

Figure 14. Policies affecting biodiesel consumption in Germany in relation to actual consumption.

4.4 DISCUSSION

It seems that tax exemptions and mandatory quotas to fuel providers are equally effective from an economic point of view. The same cost for achieving the 10% biofuel target in the EU by 2020 have been calculated for these two policy options (Wiesenthal et al., 2009). Mandatory quotas would be more accurate in reaching a specific target for a biofuel share or for a certain emissions reduction, while tax exemptions would entail a more predictable cost for biofuel users. An important difference is who will pay the additional costs. The switch towards mandatory quota schemes lately in the EU has largely been triggered by the surging tax losses due to increasing biofuel volumes. Additional costs for biofuel production will with a mandatory quota system be passed on to fuel providers and finally to consumers. This will have the effect of slightly reducing fuel demand in general. That is, using a mandatory quota system rather than tax exemptions will yield slightly larger GHG reductions given a certain biofuel share. As of 2009 only two European countries with significant shares of biofuels, Spain and Sweden, had not introduced some kind of mandatory quota system. At the date of writing this report, the Swedish government has suggested a system with mandatory quotas for fuel providers, see Section 7.2.

Another implication of the shift towards mandatory quotas instead of tax exemptions concerns the choice between pure or high-level blended biofuels and low-level blends. A case in point is the development in Germany following the introduction of a quota system in 2007. In only four years, between 2006 and 2010, the share for B100 (of all biodiesel sold) went from 65 to 11%. With mandatory quotas the additional cost for biofuels compared to fossil fuels is taken by fuel producers which, in turn, normally charge consumers. This means that a pure biofuel would be rather expensive compared to petrol or diesel, and thus difficult to market. Relying on low-level blends, on the other hand, means that the extra cost is distributed over a much larger fuel volume. The conclusion is that mandatory quotas tend to steer towards low-level blends rather than pure biofuels, even if the additional costs of dedicated vehicles is not taken into consideration.

In theory a quota system, given adequate sanctions, provides a nearly perfect target achievement. However, a presumption is that production of biofuels can adapt quickly enough. In Germany where the quota for petrol substitutes increased rapidly after 2007, the consequence was an increasing share of imported ethanol. For a comparatively limited market like Germany this may be handled in such a way, but the consequences are more uncertain if for instance all EU members move jointly in the same direction with quota systems. Another characteristic of a quota system is that it may restrict the market if the quotas are set (too) low. Here the issue of timing is crucial. In Germany it seems as if the tax exemptions were abolished some three years earlier than the industry had expected, since the European Commission had granted an application to keep the tax exemption until the end of 2009 (Peck and McCormick, 2008). The consequence was a wave of insolvencies in the German biodiesel industry and the conclusion is that quota trajectories (and tax exemptions) need to be carefully designed, only changed gradually and communicated to affect stakeholders in due time.

Capital investment support is another type of policy intervention that can be used to promote biofuels, but at least in Germany it has been of limited importance (Wiesenthal et al., 2009). This does not, however, mean that it may not be an important tool in the future, when focus is turned to second generation biofuels. The financial risk profile differs a lot between first and second generation fuels (Londo et al., 2010). While the fixed cost (mainly fuel production plants) for first generation fuels typically constitute a share of around 7% for biodiesel and 30% for ethanol, the share for second generation fuels is often more than 60% (Wiesenthal et al., 2009). For these reasons governmental support for capital investments production plants may well constitute an important policy in making second generation fuels take off (ibid.; Sims et al., 2010). For the private investor this kind of support is also associated with less uncertainty than expected future tax exemptions or biofuel quotas.

Beside policies directly affecting biofuels markets, there are also indirect policies that may have a significant influence on biofuel markets. One such policy that indirectly interacts with biofuel policies is the EU regulation setting emission performance standards for new passenger cars at 130 g CO_2/km until 2015 and 95 g CO_2/km until 2020 (European Parliament and the Council, 2009b). This regulation will steer quite firmly towards an even higher share for diesel engines in the new car sales. Consequently renewable substitutes for diesel will be much in focus. Further a proposed 2025 target of 68-78 g CO_2/km has recently been accepted by European Parliament's Environment Committee (ELTIS, 2013). If this proposal is eventually approved by the Council and the Parliament, it will require a rather high share of very low emission vehicles – this indicates that electric cars will very likely be important to meeting targets.

It is difficult to judge the resulting impact that all EU- and national policies will have on the biofuel market. One key factor is if the proposed 5% cap for first generation biofuels will be approved. Since consumption of first generation biofuels already is nearly at this level it will almost definitely constrain the industry. The question is how the remaining 5% renewable fuels of the 10% target for 2020 should be produced or acquired. It is rather uncertain whether substantial amounts of second generation biofuels will appear on the market before 2020. An alternative path for reaching the 10% target until 2020 (if the proposed 5% cap for first generation biofuels is accepted), could be to push hard for electric cars. This would also be in line with the proposed emission standards for 2025 of 68-78 g/km. However, such standards would probably make new cars significantly more expensive and thus tend to reduce new cars sales.

Another policy to consider is the EU ETS and how it is configured. With the present low prices for carbon dioxide (< 5 Euro/tonne) there is much less profitability than it was expected that there should be in using bioenergy for electricity and heat production. If the trajectory for the cap in the EU ETS is lowered, or if the price is raised by other means, the price of biomass will increase, which will make biofuels more expensive. Moreover, due to the energy losses associated with production of second generation biofuels there may be a trade-off between achieving the 20% target for renewable energy in general and the 10% target for renewable transport fuels.

5 RENEWABLE FUELS IN THE UNITED STATES

The US has followed a markedly different path to that of the EU in the design and implementation of biofuels policy measures. There has also been a fundamentally different triggering process. US biofuels established their initial volume market as an effect of air pollution interventions, with the market then being further stimulated by the flow on effects of groundwater pollution concerns – events in a quite different field. Oil dependency and climate concerns initially figured less in policy rhetoric, but in the period since circa 2005, the former item assumed a primacy. In recent years, the US biofuels policy sphere has specified fuel consumption targets in absolute quantities. This contrasts with the EU where “percentages of use” targets have been set for the contribution of renewable energy in transport use. The policy implementation mechanisms addressed in this text are also less diverse and significantly more centralized in the US.[23] While several EU Member States have unilaterally implemented mandatory targets, these are national initiatives and not an obligation from the EU. Because of this quantitative target and the fact that the implementation is through a mandate rather than a less-binding target, compliance has a higher likelihood of being attained.

The US situation has also evolved somewhat more organically than in the EU – and over a longer period of time – with a sequence of apparently unexpected events leading to step changes in the role of renewable fuels in the US fuel portfolio.

5.1 DISPOSITION

This chapter seeks to provide the reader with insights into the main triggers for biofuels policy changes; the major processes involved; the principal actors, and the on-going drivers that affect how the future situation may develop in the US. In providing these details, the discussion has the disposition listed below:

- The next section provides a brief overview of the US transportation fleet and its fuel consumption. The general role of the “biofuels of today” is then delineated, and the foundation for so called “advanced” biofuels is described.

- In Section 1.3, a detail policy timeline is presented. Four distinct stages in policy evolution are described. This section seeks to present the distinctly “path dependent” and somewhat serendipitous nature of biofuels policy evolution in the period from the late 1970s until recent years. The section concludes with a summary of important actors in the biofuel sector as they have related to the evolving field.

- In the penultimate section, more details are provided of the key policy items identified in the preceding discussion. Individual sub-sections are provided that address items such as the Clean Air Act (CAA) and it fuel oxygenate programmes; MTBE toxicity issues that led to a niche creation for ethanol as the principal fuel oxygenate in the US; energy security developments and efforts of the past decade; Department of Defence programmes, and selected examples of State level programmes.

[23] Note however, that many differing interventions have been made at state level in the US that are generally not addressed here. Rather, focus has been maintained upon the significant federal level policies that have provided the fundamental structure to the US biofuels market.

- This Chapter then concludes with a discussion of the potential developments from this point forward in the US. Within this, it is argued that despite the marked success of mandate programmes to date, the road forward for US biofuels appears much more challenging. A series of constraints or challenges are presented that include inter alia: fleet related bottlenecks; infrastructure and resource-based constraints upon expansion; slow implementation of advanced biofuel technology systems; and the erosion of the political mandate for pursuit of biofuels.

5.2 U.S. TRANSPORTATION FUELS – A BRIEF OVERVIEW

The United States has been the world's largest economy in the modern era. The US economy utilises enormous quantities of energy for the industrial, transport, and residential sectors, and for electricity generation. Since the 1950s, oil has been the major energy carrier in the US mix, followed by natural gas and coal respectively. Up until the 1950s, the US was essentially self sufficient in oil (and petroleum products). However, in the ensuing period, a gap between production and consumption grew (Nerurkar, 2012). By 2005, when the production shortfall was greatest, this amounted to some 12 million barrels per day (bbl/d) (circa 19.5 TWh/day) – well over 50% of US consumption. The policy interventions that underpin some of the most significant biofuels "achievements" that are discussed in this chapter are directly related to US concerns regarding their oil dependency.

As has been the case in many countries in the period since the first "oil shocks" of the 1970s, the US government has become increasingly sensitised to the challenges that volatile oil prices and dwindling endogenous oil supplies place upon aspirations to maintain economic growth (c.f. Moschini, Ciu and Lapan, 2013). A consensus has grown that this necessitates that existing energy sources are secured or reinvigorated, that the national energy mix is diversified, and that alternative forms of energy are developed. The US has been actively expanding its alternative energy forms, and as a result the proportion of US derived energy sources has increased rapidly over the past decade. With this, the long-term trend of worsening oil dependence has slowed, and then reversed. This trend towards energy autonomy is anticipated to continue in coming decades. As Figure 15 shows, both net consumption and imports of petroleum have fallen in the past 7 years or so, while crude oil production has risen slowly but steadily. While a major reason for this is increased domestic crude oil production, particularly from shale and other tight rock formations in North Dakota and Texas, the role of biofuels in transportation has also contributed tangibly to the reduction of petroleum product demand.[24]

Renewable energy sources however, still totalled less than 10% of total primary energy consumption in the year 2011 (US EIA, 2011a). This is displayed in Figure 16.

According to EIA's March 2013 Short-Term Energy Outlook (U.S. Energy Information Administration (US EIA, 2013c) crude oil production in the United States is expected to exceed the amount of US crude oil imports during 2013. This has not been the case since early 1995, and the trend towards reduced US oil dependency is forecast to continue. Figure 15 overleaf shows the production, consumption and imports of petroleum and other liquids in the period 1949 until 2011.

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[24] As 1bbl oil = 5861.52 MJ, then total biofuels contribution to the US in 2012 of approximately 330 TWh represents some 560 000 bbl per day of oil equivalent.

Figure 17 provides US government forecasts for crude oil production and import until 2014.[25] The (positive) gap between monthly US crude oil production and imports is projected to be almost 2 million bbl/d by the end of 2014 (i.e. improved by a further 10% or so of demand).

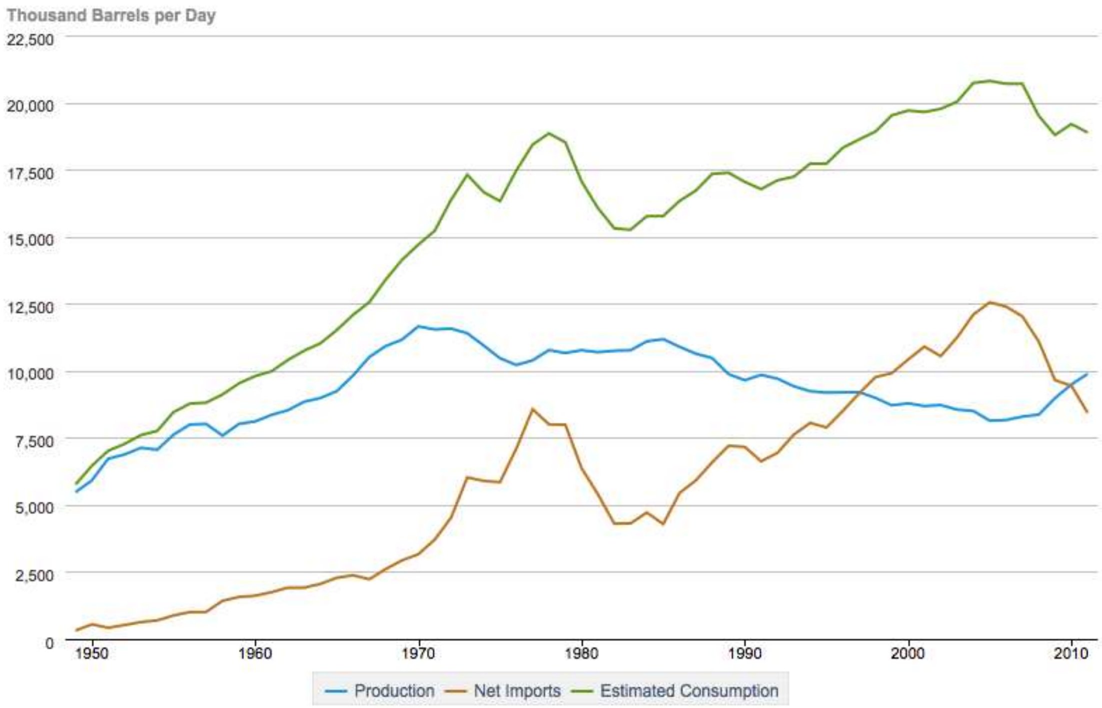

Figure 15. US Petroleum and other liquids: Consumption, production and imports 1949-2011. Source: Graph generated with data from US Energy Information Administration (2011)[26].

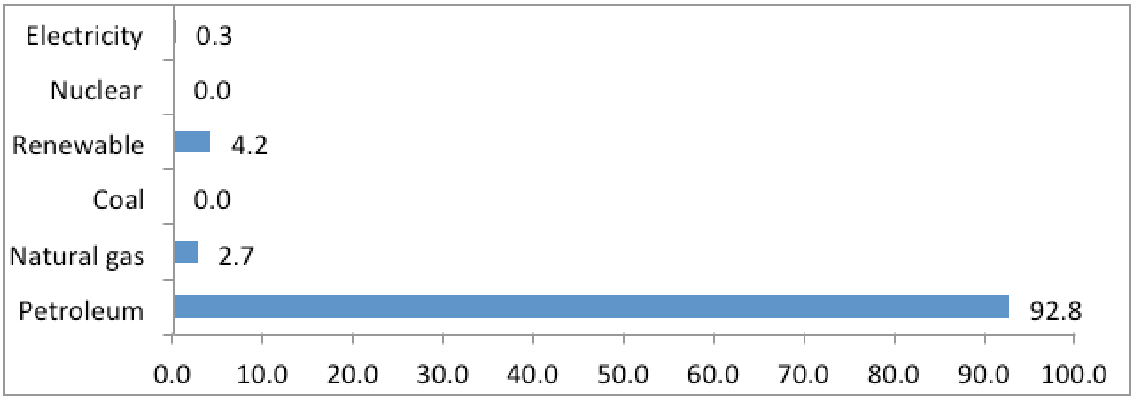

Figure 16. Percentage energy consumption by source in transportation sector in 2011. Source: US EIA (2012b).

[25] Note however that these two figures are not exactly comparable. The latter diagramme addresses only crude oil, the former includes relatively minor volumes of other fuel liquids.
[26] Figure produced by authors from online table builder with meta-data available at: http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0501a

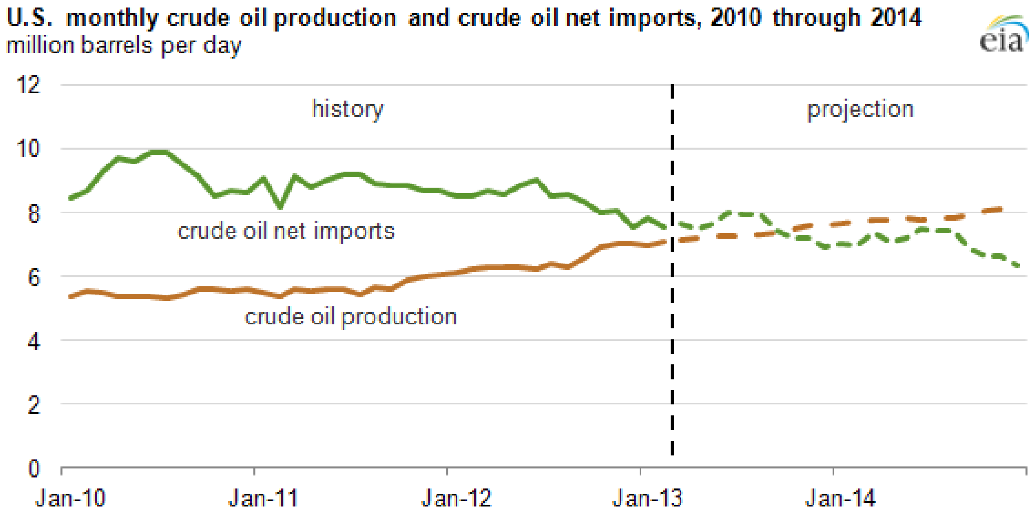

Figure 17. US monthly crude oil production and crude oil imports 2010-2014 (million bbls/day)[27].

5.2.1 Fossil fuels in transportation

The US is inarguably the largest consumer of transportation energy carriers among the OECD nationns (IEO 2011, 2011). In 2011, the transportation sector utilised circa 7940 TWh)[28] of energy. This also contributed almost 28% of the country's total greenhouse gas (GHG) emissions, making the transportation sector the second largest source of GHG emissions in the United States (Davis, Diegel, & Boundy, 2012; US EPA, 2013a, 2013c) after electricity production (US EIA 2013a; 2013b). As shown in Figure 16, nearly all energy consumed in the US transportation sector is petroleum-based and only circa 4% of total transportation energy is derived from renewable sources (US EIA, 2013b). Moreover, transportation alone accounts for about 70% of US oil consumption. As experience has shown in other countries sector – not least Sweden – reducing reliance on oil in the transportation sector is significantly more difficult than in other areas of the economy (e.g. where fuel switching to solid for gaseous fuels is easier) – a factor exacerbated by the fact that the price elasticity for transportation fuels is relatively low (Dahl & Sterner, 1991; Sterner 2006). This poses on-going challenges for both US energy security and its efforts to reduce GHG emissions.

It is also worthy of note that the despite the relatively low prices for transportation fuel in the US as compared to most developed economies (GIZ, 2012) the US public and the US economy is particularly sensitive to fuel cost increases. As examples, the GIZ global comparison shows that pump costs for US gasoline in 2010/11 were approximately 40% of that in Sweden or Germany, and circa half of that in Brazil. US diesel in 2010/11 cost circa half of that in Sweden/Germany and circa 75% of Brazil. However comparative consumption per capita is much higher – according to IndexMundi (2013)**,**[29] US per capital consumption of transportation fuels for use in internal combustion

[27] Figure produced by authors from online table builder at http://www.eia.gov/forecasts/steo/ - on 23 May, 2012.
[28] Listed in source as *27.1 quadrillion Btu* or 0.68 million ton of oil equivalent: the following conversion has been applied: 1 quadrillion btu = 293.07 terawatt hours.
[29] A comparative indicator for *Road sector gasoline fuel consumption per capita* is provided for 2009 compiled from statistics at International Road Federation, World Road Statistics and electronic files, except where noted, and International Energy Agency statistics

engine such as motor vehicles (excluding aircraft) was circa 3 times Swedish consumption, 5 times German consumption and more than 15 times Brazilian per capita consumption during 2009.

The U.S. EIA (2013a) indicates that the real cost of transportation fuels has increased markedly over the past decade for the US consumer – linked to the high global oil prices over this period. By 2007 (and then again in 2012 after a dip associated with the financial crisis years) these had reached the highest levels in over 30 years. The EIA March 2013 Short-Term Energy Outlook reports that the costs of motor gasoline in the US in (expressed in “real 1982-84 dollars”) over that period – essentially doubled from an average of circa 6.9 USD/GJ (CAR, 2011) (maintained from 1985 to 2002), to a cost of some 13.7 USD/GJ. US drivers have been sensitive at these prices (Krauss, 2008) and the impact is held to be significant on the economy, particularly that of small businesses (US Congress, 2008) A figure showing these relationships is provided in Appendix (US analysis) as Figure A5-1. While higher oil prices have aided the establishment of the biofuels industry in the US, they have concomitantly been linked as a reason for higher prices by anti-biofuels lobbies – and thus have become more sensitive in the US policy arena (c.f. Fuel-testers 2009a, 2009b).

5.2.2 U.S. vehicle fleet characteristics

The US has the largest passenger vehicle market in the world (Pearson Education, 2013). According to the US Bureau of Transportation Statistics (2013) more than 254 million passenger vehicles were registered as of 2009. Of these, 200 million were classified as “Light duty vehicle, short wheel base”, while circa 40 million were listed as “Light duty vehicle, long wheel base”. There were approximately 8 million registered motorcycles in the US at that time (ibid).

The US-based Center for Automotive Research indicates that while the average cars per household in the US have stagnated at approximately 2.07 vehicles per household, the US population is growing at circa 1% per year and the fleet is still increasing. They estimate that there will be 284 million operating light vehicles in the United States by 2025 – an approximate increase of 2 million vehicles per year (CAR, 2011).[30]

According to the United States Department of Transportation (USDOT), the average motor vehicle, including light trucks, in the US had a fuel economy rating of circa 8.5 l/100km (Corporate Average Fuel Economy (CAFE) statistics) [or 17.1 MPG or 13.8 l/100km (USDOT method)] (US DOT, 2013)[31] Consumption figures for the EU published by the European Environment Agency (average specific fuel consumption of cars) are circa 8.5 l/100km (EEA, 2012b).[32]

Important in the context of this report is that the US car fleet has a markedly different makeup to that in Europe – particularly in regards to a low penetration of diesel powered passenger vehicles.

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[30] CAR clearly states however, that the trends they base this upon can be altered by non-market and non-demographic realities, such as new regulations.

[31] USDOT MPG statistics differ dramatically from Corporate Average Fuel Economy (CAFE) statistics, with the latter being a sales-weighted composite and therefore purportedly presenting a more realistic picture of fuel economy in the USA. For example, in 2008, the CAFE composite was 28.2 mpg, substantially larger than the 17.2 mpg compiled by the USDOT.

[32] Within this study, it has been difficult to establish exactly how the US figures compare with the EU figures. Intuitively, one would expect that US consumption is higher due to larger vehicles, larger engines, and a lower penetration of diesels.

PRNewswire (2012) reports that if one excludes the large pickup truck segment, only circa 1% of US cars were diesels at that time, with the total diesel market share at around 4.5% by 2012. While the diesel market is growing, penetration of diesels in these segments are only expected to reach around 6.5% by 2015 (PRNewswire, 2011). This compares to a diesel penetration of around 34% in Europe – a figure that is growing steadily (EEA, 2012a). Diesel vehicles represented 55% of the newly registered EU vehicle fleet in 2012 (McGlone, 2013). In addition to a historical disinterest in diesels in the US, two factors are held to be still holding back growth in the diesel market; these are the cost of fuel, and the fact that diesel vehicles are around 10% more expensive that gasoline versions. While diesel fuel had been cheaper than gasoline in the past, it is now more costly. This is held to be due to a combination of higher federal and state taxes, and a smaller market for refiners (NY Daily Times, 2007).

5.2.3 Renewable fuels in transportation – "Conventional biofuels"

The major US biofuels are ethanol and biodiesel. Corn (maize) is the main feedstock for ethanol, and soya bean for biodiesel. In 2005 the US overtook Brazil as the world's largest ethanol producer (RFA, 2013). While the role of renewable fuels in the total transportation mix remains modest (at circa 4%), the share of renewable vehicle fuels for personal transportation has expanded rapidly over the past decade or so. Indeed, transportation biofuels – ethanol in particular – represent a high proportion of the total renewable energy utilised in the country. In 2011, biofuels represented circa one fifth of the renewables utilised in the country as shown in Figure 18 below.

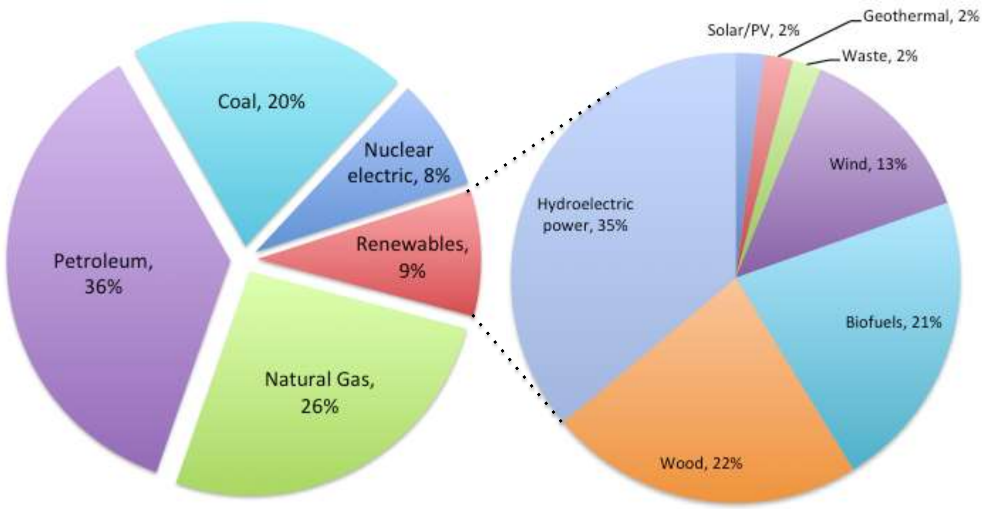

Figure 18. Renewable Energy as Share of Total Primary Energy Consumption, 2011. Source: Annual Energy Review 2011 After US EIA (2012a, p. 278).

The US government has provided incentives for biofuels for more than three decades. The Energy Tax Act of 1978 was the first time incentives for biofuels was applied – an ethanol subsidy was introduced through an excise tax exemption for 10% alcohol blended gasoline. Since that time, a series of revisions, extensions and changes of the incentives has taken place. While support existed and production did grow steadily, the production and use of biofuels remained negligible in the US transportation fuel sector until the turn of this century when a series of policy shifts led to radical changes. FiguresFigure 19 and Figure 20 below show biofuels consumption (as ethanol and biodiesel respectively) in the US over the past three decades (biodiesel is shown from only 1995 due to low consumption until circa 2000).

Since 2009, when revisions to the National Renewable Fuel Standard program were made to accommodate changes to the Renewable Fuel Standard program as required by EISA, biofuels in the US have been defined as listed in Table 4.

Table 4. Lifecycle GHG reduction thresholds specified in EISA. Source: US EPA (2009) and the American Association for the Advancement of Science (AAAS, 2011).

Fuel Class	**Lifecycle GHG Reduction Thresholds** (from 2005 baseline)	**Examples**
Conventional biofuel	20%	Corn-based Ethanol
Advanced Biofuel	50%	Sugarcane Ethanol
Biomass-Based Diesel	50%	Soy-based Biodiesel
Cellulosic Biofuel	60%	(no commercial production but ethanol from corn stover is a prime target)

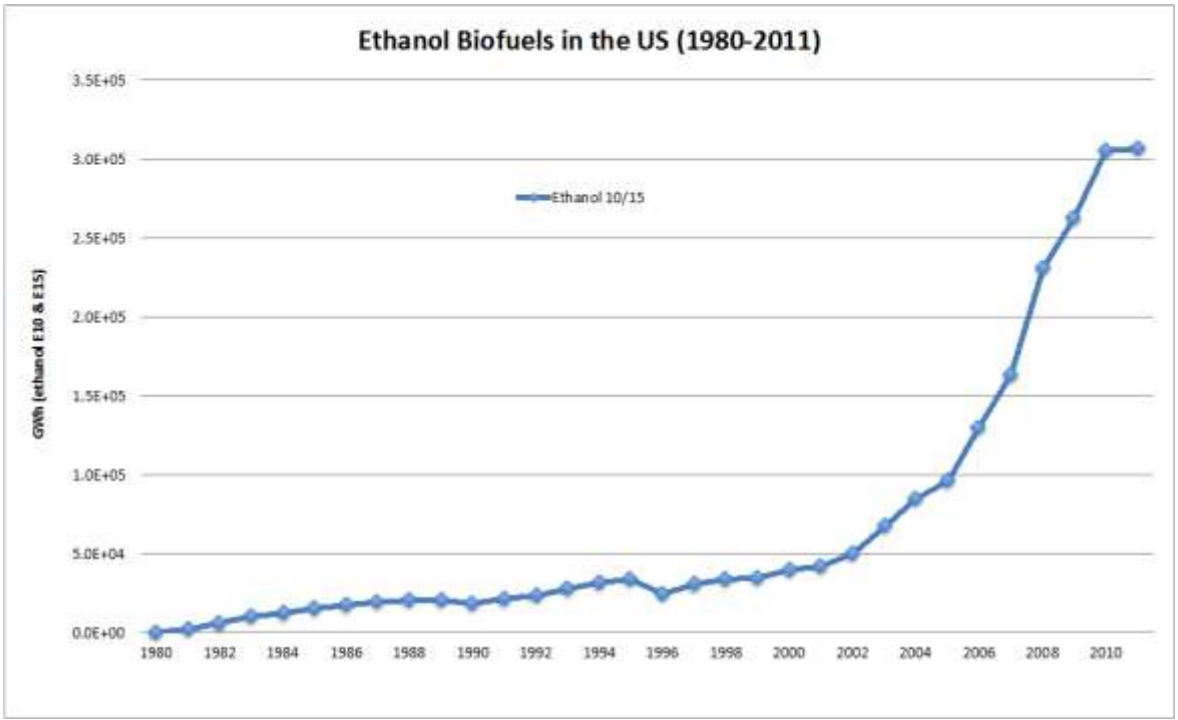

Figure 19. Ethanol consumption in the US (1980-2011). Source: (after US EIA, 2012d)[33].

[33] Table 10.2b - http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb1002b

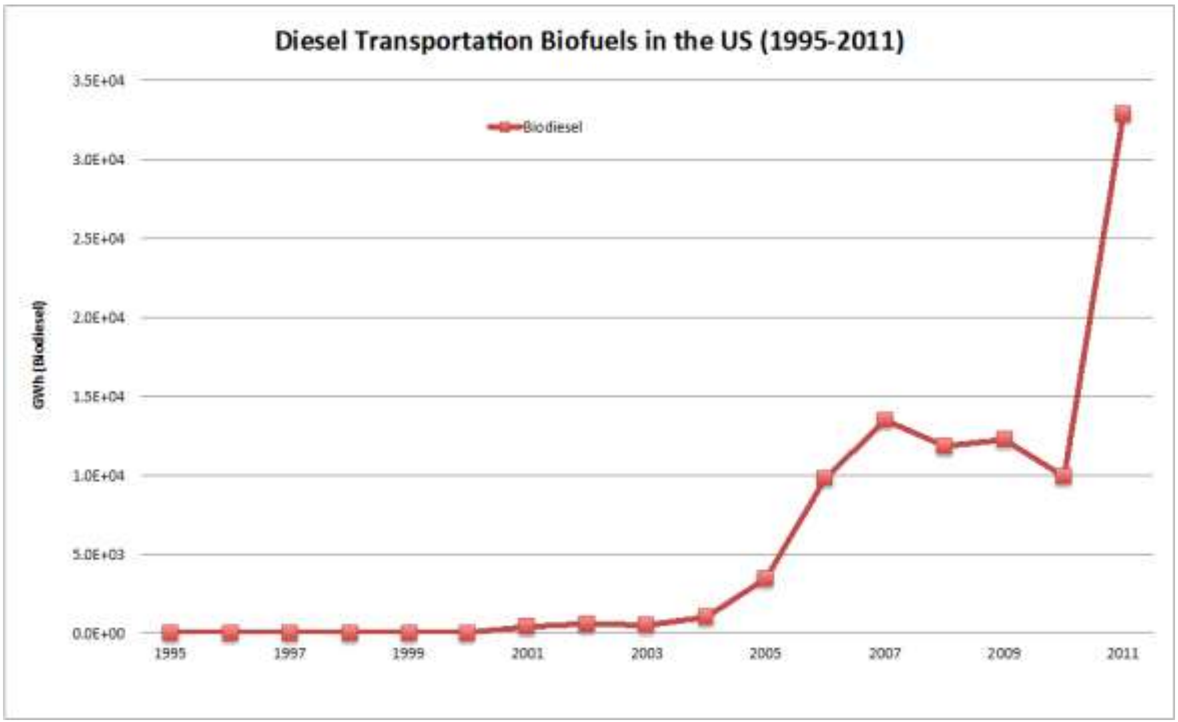

Figure 20. Biodiesel consumption in the US (1995-2011). Source: (after US EIA, 2012d)[33].

As almost all the ethanol produced in the US is corn based, the EPA ruling that it delivers "at least" a 20% GHG saving is an important factor in its acceptance. However, this situation is queried by some analysts. Fast et al. (2012) for example state that geographic variability in the GHG emissions arising from corn production casts considerable doubt on the approach used in the RFS 2 to measure compliance with the 20% target.[34]

Shifting focus to the balance between production and consumption, there has been a close match between installed production capacity and consumption for ethanol (RFA, 2013) – similarly, actual production has matched consumption (see Figure 21 below) over the past 15 years. A tabulation of plant construction and commissioning during the period of rapid expansion is provided as Table A5-1 in Appendix (US Analysis). With the exception of the years 2010-11, where low fuel prices and low transportation fuel demands led to a degree of oversupply, essentially all ethanol produced in the US has been consumed in the US.

In contrast to this, the biodiesel production has not matched installed capacity – and utilisation has often been well below half of installed capacity. The circa 110 biodiesel plants in the US are stated to have a production capacity of some 2.1 billion gallons (~8 x 10^6 m^3/yr or 7.6 x 10^4 GWh); while in 2011 and 2012 production of biodiesel totalled only circa 0.97 billion gallons (circa 3.7 x $10^6 m^3$ or 3.5 x 10^4 GWh) (US EIA, 2013e). While feedstocks vary by season, soybean oil appears to be the major feedstock in the US followed by corn (maize) oil yellow grease and canola (rapeseed) oil.

[34] They go further to state that "If regulators wish to require compliance of fuels with specific GHG emission reduction thresholds, then data from growing biomass should be disaggregated to a level that captures the level of variability in grain corn production and the application of life cycle assessment to biofuels should be modified to capture this variability."

While the ethanol industry of the US grew (relatively)[35] slowly from the 1980s until the early 2000s, and rapidly after that, the growth of the biodiesel sector started much later and has been irregular. The US biodiesel industry has experienced a lift in growth since 2006 but remains small in comparison to the corn based ethanol industry (roughly an order of magnitude less). While much smaller than the US ethanol sector, it must be stressed however that the US biodiesel sector is NOT small. 2010 rankings provided HartEnergy of the US (based on production capacity) list the installed capacity for production in the US as the largest in the world – almost 20% larger than Germany's at that time (HartEnergy, 2010).[36] Even taking into account the low production utilisation in the US at present, it can be expected that the US is still in at least the top 3 to 5 producers.

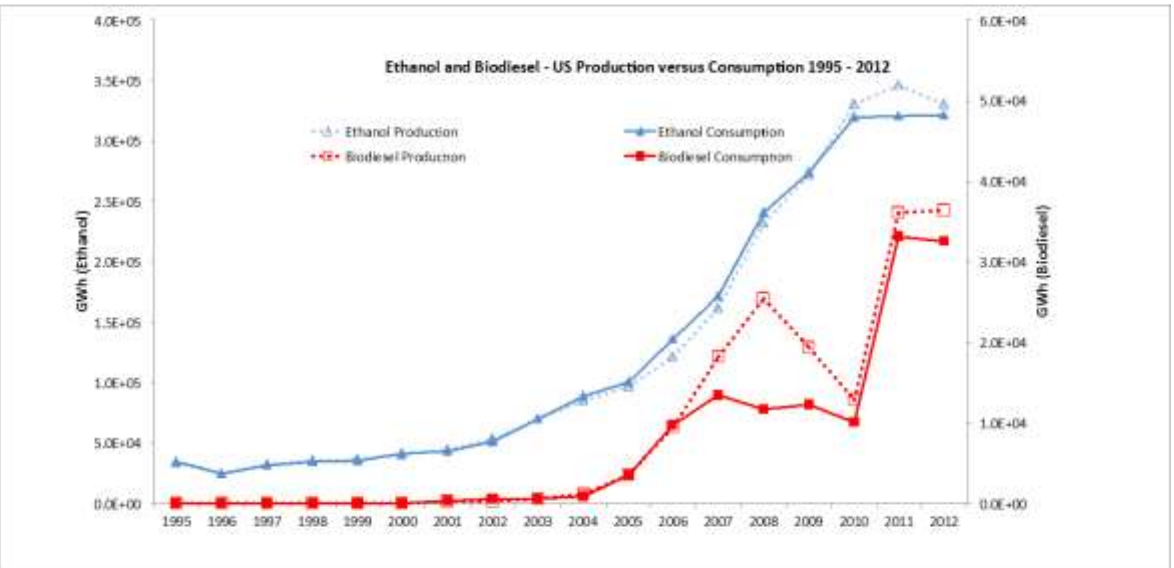

Figure 21. US Biofuel production and consumption. Source: Data from Monthly Energy Review March 2013.

An overview of development of ethanol industry in the US is shown in Table A5-1 in Appendix (US Analysis). While this largely repeats earlier figures in tabular form, an important part of this table is the inclusion of the commissioning rates of new plants.

5.2.4 Biofuels in transportation – "Advanced biofuels"

As shown in Table 5, US biofuels follow a "nomenclature" that does not align well with that used in Europe – however, such definitions are important when considering the "future" of US biofuels as mandated growth requirements are different for differing categories of "Renewable Biofuels" (c.f. Moshini *et al*, 2012 for discussions of these categories).

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[35] This term should be used carefully. Growth was 'slow' in comparison to the rapid growth to come, however examination of older analyses (c.f. DiPardo, 2000, p.2) show a factor 7 increase between circa 1980 and 1998. In other contexts, this could be seen as rapid indeed!

[36] The indicated production capacity for 2010 in that tabulation was circa 6 million m^3 biodiesel (circa 1560 million gallons); this is some 25% less than the production capacity indicated by the sources used in this study (ie. US EIA, Monthly Biodiesel report April, 2013).

Conventional biofuel (renewable biofuel)

Under the conditions outlined in the 2009 Revisions to the RFS, biofuels must achieve at least a 20% reduction in greenhouse gas (GHG) emissions, relative to the conventional fuel it replaces, based on a lifecycle analysis.[37] US EPA LCA work determined that most biofuels (including corn-based ethanol – a conventional biofuel) meet this carbon reduction requirement.[38]

Advanced Biofuel

Fuels in this category are defined as biofuels that achieve at least a 50% GHG emission reduction. This category, from which corn-based ethanol is excluded, encompasses a variety of biofuels, including sugarcane ethanol and biodiesel.[39]

Biomass-Based Diesel

See above. Biodiesel has been categorized as an "advanced biofuel" as the US EPA deems that biodiesel produced in the US delivers at least a 50% GHG reduction.

Cellulosic Biofuel

Cellulosic biofuels have been determined to deliver a GHG emission reduction of 60%. As an "advanced biofuel", cellulosic has been identified by policymakers as the priority production pathway for the US.[40]

Figure 22 below shows the mandated volumes allocated for the period 2009 to 2022. The largest proportion is allocated to cellulosic biofuel (i.e. in practice ethanol) by the end of the period.

[37] See Fast et al (2012) for a critique of the US EPA approach.

[38] Corn-based ethanol is implicitly capped to a maximum of 15 billion gallons from 2015 onward within this category.

[39] "Advanced biofuels" are supposed to grow to 21 billion gallons by 2012.

[40] This category is envisioned to grow to 16 billion gallons by 2022 – i.e. 16 of the 21 billion mandated gallons.

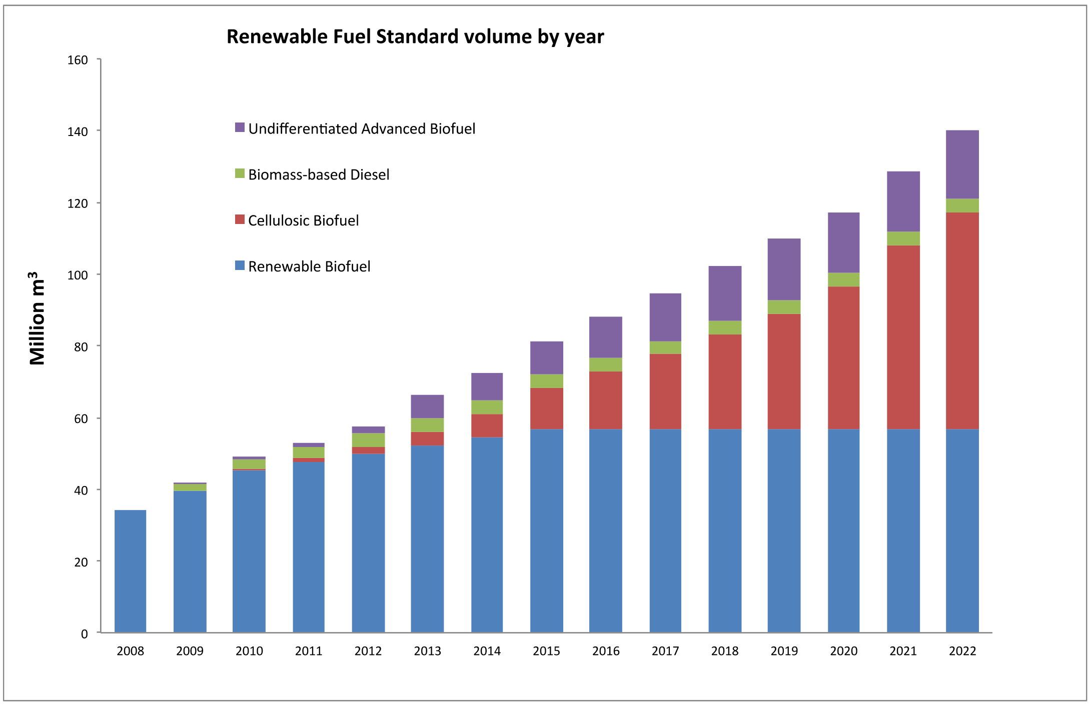

Figure 22. RFS2 Mandates – Renewable fuel standard volumes by year. Source: Graph generated with data from US Energy Information Administration (2011).

The US government is actively promoting the development of ethanol from cellulosic feedstock as an alternative to conventional petroleum transportation fuels. Between the period of 2000 and 2010 a number of companies announced plans to build commercial cellulosic ethanol plants, but eventually most of those plans failed, and a number of the smaller companies disappeared from the market. In 2008, plants producing 12 million litres of ethanol per year were operational, and an additional 80 million litres per year of capacity – in 26 new plants – was under construction at that time. During 2011, the USDA also released a list of advanced biofuel producers who will receive payments or loan guarantees to expand the production of advanced biofuels (Bevell, 2011). By the end of 2012 there was a number of demonstration plants running throughout the country, and handful of commercial-scale plants were reported to being close to operation.

While difficult to assess due to limited information in the public arena efforts to update the progress of US cellulosic biofuel plants are also documented in this study (See Tables A5-2 and A5-3 in Appendix (US Analysis). A sample of 17 commercial scale projects listed in 2008-2010 sources (i.e. Biofuels Journal (2010), Gardner (2009) and Biofuels (2010)) was cross-checked with more recent information (e.g. Company websites and Barnett (2012), Fehrenbecher (2008), Griekspoor (2012), Lane (2012), Schiffer (2012) and Schill (2012)) to provide an update of the status of the US cellulosic sector. This cross-check sought to capture <u>all</u> commercial scale plants. This research indicates that at least nine projects have withdrawn from the sector (e.g become insolvent, been sold and restructured, or have shifted their business development focus to other areas of activity). Between six and eight projects seem to still be moving forward – albeit all more slowly than initially projected. The indicative capacity for these plants is some 550-590 thousand m^3 ethanol (corresponding to between 3000–3300 GWh fuel energy).

Despite widespread doubts regarding the sector's ability to deliver, Herndon (2012) reports that six lignocellulosic plants are scheduled to open during the 2013/14 period. While this source indicates that it seems unlikely that the plants coming online will produce sufficient fuel to meet 2014 mandate targets, it is reported that industry experts believe that the industry will "catch up in the next three to five years".[41]

5.3 TIMELINES AND IMPORTANT ACTORS

As mentioned in the introduction to this chapter, the rise in use of biofuels in the US transportation sector cannot be attributed directly to one policy intervention. Rather, the development of the biofuels sector – and particularly the dominating ethanol sector – has had a distinct and complex path dependency where different types of actions have triggered the establishment and then expansion of the sector.

We commence this section with and overview of developments in the US biofuels sector over the past decades.[42] This is predominantly focused upon ethanol – not least as biodiesel has been a "latecomer" and is much more clearly bound to distinct interventions. While the biodiesel sector will have lower potential penetration rates due to the minor share of diesel vehicles in the US car pool (circa 5%), it must be noted that the sector is still of a very significant size. With reference to the timeline presented in this text, it is also important to note that many of the interventions important to the "building" of a niche for the US renewable fuels sector were directed at other issues – primarily air pollution from transport and protection of important groundwater resources.

A number of the key events are then represented in figures that seek to demonstrate links between the quantitative developments in renewable fuel production/utilisation and policy interventions, see Figure 23. Important policy interventions and events that have driven such interventions are outlined in the following section. A number of them are then taken up in more detail in Section 5.4.

5.3.1 Important actors in the U.S. biofuels arena

A brief overview of important actor groups involved in the US biofuel industry in included in the table below. Where relevant, cross references are provided to key activities presented in the next section, 5.3.2, or later in the chapter.

[41] In this case, the informant being Adam Monroe, North America president for the Danish company Novozymes A/S that supplies enzymes for the lignocellulosic processes.

[42] This material has been built from a summary provided in two commercial sources (c.f. Fuel-testers, 2009a) and Reid (2010). Where these have been supplemented with information from other sources this is noted.

Table 5. List of key actors and their position in biofuel general biofuels development.

Key Actor	Position
Federal Government	The US government has stimulated and underpinned biofuel production, distribution and use via a range of policy measures and incentives applied in different periods since the late 1970s. The Federal commitments applied in order to improve energy dependence, increase energy security and abate GHG emissions have aided the development and diffusion of biofuels in the US. The "timeline" presented in the next Section (5.3.2) of this text focuses upon Federal level interventions.
State Governments	Several states bolster Federal biofuel policies (incentives, programmes and regulations) with state policies to promote biofuels and improve air quality. While a number of interventions are mentioned in this report (e.g. California moves from fossil oxygenates to ethanol in Section 5.3.2 and the moves of several states to Low Carbon Fuel Standards (LCFS) in Section 5.4.8), the focus has generally been maintained at the Federal level.
Department of Energy (DOE)	The US Department of Energy encourage development of transformational technologies by providing funds. The DOE funds three Bioenergy Research Centres: the DOE BioEnergy Science Centre (BESC), the DOE Great Lakes Bioenergy Research Centre, and the DOE Joint BioEnergy Institute (JBEI). The DOE has been accountable for the initiation and/or management of a number of programmes to encourage energy efficiency and advance towards energy security. Examples addressed in this text (predominantly throughout Section 5.3.2) include progammes ensuing from the 1998ECRA, the 2005EPA, the 2007EISA and the 2009ARRA.
United States Department of Agriculture (USDA)	The USDA has been tasked the support of biofuels as an opportunity to create jobs through increased agricultural production and value adding of fuel crops. Amendments in the Farm Bill and Recovery Act, incentives offered under RFS mandate, and capital grant programmes created under the 2005EPA are examples of where the USDA has been accountable for biofuels activities. These items are discussed throughout Sections 5.3.2 and 5.4.5.
US Department of Defence (DOD)	The US DOD, the single largest institutional consumer of fuels in the US has invested significantly in biofuels. Due to differing fleet requirements, this market will be more aligned with biodiesel derived fuels (e.g. for jet fuels and military ground transports) and heavy fuel oil markets (seagoing vessels). The US Air force has ambitious targets to achieve up to 50-50 blends for air fleet requirements. The US Navy has also signed a MOU with DoE and USDA to produce biofuels. DOD activities are discussed in more detail in Section 5.4.7.
US Environment Protection Agency (US EPA)	The US EPA has been at the centre of biofuel policy initiatives in the US – first in its role as the regulating agency for air pollution effects of road transportation and then groundwater pollution, but then later as a central market regulator for biofuel production mandates (see Sections 5.4.2 – addressing air pollution; 5.4.3– addressing MTBE toxicity; 5.4.5– addressing regulating role in the RFS and 5.4.6. – addressing its GHG assessment and specification role. In recent years, the EPA has had a central position accountable for developing and effecting regulations to ensure biofuel mandates in the US are achieved.
Oil Companies	US oil companies are represented by American Fuel Petroleum Manufacturers (AFPM). AFPM states that is not against renewable fuels, however, it opposes the "mandated use of alternative fuels" and provides only "qualified" support for integration of alternative fuels. AFPM holds a position that it "is not in favour of premature introduction of new transportation fuel before thorough testing" – this appears to be translatable to a position that 'AFPM opposes the higher blending of ethanol in standard gasoline (e.g. E15)'. The role of lobby interests can be expected to be important in forthcoming years as the US seeks to deal with "blend wall" challenges (see Section 5.3.2).
Renewable fuel producers, blenders and retailers	Incentives such as tax credits, grants and payments targeted towards biomass producers, biofuel producers and blenders presented throughout this text have underpinnded the expansion of the Sector. These actors are crucial to efforts to achieve the targets set under various Federal and State policies. RFS II mandates oil refiners, blenders and retailers to use biofuels. Specific actors have not been analysed in this chapter.
Academic Support including Research and Development	The extensive literature review conducted for this analysis draws significantly upon (and provides an overview of) the key actors in Biofuels research and analysis – albeit, private research into technology systems is not included in this study. Important academic or scientific bodies supporting the US sector include institutions in the mid-western US such as Iowa, Minnesota and Rice Universities (conducting research in to the policy and development of renewable fuels), the University of California, Berkeley with its Energy Biosciences Institute to develop biofuels technologies and improve crops; and the US EPA who conduct studies and for GHG emissions and Indirect Land Use Changes (ILUC). In the private sector the Renewable Fuel Association (RFA) is conducting studies that help in popularisation of biofuels, while the American Fuel & Petrochemical Manufacturers (AFPM) funds research activities both for and against biofuels expansion.

5.3.2 Policy timeline and key triggers for change

Stage 0 – Early experience

1920s to 1940s – Ethanol was produced and used in a number of US regional markets and represented a significant share of automobile fuel in 1920s and 1930s (DiPardo, 2000). As one example, an ethanol plant in Atchison, Kansas produced circa 6.8 x 10^4 m^3/yr (18 million gallons/yr, 375 GWh) per year and supplied over 2000 Midwest service stations in the late 1930s. One of the mainstream US suppliers, Standard Oil, utilised ethanol as a fuel additive throughout the 1920s to increase octane levels. In the early 1940s, a large ethanol plant was constructed by the U.S. Army in Omaha, Nebraska and used to supply ethanol to the army throughout the Second World War (Jessup, 2011).

1940s to late 1970s – During this period, virtually no commercial fuel ethanol was sold to the general public in the US as a direct consequence of low gasoline fuel prices.

Stage I – path dependent development of production resources, skills and legitimacy

1975 – The US begins to phase out lead in gasoline and fuel supplements are required to maintain fuel functionality (e.g. octane adjusters/anti-knocking agents). Methyl tertiary butyl ether (MTBE), an oxygenate derived from fossil natural gas and petroleum, eventually became the dominant replacement for lead tetraethyl lead (TEL) previously used to improve octane ratings.

1977/78 – Amendments to the Clean Air Act: The CAA (first enacted in 1963) was revised in 1977. Within changes pursuant to CAA, the US EPA approved 10% blending for ethanol in fuels as an oxygenate (US EPA, 2012a). The Energy Tax Act of 1978 was the first time incentives for biofuels were applied – an ethanol subsidy was introduced through an excise tax exemption for 10-percent alcohol blended gasoline.

1978 – The Energy Tax Act of 1978 provided the significant excise tax exemption of 40c/gal (circa 0.1 USD/l) to support ethanol production in the US – this intervention being significantly directed towards the production of ethanol as an input for vehicular fuel oxygenates, particularly Ethyl Tertiary Butyl Ether (ETBE) made from ethanol and petroleum.

1980s – Dominant oxygenates added to gasoline are MTBE and ETBE. The US ethanol sector grew at a rate of approximately 265 000 m^3/year (1.65 TWh, 70 million gallons/year) throughout the decade (DiPardo, 2000).

1984 – the Tax Reform Act increases support for US produced ethanol to 60c/gal (circa 0.15 USD/l). While commercial fuel ethanol production is firmly established in the US by this time, it remains minor in comparison to the volumes of fuels utilised in the US and remains only a small proportion of fuel oxygenates.

1988 – Denver, Colorado, mandated ethanol oxygenates fuels for winter use to control carbon monoxide emissions. This set off a series of lawmaking efforts where other US cities followed suit.

1988 – the Alternative Motor Fuels Act (1988) contains provisions for mandating oxygenated fuel. Requirements are set for two types of cleaner-burning gasoline formulations. These are known as Federal Reformulated Gasoline (RFG) and Wintertime Oxygenated Fuel. To incentivize alternative fuel vehicle development, the Alternative Motor Fuels Act of 1988 established vehicle manufacturer incentives in the form of corporate average fuel economy (CAFE) credits (USDOE AFDC, 2013b)

1990 – Amendments to the Clean Air Act include important items that provide stimulus for the ethanol sector in the US; these include:

- 2% oxygen requirement for gasoline – both fossil oxygenates (e.g. MTBE) and bio-derived (e.g. ethanol) are approved for addition;
- mandated winter time supply and utilisation of use of oxygenated fuels in 39 major carbon monoxide non-attainment areas (ie. areas failing to achieve EPA standards for ambient CO)

1992 – The Energy Policy Act of 1992 established regulations requiring certain federal, state, and alternative fuel provider fleets to build an inventory of alternative fuel vehicles[43] (USDOE AFDC, 2013b). The Act had aims to reduce U.S. dependence on imported petroleum and improve air quality by addressing all aspects of energy supply and demand, including alternative fuels, renewable energy, and energy efficiency. The use of alternative fuels were stimulated through both regulatory and voluntary activities and approaches led by the U.S. Department of Energy (DOE)[44], (USDOE AFDC, 2013b).

1995 – the US EPA dictated year-round use of oxygenates in 9 severe ozone "non-attainment" areas in 1995 (thus RFG must be used year round in the largest metropolitan areas with smog problems).

1998 – the 1992 policy act is revised in a manner that stimulates biodiesel utilisation. In the original act, biodiesel was excluded as an alternative fuel, but the 1998 amendment allowed fleet managers to comply with part of their alternative fuel usage requirement by using biodiesel, as long as it was used by heavy-duty vehicles in at least a 20% (B20) concentration. Cash support from the USDA Commodity Credit Corporation's (CCC) Bioenergy Program provided a further boost (Carriquiry, 2007).[45]

Stage II – Market opportunities and rapid expansion

Late 1990s – Major U.S. auto manufacturers began selling so called Flexible Fuel Vehicles (FFVs) that ran on up to 85% ethanol – over 5 million FFVs/AFV's were in circulation in the US by 2012.

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[43] These conditions were amended several times in the Energy Conservation and Reauthorization Act of 1998 and in 2005 via the Energy Policy Act in 2005, which emphasized alternative fuel use and infrastructure development (USDOE AFDC, 2013).

[44] EPA92 also defines "alternative fuels" as: methanol, ethanol, and other alcohols; blends of 85% or more of alcohol with gasoline (E85); natural gas and liquid fuels domestically produced from natural gas; propane; hydrogen; electricity; biodiesel (B100); coal-derived liquid fuels; fuels, other than alcohol, derived from biological materials; and P-Series fuels, which were added to the definition in 1999.

[45] The CCC Bioenergy Program provided payments to producers to encourage biodiesel production. Plants with capacity under 65 million gallons per year (2.46 x $10^5 m^3$; 2360GWh) were reimbursed 1 bushel of feedstock for every 2.5 bushels used for increased production (those over 65 million gallons were reimbursed 1 bushel for every 3.5 bushels used for increased production). Although initially only biodiesel made from oil crops was eligible for payments, the 2002 farm bill extended the list of allowed feedstocks to include animal by-products, fats, and recycled oils of an agricultural origin. The programme ended in June of 2006.

Apart from a retraction of the market in the mid-1990s, the US ethanol sector grew at a rate similar to that of the 1980s (circa 1.5TWh/yr until the late 1990s). By 1998, the market had reached some 29.1TWh/year (5.3 x $10^6 m^3$/yr; 1.4 billion gallons/year (DiPardo, 2000).

1999 - the first States began to place restrictions on the utilisation of MTBE as a result of ground-water contamination concerns. This development was pursuant to a series of environmental scandals in the 1980s related to toxic sites – as a result of these, much stricter environmental regulations were developed for risks to soil groundwater. This fundamentally affected the licensing, monitoring and control of potential sources of pollution such as underground storage tanks for transportation fuels. MTBE has a high solubility in water, and was soon found to be both entering and spoiling groundwater resources. At this stage a significant market pull was instigated in the US – with robust support factors already available in the form of subsidies.

2000 (Biodiesel) – A rapid expansion of biodiesel production took place during the period 2000-2006, triggered by a 1998 amendment to the 1992 Energy Policy Act (Carriquiry, 2007). Production increased from some 2 million gallons in 2000 (7570 m^3; 72.6 GWh) to an estimated 250 million gallons in 2006 (9.46 x 10^5 m^3; 9070 GWh)

2003 – California began switching from MTBE to ethanol in the production of reformulated gasoline. California was the first state to completely ban MTBE, as of January 1, 2004. The growth rate of the ethanol industry rapidly escalated at this time.

2003 to 2006 – Almost all US states followed California's action on MTBE and banning the use of the substance in gasoline – albeit, a few states still have lawsuits pending with the EPA for exemption from MTBE ban. The net result of the MTBE ban was that ethanol took over as the major oxygenate nationwide.

2004 (**Biodiesel**) – The biodiesel industry in the US reached a production/-consumption scale of circa 1TWh (circa 100 000m^3) and at this staged gained increasing attention. Further support to the burgeoning sector was created through the American Jobs Creation Act (Jobs Act) of 2004 and the Energy Policy Act of 2005 (Carriquiry, 2007).[46]

Stage III – Energy dependence, rural economic stimuli and climate

2005 – the Energy Policy Act was enacted by the Bush Administration; the Act required the use of circa 15 x 10^6 m^3/yr m^3 (4 billion gallons, 83 TWh) of renewable fuel in 2006, increasing to 28.4 x 10^6 m^3(7.5 billion gallons, 156 TWh) in 2012.[47] On the demand side, the 2005 act mandated a renewable fuels phase-in (the Renewable Fuels Standard, RFS), requiring fuel producers to include a minimum amount of biofuels, and extended the existing excise credit to blenders until the end of 2008. Under the RFS, fuel producers were required to include the mandated volumes listed above. The EPA2005 applies to both biodiesel and ethanol (Carriquiry, 2007)

[46] The Jobs Act provided demand side incentives for the biofuels industry. Blenders could claim $1.00 per gallon of biodiesel made from virgin vegetable oils or animal fats and $0.50 per gallon made from recycled oils and fats mixed with diesel. To receive the tax credit, the biodiesel was required to be registered as fuel with the Environmental Protection Agency and meet ASTM D6751 standard (Carriquiry, 2007).
[47] Here, the figures have been assumed as ethanol equivalents as this is absolutely dominant fuel volume at this stage.

The act called for the development of grant programmes, demonstration and testing initiatives, and tax incentives that promote alternative fuels and advanced vehicles production and use. EPAct 2005 also amends existing regulations, including fuel economy testing procedures and EPAct 1992 requirements for federal, state, and alternative fuel provider fleets (USDOE AFDC, 2013b).

The EPA is responsible for regulations to ensure that gasoline sold in the United States contains a minimum volume of renewable fuel. The current National Renewable Fuel Standard program (RFS1) was established under the Energy Policy Act of 2005, which amended the Clean Air Act by establishing the first national renewable fuel standard. The U.S. Congress gave the U.S. Environmental Protection Agency (EPA) the responsibility to coordinate with the U.S. Department of Energy, the U.S. Department of Agriculture, and stakeholders to design and implement this new programme (US EPA, 2009).

For biodiesel, the 2005 Act provided incentives for both supply and demand. On the supply side, the act sought to lower production costs by providing tax credits at a rate of 10¢ per gallon to small producers of biodiesel. The credit was made available for the first 15 million gallons (56 800 m^3; 544 GWh) produced by a plant with annual production capacity of less than 60 million gallons ($2.27x10^5 m^3$; 2180GWh) (Carriquiry, 2007).

2006 – The Renewable Fuel Standard program (RFS1) was enacted. This national renewable fuel programme was designed to further encourage the blending of renewable fuels (particularly ethanol) into US motor vehicle fuel. The nationwide RFS was intended to double the use of ethanol and biodiesel by 2012. Obligated parties (refiners, importers, and fuel blenders), were required to meet their annual transportation fuel sales "irrespective of market prices" for ethanol.[48] By guaranteeing a market for biofuels the RFS substantially reduces the risks associated with biofuels production, thus providing an indirect subsidy for capital investment in the construction of biofuels plants. In 2006, production of ethanol was 18.5 x $10^6 m^3$/yr (4.9 billion gallons, 102 TWh) and use was at 20.4 x 10^6 m^3/yr (5.4 billion gallons, 112 TWh) – already exceeding the requirements of the Energy Policy Act.

December 2007 – The Energy Independence and Security Act (EISA) was passed. The EISA aimed to improve vehicle fuel economy and reduce U.S. dependence on petroleum. EISA included provisions to increase the supply of renewable alternative fuel sources by setting a mandatory Renewable Fuel Standard. This required transportation fuel sold in the United States to contain a minimum of 36 billion gallons of renewable fuels annually by 2022. EISA also included grant programmes to encourage the development of cellulosic biofuels, plug-in hybrid electric vehicles, and other emerging electric technologies. The law is projected to reduce greenhouse gas emissions by 9% by 2030 (USDOE AFDC, 2013b). The volumes in the Act require the use of 56.8 x 10^6 m^3/yr (15 billion gallons, 312 TWh) of renewable (ethanol) fuel by 2015. In 2007 about 56.8 x 10^6 m^3/yr (6.5 billion gallons, 135 TWh) were produced.

2007 (**Biodiesel**) – By 2007 biodiesel production had increased more than 10-fold in a period of 3 years and exceeded 14 TWh fuel energy (circa 1.5 million m^3) – from this point however, biodiesel production decreased markedly for a period of 2 years – related to high feedstock prices with the commodities boom, and then effects of the Global Financial Crisis (GFC). Carriquiry (2007)

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[48] Information on incentives (both tax and non-tax) for ethanol is available in the CRS Report (Yacobucci, 2012).

reports that other important influences can be found in the relative prices of biodiesel versus diesel fuels and the reluctance of engine manufacturers to approve usage of the fuel until circa 2007.[49]

2008 – the Renewable Fuel Standard (RFS) was revised and required obligated parties (refiners, importers, and blenders, other than oxygen blenders), to assess and then achieve their renewable mandatory volume obligation. As with RFS1, they must meet their annual transportation fuel sales irrespective of market prices (c.f. Yacobucci, 2012). During 2008, the EPA had issued detailed compliance standards for fuel suppliers, and a tracking system based on renewable identification numbers (RINs) (Schnepf & Yacobucci, 2012) for each fuel batch, that includes a credit verification and credit trading system.

Also during 2008, the Emergency Economic Stabilization Act was passed and included provisions related to tax credits and exemptions for alternative fuels and fuel-efficient technologies. The ethanol content of gasoline had reached an estimated 8.0% in 2008 (US EIA, 2012e; USDOE AFDC, 2013b) and over 170 ethanol plants had been established across 25 states (US EIA, 2012e).

Stage IV – Technical, market and legitimacy constraints escalate

Early **2009** – The ethanol subsidy (by then a blender tax credit) was decreased to $0.45/gallon (12 c/l) as of January 2009. Concomitantly, a $0.54/gallon (14 c/l) duty on ethanol imports was put in place to supplement federal revenue (Moschini *et al*, 2012) and to protect US producers from imports. At this time, the main industry lobby group for the ethanol industry, the American Coalition for Ethanol (ACE) along with more than 50 major producers, submitted a waiver application to the US EPA increase E10 to E15, thus allowing 15% ethanol fuel blends to be utilised in conventional gasoline engines.

2009 – The 2009 RFS requires most refiners, importers, and non-oxygenate blenders of gasoline to displace 10.21% of their gasoline with renewable fuels such as ethanol. That requirement aims to ensure that at least 11.1 billion US gallons (circa 42×10^6 m^3 of renewable fuels will be sold in 2009, to meet the targets of the 2007 EISA) (EERE Network News, 2008).[50] Most states complete rapid switchover from conventional, non-ethanol 100% gasoline, to blends that “may contain up to 10% ethanol”. At the same time lobby-based opposition to biofuels grows “on behalf” of consumers that lose their “right” and “choice” to purchase non-alcohol fuel at the pumps. By this time, several states require “mandatory” ethanol blending, while others propose legislation to allow non-ethanol premium grade to be available at refueling stations (usually sold as premium octane91 or 93 at higher prices). Fuel distributors reportedly willingly/-actively switch to E10 as the government funded tax credits of up to 53 cents per gallon (14 USc/L) improve profit margin for distributors and gas retailers (Fuel-testers, 2009b).

2009-2012 – The “blend wall” is essentially reached – this refers to the situation where even if all gasoline-powered motor vehicles were to use a 10% ethanol blend, this would be insufficient to

[49] Carriquiry (2007) also indicates that at that time quality standards for biodiesel were developing and quality certification systems have started to emerge, prompting engine manufacturers to extend their warranties. As a result, an increasing proportion of manufacturers were approving the use of B20 in some or all of their engines, thus increasing acceptance for the fuel on the market.

[50] This source also explains that the 2009 RFS is also pushing up against the so-called “blend wall”. To address the blend wall issue, DOE and others are studying the use of mid-range blends, such as E15 and E20, for use in standard gasoline-burning vehicles.

meet the nationally mandated biofuels usage level. The ethanol share of gasoline consumption has been fluctuating at just under 10% since the first half of 2010. In this period the U.S. biofuels industry increased its output capacity and prepared to meet an expanded Renewable Fuel Standard (RFS2).

2009 – The American Recovery and Reinvestment Act (ARRA) of 2009, enacted at the start of the year, has provided major subsidy support as well as underpinning for capital projects in biofuels. The act appropriated nearly $800 billion towards the creation of jobs, economic growth, tax relief, improvements in education and healthcare, infrastructure modernization, and investments in energy independence and renewable energy technologies. ARRA supports a variety of alternative fuel and advanced vehicle technologies through grant programmes, tax credits, research and development, fleet funding, and other measures (USDOE AFDC, 2013b).

2010 – Despite the expansion of the geographical span of the market achieved in 2009, falling oil prices in 2009 and continued falling overall consumption of fuels in the US challenge the ethanol industry. The industry retracted, with more than 20 plants were reported to have closed or placed on care and maintenance by 2010 (Fuel-testers 2009b). Also in 2010 in response to "blend wall" concerns, on October 13, 2010, the EPA announced a partial waiver to allow 15% blends to be sold. This applied for only for "model year 2007 and newer light-duty motor vehicles." The EPA deferred a decision on 2001-2006 light-duty motor vehicles until further testing can be undertaken. In the 2010/11 agricultural marketing year, 40% of the US maize crop and 14% of US soybean oil production was used to produce biodiesel (US EIA, 2012d).

2010 (Biodiesel) – In 2010, the production of biodiesel fell to 343 million gallons, or 34 percent below 2009 level in 2009, partly due to the expiration of the biodiesel tax credit at the end of 2009. A reinstatement of the credit retroactive to the beginning of 2010 was passed late in 2010, which helped the biodiesel industry recover and increase production in 2011. (Schnepf & Yacobucci, 2012; US EIA, 2012e).

2011 – The ethanol retraction continued during 2011. At the end of the year, the ethanol subsidy (by then a blender tax credit) was finally phased out. At the same time, the $0.54/gallon duty on ethanol imports introduced in 2009 was also withdrawn (Moschini *et al*, 2012) and the biofuels industry transitioned away from tax incentives for non-cellulosic biofuels, which expired at the end of 2011. Exports of ethanol increased substantially as producers looked abroad for new markets and Brazil experienced a poor sugar harvest during 2011-12.

2011 however, saw strong growth in demand for biodiesel as fuel blenders needed to meet an increased RFS2 volume of 1 billion gallons of biomass-based diesel. Biodiesel production reached 967 million gallons (3.7×10^6 m^3) for 2011, nearly twice that that of 2010.

2012 – As overall fuel consumption in the US falls, the ethanol content of gasoline had reached an estimated 9.7% by 2012 (US EIA, 2012e). With the biofuel market to trade some $2 billion in RIN value for advanced biofuels market in 2012, the US EPA increased its resources for policing and enforcement of the RIN market (McKintyre & Noyes, 2011) [c.f. Ziolkowska, J. et al (2010) for a detail discussion of the RIN market]. A drought in the midwestern US during summer 2012 lowered production estimates for corn and other crops, resulting in higher prices and a reduced forecast for biofuels production for the 2012/13 marketing year (US EIA, 2012e; 2012d). During 2012, it also became increasingly apparent that cellulosic ethanol mandates would not be met in the near future. The EPA issued waivers that substantially reduced the cellulosic biofuels obligation under RFS2 for the 2010, 2011, and 2012 programme years but even the reduced levels of commercial production failed to materialize. While there was no production of cellulosic biofuels for 2010 or 2011, some production of cellulosic biofuel RINs in 2012 did occur (Schnepf & Yacobucci, 2012). During 2012, biodiesel production remained at similar levels to those of 2011 (ibid.).

2013 – The American Taxpayer Relief Act of 2012 was passed. It extends and reinstates several alternative fuel incentives. The law reinstates, effective through December 31, 2013, the alternative fuel infrastructure tax credit, biodiesel income tax credit, biodiesel mixture excise tax credit, and alternative fuel mixture excise tax credits. It also incorporates a tax credit for two- and three-wheeled plug-in electric vehicles through December 31, 2013. It also extends until December 31, 2014, the second generation biofuel producer tax credit and second generation biofuel plant depreciation deduction allowance and extends discretionary funding for the U.S. Department of Agriculture's Advanced Biofuel Production Grants and Loan Guarantees, Advanced Biofuel Production Payments, Biodiesel Education Grants, Biomass Research and Development Initiative, and Ethanol Infrastructure Grants and Loan Guarantees. (USDOE AFDC, 2013b)

2013 into the future – theoretical growth projections but significant constraints.

During this period the industry is ostensibly preparing itself to further increase its production under new mandated volumetric increases for the use of biofuels in transportation. The latest conditions of the Renewable Fuel Standard (the so-called RFS2) requires an increase in the use of biofuels in transportation from current levels circa 330 TWh (16 billion gallons) up to circa 780 TWh or around (36 billion gallons biofuels)[51] by 2022 (US EIA, 2012e).

The mandated projections for the first years are shown from 2012 forward in Figure 23 overleaf and in Figure 24 in Section 5.4.1. The reader should note however, that these represent the theoretical projections. Real developments and emerging expectations are currently the topic of speculation. As noted, cellulosic targets for the period 2009 to 2012 were not met. Expectations are that cellulosic ethanol will be available in minimal quantities in the next three years – reflecting this, the US EPA has reduced the RFS for cellulosic ethanol in 2013 from one billion gallons (3.79×10^6 m^3; 2.08×10^4 GWh) to 11 million gallons (41 000m^3; 229 GWh) (Irwin & Good, 2013b).

Moreover, the issue of the blend wall is becoming increasingly acute (Irwin & Good, 2013b). As the total mandate for biofuels continues to increase – from 16.55 billion gallons for 2013 ($6.25 \times 10^7 m^3$) to 20.5 billion gallons (7.76×10^7 m^3) in 2015, it appears increasingly likely that the mandates could exceed the capacity to produce and/or blend biofuels by a substantial amount as soon as mid-2014 (Ibid).

[51] Note that this is a compound figure that includes both biodiesel and ethanol.

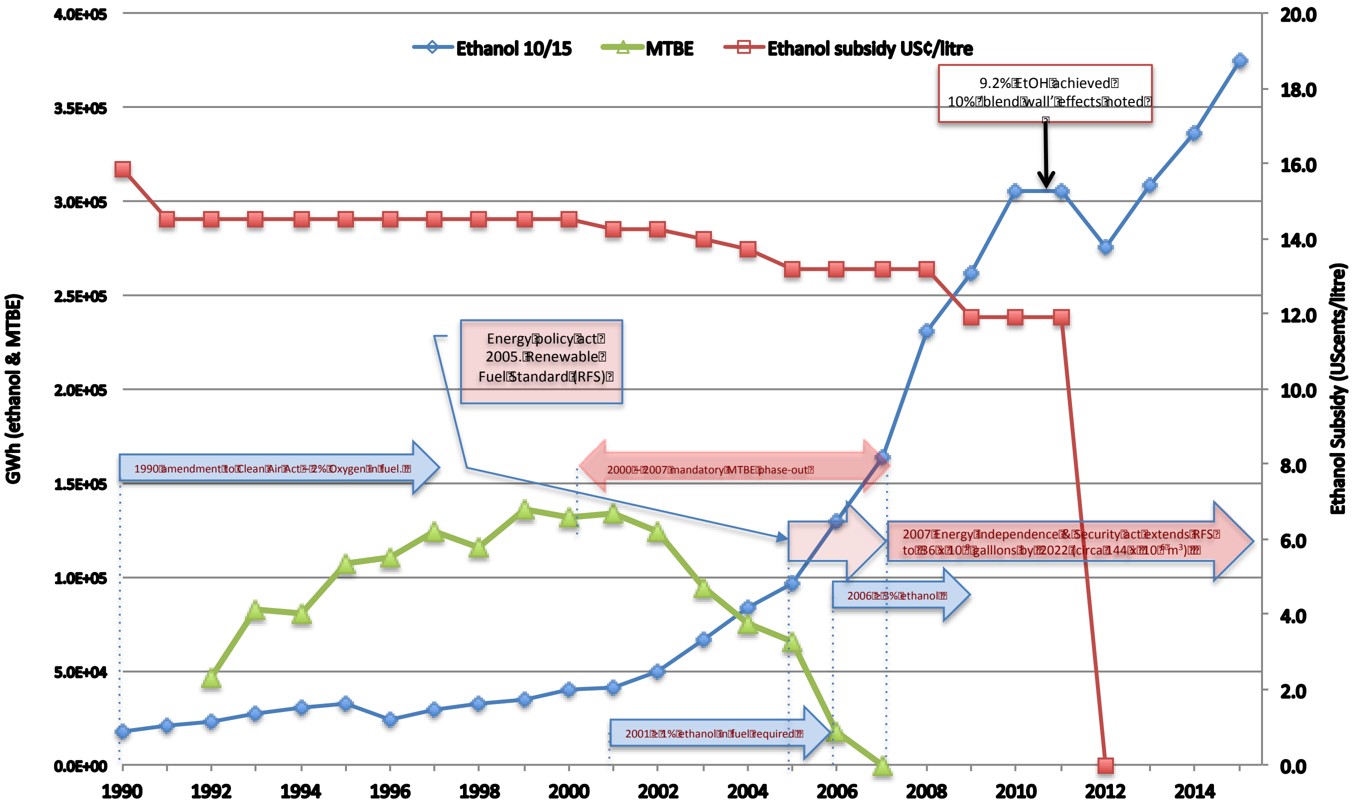

Figure 23. US ethanol consumption, MTBE consumption, Subsidies and Key Policy Interventions and production capacity 1990 to 2015 (projections post 2011). Source: (after US EIA, 2011).

5.4 U.S. BIOFUEL POLICIES AND POLICY ISSUES

This section is utilised to present additional detail for some of the key items included in the time-line (Section 5.3.2) as well as a limited number of other activities mentioned in Table 2 in the preceding section. The items addressed here include:

- principal approaches taken in the US – and an overview of the biofuels development to date – and mandated out to 2022:
- additional details pertaining to the the Clean Air Act (CAA) and fuel oxygenate programmes;
- the role of MTBE toxicity in escalating the rate of ethanol uptake;
- specific interventions related to energy security and oil dependence;
- the introduction of the Renewable Fuel Standard (RFS) and its update;
- US GHG emission reduction categories for biofuels;
- Department of Defence energy security activities, and
- the Low Carbon Fuel Standard (LCFS) implemented in California, and anticipated for uptake in a number of additional jurisdictions.

5.4.1 Principal approaches

As has been indicated in preceding sections, US biofuel policies in recent times have primarily been driven by aspirations to reduce the import of fossil fuels to minimise fuel dependence, to reduce GHG emissions, and to increase demand for domestic farm commodities serving as a raw material for biofuels (Janda, Kristoufek, & Zilberman, 2012). According to Schnepf and Yacobucci (2012) U.S. policymakers have responded to such drivers with an increasing variety of policies, at both the state and federal levels that support U.S. biofuels production and use (Schnepf, 2012). Policy measures have included blending and production tax credits to lower the cost of biofuels to end users, an import tariff to protect domestic ethanol from cheaper foreign-produced ethanol, research grants to stimulate the development of new biofuels technologies, loans and loan guarantees to facilitate the development of biofuels production and distribution infrastructure. While Moschini *et al* (2012) hold that the federal subsidy undoubtedly supported the earlier growth of the US ethanol industry, environmentally-led regulations also played an important role. Apparently most important however, has been a set of minimum usage requirements to guarantee a market for biofuels irrespective of their cost that has been applied in recent years (Yacobucci, 2012).

Three primary instruments are discussed in US biofuel policies. These are: output (production) connected measures, support for input factors[52] and consumption subsidies. Tariffs are designed to benefit biofuel producers through both direct and indirect price support. Mandates on the other hand, work in the form of indirect subsidies[53] and do not provide direct price support. Until their expiry in 2012, the tax credits served as the largest form of direct subsidies in the US. Higher tariffs

[52] e.g. direct input subsidies for items such as fertilizers, feed, energy, water and transportation.

[53] A more certain market for biofuels reduces the risks associated with biofuels production – this provides an indirect but tangible subsidy for capital investments in biofuels plants.

on ethanol (24% in ad-valorem[54] equivalent) compared to biodiesel (1% in ad-valorem equivalent) also acted as a barrier to imports; this difference in tariff treatment limited imports of ethanol. In the period that it applied, the Volumetric Ethanol Excise Tax Credit (VEETC) and the Volumetric Biodiesel Excise Tax Credit provided the largest tax credit subsidies to biofuels (Janda, Kristoufek, & Zilberman, 2012). While subsidies are held to have provided underlying support for both ethanol and biodiesel, other policy areas have also been central to the growing role of ethanol. Two of these that may be initially counter-intuitive, shall be addressed in the following sections – air pollution and protection of groundwater resources.

On top of to these incentives, a number of fuel standards, fleet requirements etc. supplement the Federal biofuel policies (examples provided below). State incentives also play a role in supporting biofuels (c.f. Moschini et al, 2012 for a more detailed discussion). Broad categories of Federal as well as State policy measures targeting production, distribution and use of biofuels include:

a. Financial Incentives: Tax credits, tax exemptions, reduced tax rates, grants, loans, loan guarantees and funds – examples of support for capital investment are provided in Box 1 below.

b. Vehicle Acquisition and Fuel Use Requirements: Mandates for states, schools, and public fleets to acquire alternative fuel vehicles that run on biofuels, or use a certain percentage of biofuels.

c. Fuel Standards and Mandates: Low-carbon fuel standards and fuel blend mandates such as the RFSI and II.

A tabulation of different Federal and State level policy interventions is provided in Table A5-3 “Key federal level policy measures to promote biofuels in the US” and Table A5-4 “Examples of state level policy measures to promote biofuels in the US” included in Appendix (US Analysis).

[54] An *ad valorem* tax (Latin for “according to value”) is typically a tax based on the value of real estate or personal property. It is more common than a specific tax, a tax based on the quantity of an item, such as cents per kilogram, regardless of price.

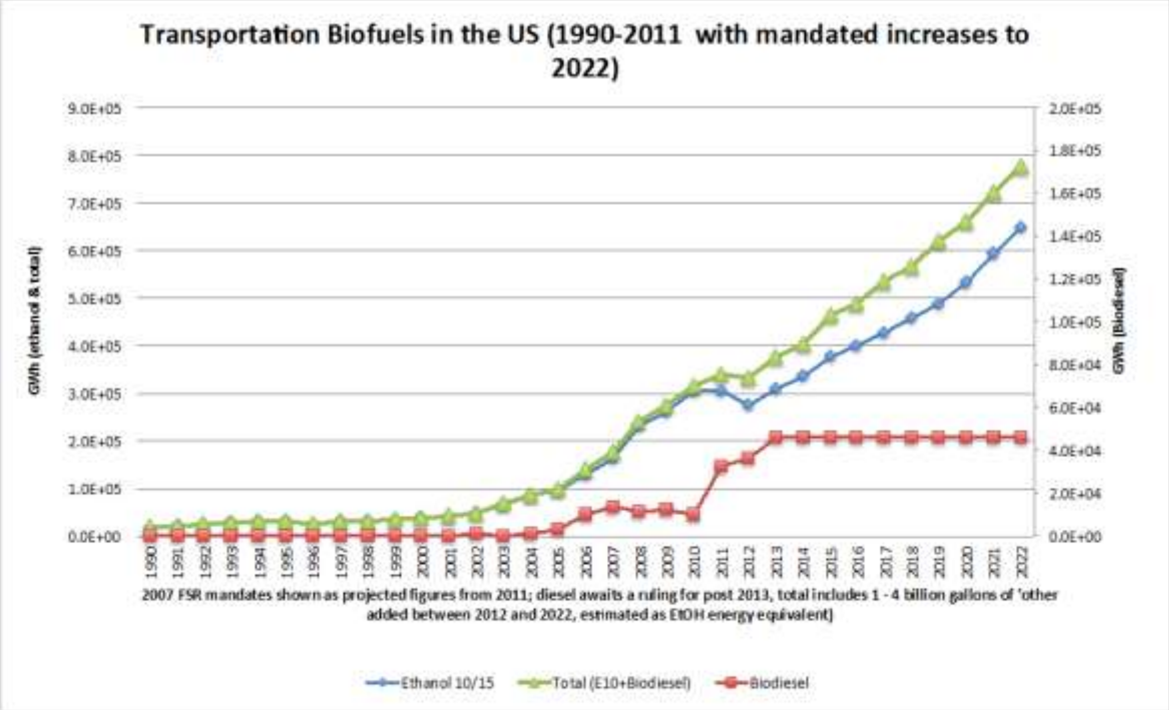

Figure 24. US transportation biofuels 1990-2022 with mandated projections from 2011. Source: after US EIA, 2011.

Box 1. Examples of US Government financial support for Biofuels Infrastructure.

As indications of the scale of US Governmental support to cellulosic ethanol, and the indicative production volumes should they come to fruition, the following examples are pertinent:

- January 2011, the US Department of Agriculture approved $405 million in loan guarantees through the 2008 Farm Bill to support the commercialization of cellulosic ethanol at three facilities owned by Coskata, Enerkem and INEOS New Planet BioEnergy. The projects represent a combined 73 million US gallons (280 000 m^3) per year production capacity (now anticipated to begin producing cellulosic ethanol in the period 2013-14).
- In July 2011, the US Department of Energy provided $105 million in loan guarantees to POET for a commercial-scale plant to be built in Emmetsburg, Iowa (Wald, 2011).

5.4.2 The Clean Air Act (CAA) and fuel oxygenate programmes

In the aftermath of devastating air pollution events such as the London smogs of 1952, a number of industrialised nations started looking at air pollution more seriously. In order to reduce air pollution and in particular to address the concerns of increasing levels of SO_2, the US Clean Air Act (CAA) was first introduced in 1963 – a stronger amendment to the CAA was made in 1970. The amended law also authorized newly recognised US Environment Protection Agency (US EPA) to establish National Ambient Air Quality Standards (NAAQS) in order to protect public health and public welfare in addition to regulating emissions of hazardous air pollutants in every State. The Act was further amended in 1977 and 1990; changes at these times were primarily to set new goals for achieving targets of NAAQS.

Under the CAA 1990 amendments, the US EPA was mandated to take measures to minimise the levels of pollutants emitted from mobile sources as well as from stationary. Actions comprised the monitoring the levels of various air pollutants, providing pollution control measures and investing in alternative fuels. One of the key amendments of CAA was to allow an increase the amount of biofuels to be blended with gasoline, and to replace the lead in the gasoline with a less hazardous oxygenated compound, with particular focus upon in the most highly polluted airsheds (US EPA, 2013d). As an octane booster to assist complete combustion of gasoline, Methyl tertiary-butyl ether (MTBE), Tertiary Butyl Alcohol (TBA) and ethanol were used extensively. These fuel oxygenates raise the oxygen content of gasoline to help optimize oxidation during fuel combustion, resulting in a more complete combustion reaction and a reduction of harmful tailpipe emissions – being partially oxidized gasoline components from motor vehicles. Thus, Reformulated Gasoline (RFG) i.e. gasoline(s) blended with oxygenated compounds such as ethanol and MTBE, were introduced in the US fuel market. The RFGs helped to improve the quality of air by reducing air pollutants in the polluted urban areas.

Under the 1990 CAA amendments two nationwide oxygenated gasoline programmes were developed in the US. The Winter Oxygenated Fuel Program required use of gasoline with 2.7% oxygen by weight during cold months in cities exceeding a carbon monoxide threshold (Anderson & Elzinga, 2012). The Year-round Reformulated Gasoline Program demanded the use of RFG throughout the year in cities with the highest ground-level ozone (smog) pollution (US EPA, 2013d). Under the conditions of the amendment, RFG was to contain a minimum of 2% oxygen by weight and is blended to contain fewer polluting compounds than conventional gasoline. MTBE – an effective fuel oxygenate – had proven the dominant choice to replaced lead as an octane-enhancing fuel additive in motor gasoline pursuant to earlier regulation. Higher concentrations of MTBE were added to fuel to ensure an efficient burning of gasoline and reducing emissions. This helped to fulfil the nationwide oxygenate requirements set by the 1990 CAA amendments. MTBE was preferred over ethanol for a number of reasons: lower cost, low volatility, and easy solubility plus blending characteristics (US EPA, 2013d). The Clean Air Act Amendments of 1990 and subsequent laws spurred the demand of MTBE as fuel additives.

In order to meet national demand the production of MTBE increased by about 20% annually between 1984 and 2000 (refer back to Figure 23). Ethanol; the second most commonly used gasoline oxygenate, had an average increase in production of 10% year on year at the same time (but from a much smaller base, and thus in much smaller volumes).

5.4.3 MTBE toxicity – a game changer for ethanol

However, the situation changed drastically in the late 1990s in the state of California where complaints of ground water pollution due to MTBE were registered. MTBE is easily soluble in water and poorly-biodegradable – and traces of the substance were found in groundwater used as a source of drinking water (Horelik, 2008).[55] Problems were often related to leaking gasoline tanks (often single-skinned underground tanks at refuelling stations) – endemic throughout the country. In response to growing concerns regarding MTBE in water, the so-called MTBE Blue Ribbon Panel

[55] While in some cases MTBE found in drinking water was above US EPA's drinking water permissible limit (USGS, 2013), the CAA advisory committee concluded that even at low concentration MTBE gives water an unpleasant taste largely making it unsuitable for use.

was created by the CAA Advisory Committee in 1998 (US EPA, 2013a, 2012b). The panel was tasked with advising the US EPA regarding the use of MTBE and other oxygenates in gasoline.

Due to its health risks and ability to contaminate water resources, the State of California first banned the use of MTBE in 2003. As a result, 15 more states banned MTBE in 2003-04. This helped drive a switch to ethanol as oxygenate to meet end of tail pipe emissions under Clean Air Act. Owing to these proceedings, MTBE producing companies decided to phase out MTBE completely from 2005-06. The gradual phasing out of MTBE resulted into increasing consumption of ethanol as a substitute oxygenate compound in gasoline (as illustrated in Figure 25). Today, ethanol is used as a gasoline additive in all US States.

As the replacement of MTBE demanded significant increases (circa 150% increase in market volumes) a significant impetus was supplied to the ethanol market. As can be seen in the figure however, this was just the start of a rapid growth period. The link to further policy stimulation in the form of the Renewable Fuel Standard (RFS) included in the Energy Policy Act of 2005 is taken up in the next section of this discussion.

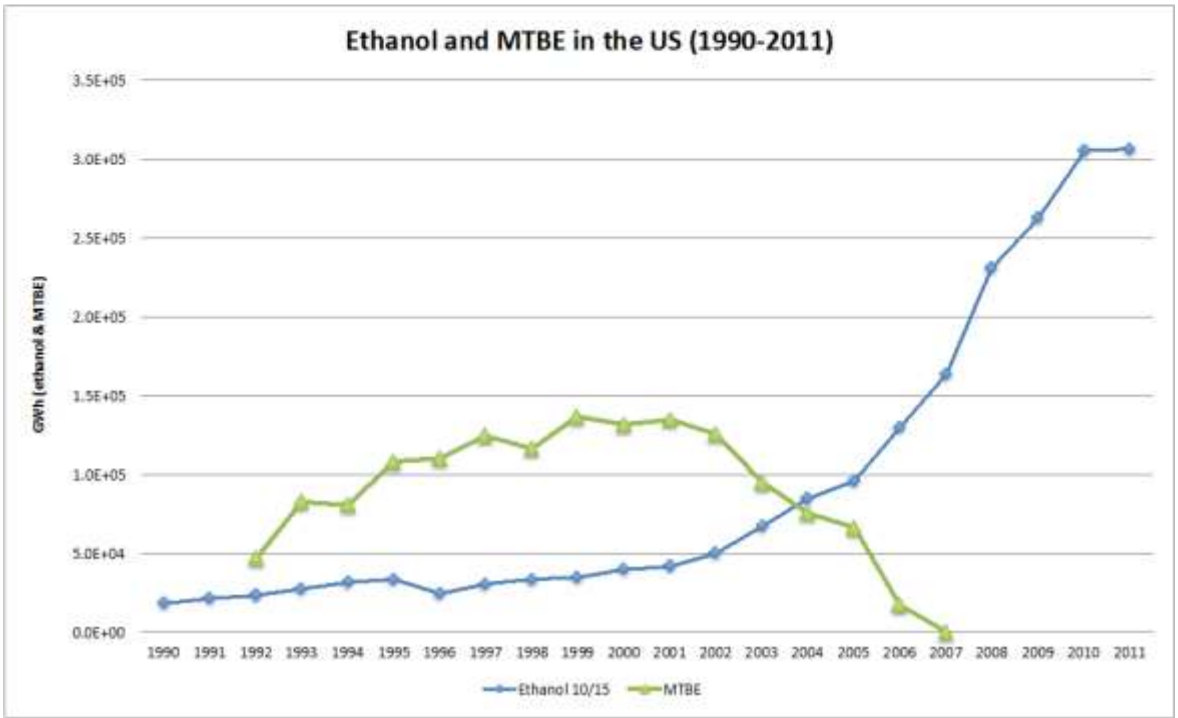

Figure 25. US consumption of ethanol and MTBE oxygenate. Source: After US EIA, 2011.

5.4.4 Energy security and independence efforts

The United States is indisputably the world's largest energy consumer but importantly in the context of this report is that historically, rising gasoline consumption has been the most important reason behind the US dependence on imported oil. The US relied on net imports for about 45% of all the petroleum (crude oil and petroleum products) consumed in the year 2011 (US EIA, 2012d). This is also clearly displayed in Figure 15 in Section 5.2. The absence of any major substitute fuel that can be easily and broadly distributed into the system in case of major disturbance or oil shocks has underpinned the heavy energy dependence of US on foreign oil (Alvarez et al., 2010).[56] Taking into consideration the reliance on oil, any natural or artificial disruptions in the oil supply can potentially become a major threat to the national security. Increasing energy efficiency, using alternative energy sources, and increasing domestic sources of energy for transportation are held by analysts in the US to be important parts of a comprehensive strategy to achieve overall energy independence (C2ES, 2011).

The Energy Policy Act (EPAct) of 1992 sought to reduce the US dependence on foreign oil and improve air quality. The EPAct addresses various aspects of energy supply and demand, including alternative fuels, renewable energy, and energy efficiency. It also encouraged the use of alternative fuels through regulatory and voluntary activities (AFDC, 2013b). Examination of Figure 15 in Section 5.2 shows however that dependence upon foreign continued to worsen until circa 2007 (when the combined effects of a) reduced consumption and b) increased US production of “non conventional” oil and gas associated with fracking programmes) commenced a reversal of the trend.

A series of US administrations have realised the importance of energy security and its relation to the national security. President Bush in 2007 expressed concerns on heavy dependence on imported oil and added that the US heavy dependence on imported crude oil makes it more vulnerable to hostile regimes and terrorism (Bush, 2007). In order to reduce the oil imports and ensure the energy security of the nation, the Obama administration has set a goal of reducing oil imports by one third by 2025 (Obama, 2010). Increasing energy efficiency and investing in biofuel and other alternative technologies are to assist to achieve the targeted goal.

In order to address the energy security issues the US Congress passed the Energy Independence and Security Act (EISA) in 2007 that mandated production targets for renewable fuels such as ethanol and biodiesel. The bill mandated ambitious production targets of 9 billion gallons of biofuels a year in 2008 (240 TWh energy equivalent) and raising it to 36 billion gallons a year by 2022 (780 TWh) under the Renewable Fuel Standards 2 (RFS2). The US Congress earlier established a Renewable Fuel Standard (RFS) with the enactment of the Energy Policy Act of 2005. The RFS programme mandated a minimum of 4 billion gallons of biofuels to be used in 2006, and this rose to minimum of 7.5 billion gallons by the year 2012 (Schnepf & Yacobucci, 2012).

In the long run, the expanded RFS i.e. RFS2 is expected to play an important role in the expansion of the US biofuels sector. However, policy experts argue that possibilities of the potential spill over effects in other markets still remain uncertain.[57]

5.4.5 Renewable Fuel Standard

As presented at different points on the timeline in Section 5.3.2, The Renewable Fuel Standard requires transportation fuel sold in the US to contain a minimum volume of renewable fuel until (at least) 2022. Endogenous renewables in fuels were deemed to improve energy security and to reduce the carbon emissions from the vehicles. Under the Energy Policy Act, 2005 the Renewable

[56] Past tense is used here in recognition that non-conventional oil is rapidly expanding in the US with the fracking of oil and gas rich shale deposits and “tight rock” reservoirs. The implications of this are discussed briefly in Sections 1.2 and 1.5.4 of this report.
[57] For example the impacts of increased maize prices on other areas of utilisation, flow on effects to protein feed markets due to increased by-product volumes etc.

Fuel Standard (RFS1) was introduced. Further changes were made in the Renewable Fuel Standard (RFS2) in 2007, under the Energy Independence and Security Act, 2007. One of the key amendments was to increase the amount of renewable fuels[58] in gasoline but to set a cap on corn ethanol at 15 billion gallons (circa 312 TWh). The rest of the demand must now be met of advanced biofuels. Advanced biofuels are ethanol produced from sources other than corn starch that also have GHG emissions reductions (estimates provided by US EPA studies) of at least 50%. Corn-based biofuels are assumed to contribute at least a 20% GHG reduction in the US Cellulosic biofuel, biomass-based diesel and undifferentiated advanced biofuels are examples of fuels categorised as “advanced” in the US. (These items are presented in the next section).

5.4.6 GHG emission reduction efforts

The US transportation sector accounts for approximately 27% of the GHG emissions of the entire US economy. For the past three decades, the transportation sector has had the highest growth rate in energy consumption and GHG emissions of all US end use sectors. Since 1990 the GHG emissions from US transportation have increased by about 19% (US EPA, 2013b). Without shifts in existing policies, the US transportation sector’s GHG emissions are expected to grow by about 10% by 2035 (C2ES, 2011).

Table 6. Lifecycle GHG reduction thresholds. Source: The American Association for the Advancement of Science (AAAS, 2011).

Fuel Class	Lifecycle GHG Reduction Thresholds	Examples
Renewable Fuel	20%	Corn-based Ethanol
Advanced Biofuel	50%	Sugarcane Ethanol
Biomass-Based Diesel	50%	Soy-based Biodiesel
Cellulosic Biofuel	60%	(none in production yet)

5.4.7 Department of Defence energy security activities

The Department of Defence (DOD) is the largest institutional energy-consuming sector in the US. The DOD has established the Office of Defence for Operational Energy to enhance the energy security of the US military operations. It helps military services to follow energy accounting, planning, management, and innovation in order to improve capabilities, cut costs, and lower operational risks (Department of Defence, 2011). The DOD has been developing strategic plans to reduce the energy demand and to guide the search for alternative technologies that will consume less energy and yet deliver higher output. In the context of engine fuels, energy security for the military can be interpreted in a different manner to that of domestic concern – not least as there is a very significant “field operations” aspect to fuel supply security that steps beyond national borders.

The DOD accounts for over 90% of all US government fuel consumption with the largest single item being jet fuel. In 2007 fuel consumption had the following approximate breakdown: Air

[58] The term “Renewable fuel” is used to include all motor vehicle fuel that is a. produced from grain, starch, oilseeds, vegetable, animal, or fish materials including fats, greases, and oils, sugarcane, sugar beets, sugar components, tobacco, potatoes, or other biomass; or b. is methane gas produced from a biogas source, including a landfill, sewage waste treatment plant, feedlot, or other place where decaying organic material is found.

Force: 52%; Navy: 33%; US Army: 7%; other DoD components: 1% (Lengyel, 2007). The DoD uses 4.6 Billion US gallons (17.4 x 10^6 m^3; 170 TWh) of fuel annually, an average of 466 GWh fuel energy of fuel per day if this were assumed to be equivalent to jet fuel in energy content (circa 35 MJ/l). According to the 2005 CIA World Factbook, if it were a country, the DoD would rank 34th in the world in average daily oil use. (Lengyel, 2007). Important from a biofuels perspective is that bio-oil feedstock-derived jet fuels (closer to traditional biodiesels) are typically associated with algae, or crops such as jatropha and camelina (for oil-based fuels), and waste (used oils and animal fat) at present. Cellulose feedstock-based jet fuels are being developed from waste products such as forest products, industry residue, or sugarcane but these areas are reliant upon technology advancement (McIvor, 2011).

A number of significant activities in the renewable fuels area are listed below.

Airforce: The US Air force has set a target to test and certify all aircraft and systems on a 50:50 alternative fuel blend by 2012. Pursuant to cost effective availability of fuels, this should prepare the Air force to purchase up to 50% of the domestic aviation fuel used as an alternative fuel blend by 2016 (Blakeley, 2012).

Navy: The US Navy has a goal to deploy a “Great Green Fleet” strike group of ships and aircrafts by 2016 that shall consume alternative fuel blends. It further aims to meet 50% of its total energy consumption from alternative fuels by 2020 (Blakeley, 2012). In order to meet these targets, a Memorandum of Understanding (MOU) was signed between Department of Navy, Department of Energy and the Department of Agriculture to initiate a cooperative effort to assist the development and support of sustainable commercial biofuels (USDA, 2011). Reliable and diversified fuel sources including advanced drop-in biofuels are held to be essential to continue US military operations which are otherwise in jeopardy due to heavy dependence on foreign oil.

The Department of the Navy established Task Force Energy to focus on meeting energy goals, which include reducing non-tactical petroleum use in the commercial fleet by 50 percent by 2015, producing at least 50 percent of shore based energy from alternative sources by 2050, and acquiring 50 percent of total energy from alternative sources by 2020 (EESI, 2011). The Navy demonstrated a Green Strike Group (fueled by biofuels and nuclear power) during 2012 (see Box 2) (Woody 2012; EESI, 2011).

Box 2. Biofuels in the Green Strike Group.

In Hawaii, the US Navy demonstrated its Green Strike Group as part of the 2012 Rim of the Pacific Exercise (RIMPAC), the world's largest international maritime warfare exercise that includes 40 surface ships, six submarines, more than 200 aircraft and 25 000 personnel from 22 different nations. (Biofuels Digest, 2012)

On July 17th, military Sealift Command fleet replenishment oiler USNS Henry J. Kaiser delivered 700 000 gallons (2650m^3) of hydro-treated renewable diesel fuel, or HRD76, to three ships of the strike group. Kaiser also delivered 200 000 gallons (760m^3)of hydro-treated renewable aviation fuel, or HRJ5, to Nimitz (Biofuels Digest, 2012).

Both fuels are a 50-50 blend of traditional petroleum-based fuel and biofuel comprised of a mix of waste cooking oil and algae oil. The fuel delivery is part of the Navy's Great Green Fleet demonstration, which allows the Navy to test, evaluate and demonstrate the cross-platform utility and functionality of advanced biofuels in an operational setting (Biofuels Digest, 2012). The 900 000 gallons of the biofuel blend used during the Great Green Fleet demonstration cost circa $13 million – four times that cost of petroleum (Woody, 2012).

5.4.8 Low Carbon Fuel Standard (LCFS)

An LCFS is a policy designed to accelerate the transition to low-carbon alternative transportation fuels by stimulating innovation and investment in new fuels and technologies. (Yeh et al., 2012). According to research consortium members of the National Low Carbon Fuel Standard (LCFS) Study,[59] LCFS implementations seek to provide a durable policy framework that will stimulate innovation and technological development. According to the study consortium, this is achieved by the application of technology-neutral performance targets and credit trading between regulated parties. Life-cycle measurements of GHG emissions are applied to ensure that emissions can be regulated. As such, LCFSs are hybrid regulatory and market policy instruments that do not include mandates for any particular fuel or technology. Rather, average emissions intensity standards are defined (e.g. measured in g CO_2 e/MJ)) that must be met by regulated energy carrier providers. Regulated parties are free to pursue any combination of strategies; including the purchase of credits from other companies (Yeh et al., 2012). Yeh et al (2012) argue that an LCFS and relevant fuel policies (including RFS2 and the EU's biofuel policy RED and LCFS-like policy Fuel Quality Directive) are technology-forcing policies (as opposed to demand-pull policies that focus on creating demands directly).

Three significant applications of LCFS policy have been adopted – in California (California Governor, 2007), in the EU [as the Fuel Quality Directive – see EC (2012)] and in British Columbia, Canada (Ministry of Energy BC, 2013) (Renewable and Low Carbon Fuel Requirement Regula-

[59] The National Low Carbon Fuel Standard (LCFS) Study, a collaboration between: Institute of Transportation Studies, University of California, Davis; Department of Agricultural and Consumer Economics and Energy Biosciences Institute, University of Illinois, Urbana-Champaign; Margaret Chase Smith Policy Center and School of Economics, University of Maine; Environmental Sciences Division, Oak Ridge National Laboratory; International Food Policy Research Institute; and Green Design Institute of Carnegie Mellon University. The consortium has produced a suite of studies and has undertaken a thorough review process. According to Yeh et al (2012) *"The National LCFS Study has gone through an extensive internal and external peer-review process participated in by more than a hundred stakeholders, including review of the seven research reports…".* All the research reports are now published in the peer-reviewed journal *Energy Policy* in a special issue, "Low Carbon Fuel Policy."

tion, RLCFRR). Yeh et al (2012) also report that adoption of LCFS policies is being assessed by a number of states in the Midwest and the Northeast/Mid-Atlantic region, and in Pacific Northwest.[60]

In the US, the LCFS approach was first adopted by the Government of California to help reduce the GHGs emitted from the transportation sector. This policy was approved under the AB 32, the California Global Warming Solutions Act of 2006 (Cackette, 2011). Unlike the RFS that specifies fuels and sets volumetric targets, the LCFS policy promotes the use of all non-petroleum fuel that emit less carbon, including biofuels – and targets are based on GHG emission reduction. Thus, LCFS is based on the life cycle of the carbon intensity of fuels (Yeh et al., 2012). The LCFS policy in California has a goal to reduce carbon emissions from vehicles by 10% from 1990 levels by 2020, and is currently in its implementation phase – having come into effect during 2011. Proponents argue that LCFS is a better policy in term of technological advancement (Farrell & Sperling, 2007). They hold that LCFS can concomitantly creates markets for renewable fuels, and open new ideas for innovation – especially in the area of vehicles that can use combined renewable fuel and gasoline or diesel, with environmental, health and social benefits.

LCFS policies in California and British Columbia have both adopted a “technology-forcing” carbon intensity (CI) trajectory, in which modest reductions are required for initial years in the programme. These are then followed by more substantial reductions later on. Such backloading is intended to provide sufficient lag time to develop new low-carbon fuel supplies, perform research and development, construct advanced fuel plants, develop feedstock supplies and infrastructure, and to integrate systems (NRC 2011). While critics suggest that this approach may create additional challenges to financing low-carbon fuel development, as modest initial reduction targets yield relatively low LCFS credit prices early in the programme, the LCFS Study indicates that their credit analysis study demonstrates that uncertainty in mitigation costs, feedstock and technology availability, and credit prices can largely be mitigated via credit trading and banking (Rubin and Leiby 2012).

Analysis of the systems implemented indicate that fuel suppliers and importers are the obvious and capable parties to regulate (Yeh et al, 2012). The US LCFS studies indicate that these actors have adequate control over fuels and/or feedstock sourcing and processing to enable implementation of carbon-intensity-reduction strategies; have sufficient knowledge of life-cycle emissions to fulfill compliance obligations; are sufficiently few in number to enable effective administration and enforcement; are capable of making long-term commercial and R&D investments in increasing the supply of low-carbon transportation fuels; and have sufficient resources to manage the trade of carbon credits.

Experience gained in the implementation process in California and analysis of other systems documented in the LCFS studies indicate that fuel producers can choose among five methods to meet LCFS targets:

1. Reduce the carbon intensity (CI) of fuels (e.g. gasoline and diesel).
2. Increase the use of alternative fuel blends in gasoline and diesel.

[60] Including among others: Oregon, Washington, Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.

3. Substitute lower-CI for higher-CI biofuels in blends (for example, substitute low-carbon ethanol for corn ethanol).
4. Sell higher volumes of low CI alternative fuels (for example, E85, B100, and CNG).
5. Purchase credits from other regulated parties or use credits banked in previous years.

While proponents of the approach hold that the theory underlying LCFS has been strongly established, effects of the California programme are still emerging and a number of difficulties are being reported that will almost certainly have political ramifications. Boston Consulting Group (BCG, 2012) reports that oil refinery closures are forecasted, “largely resulting from full implementation of LCFS” and that California could lose up to 51 000 direct jobs, as well as indirect job losses due to multiplier effects (net of 2500 to 5000 direct and indirect jobs created due to investments in energy efficiency). Gatto (2013) indicates that such effects flow from on from the embedded processes that assign emission scores to oil from around the world. These take into account emissions during the processes of extraction, refining, transportation and consumer use. Oil that requires more refining, for example from California and Canada, scores worse than that from other areas such as Saudi Arabia. Thus the gasoline produced from it must be mixed with “cleaner” fuels to achieve required carbon reductions (Gatto, 2013). BCG indicates that California could lose up to $4.4 billion in tax revenue per year by 2020, the majority of which will come from lost excise taxes on fuels and that other revenue losses will come from decreases in personal income taxes, corporate taxes, property taxes, and sales taxes.

Not surprisingly (i.e. based on the experiences in Europe in the same area) a pressing and difficult challenge for the implementation of LCFS also lies in dealing with the issue of ILUC associated with clearing of land and cultivation of energy crops (Farrell & Sperling, 2007). In short, US actors are also finding these are complex and difficult to quantify accurately (Yeh et al, 2012). Public legitimacy issues are also growing in this area (Gatto, 2013).

5.5 POTENTIAL DEVELOPMENTS IN THE U.S.

The content of this chapter has presented a complex and path dependent emergence of the biofuels sector in the US. The first decade of this century saw extremely rapid expansion of the ethanol sector and the emergence, and rapid growth of the US biodiesel as well. At the current juncture, this analysis indicates that while the current size of the sector appears assured – and its further growth is mandated – there lie a number of constraints that US policymakers must track in coming years. This brief section focuses on the issue that must be overcome in the near future for the US biofuels industry to move forward at the rates envisioned by policymakers.

5.5.1 Fleet related bottlenecks for U.S. ethanol

A major challenge facing the continued expansion of the US ethanol market is that the country does not appear to have the vehicles to consume the fuel that will be produced by mandated increases in production. The 10% blend wall on ethanol in gasoline for conventional vehicles still poses a significant barrier to expanding ethanol consumption beyond current levels (circa a half million m^3/yr; 14 billion gallons/yr) (Schnepf & Yacobucci, 2012)[61] which is far less than future RFS mandates

[61] Note that 15 billion gallons is the cornstarch ethanol limit for the expanded RFS in the EISA.

Almost all gasoline in the United States is already blended with 10% ethanol (E10). A key benefit of gasoline-ethanol blends up to 10% ethanol is that they are compatible with existing vehicles and infrastructure (fuel tanks, retail pumps, etc.). All automakers that produce cars and light trucks for the U.S. market warranty their vehicles to run on gasoline with E10 (Yacobuccie, 2010; Shnepf 2012). For ethanol consumption to exceed the so-called blend wall and meet the RFS mandates, increased consumption at higher blending ratios is needed. For example, raising the blending limit from 10% to a higher ratio such as 15% or 20% would immediately expand the "blend wall" to somewhere in the range of 77 x 10^6 m^3 to 100 x 10^6 m^3 (20 billion to 27 billion) gallons. The U.S. ethanol industry is a strong proponent of raising the blending ratio.

To allow more ethanol use, vehicles will need to be certified and warranted for higher-level ethanol blends, or the number of ethanol FFVs will need to increase markedly. Indeed, unless higher-percentage ethanol blends can achieve significant market penetration the situation looks very challenging. E10 was the maximum ethanol blend allowed for use in most of the vehicle fleet until 2011. In response to industry concerns regarding the impending "blend wall", the EPA, after substantial vehicle testing, issued a partial waiver for gasoline that contains up to a 15% ethanol blend (E15) for use in model year 2001 or newer light-duty motor vehicles (i.e., passenger cars, light-duty trucks, and sport utility vehicles). However the EPA also ruled that no waiver would be granted for E15 use in model year 2000 and older light-duty motor vehicles, as well as in any motorcycles, heavy duty vehicles, or non-road engines (Schnepf, 2012). According to the Renewable Fuel Association (RFA), the approval of E15 use in model year 2001 and newer passenger vehicles expands eligibility to 62% of vehicles on U.S. roads at the end of 2010 (RFA, 2011).

However, while numerous ethanol producers have been approved by EPA to sell their ethanol for blending into E15, as of August 2012, only one retailer in Kansas had announced that it has E15 for sale (US EIA, 2012d). Shifting focuse to motor vehicles, Irwin and Good (2013a) indicate that to date only GM and Ford have warrantied 2012 or 2013 models for E15.

Figure 26 below shows ethanol and diesel shares in their respective fuel pools. As can be seen the ethanol share has fluctuated near 10% since 2010.

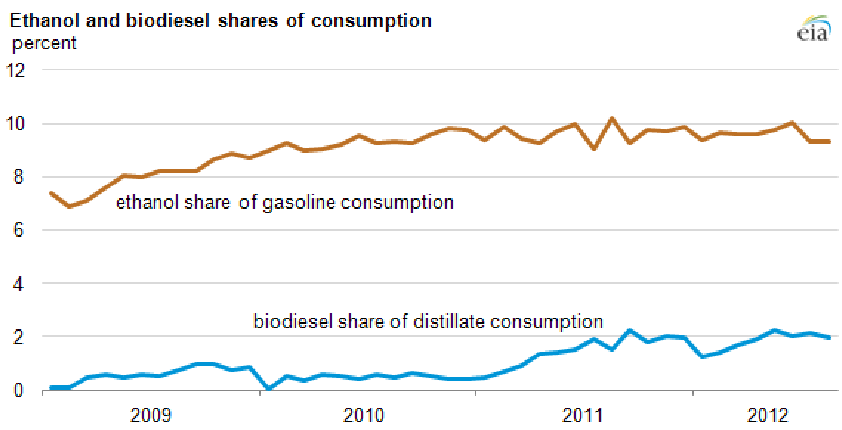

Figure 26. Ethanol and biodiesel shares (consumption). Source: U.S. Energy Information Administration (US EIA, 2012e)[62].

[62] US EIA (2012e) Figures 1 and 6.

While the blend wall issue appears acute for ethanol, diesel on the other hand is not affected by blend wall considerations. This is because up to a 5% share of distillate is approved in (essentially) all blends, a level not yet approached by production. While it is challenged by feedstock cost issues, unlike the ethanol industry, the biodiesel industry still has room to grow without major changes to existing regulations or to vehicle fleets. Biodiesel made up less than 1% of diesel fuel and heating oil consumption in 2009, growing to 1.5% in 2011 (US EIA, 2012d). Biodiesel's share of all distillate peaked at 2.2% in September 2011 and peaked again at similar levels in mid 2012. As indicated, these peaks still lie far below the 5% by volume that is approved for use in all diesel engines in the US (US DOE AFDC, 2013a).

5.5.2 Slow progress with 2nd Generation Fuels

Cellulosic biofuels production to date is far below the targets set by the Energy Independence and Security Act of 2007 (EISA 2007) and significant doubts exist in the US regarding the ability of the U.S. biofuels industry to meet the expanding mandate for biofuels from non-corn sources such as cellulosic biomass materials (Schnepf & Yacobucci, 2012, EIA 2013b). Cellulosic ethanol production capacity has been very slow to develop to develop to date (EIA, 2013b), and biomass-based biodiesel remains expensive to produce.[63] For the latter, this is largely owing to the relatively high prices of its feedstocks (Schnepf & Yacobucci, 2012).

The US EIA (2013b) indicates that despite the growth potential over the next several years, the path to commercial cellulosic or other second-generation technologies has been difficult. A number of biofuels projects were canceled before starting major construction and many projects have experienced delays in their commercialization attempts. They indicate that several factors have retarded the commercialization of the new technology systems (ibid.):

- Difficulties obtaining financing in the aftermath of the debt crisis
- Technology scale-up difficulties at startup companies
- Shifts in corporate investment strategies related to the increased availability of low-cost natural gas

US EIA (2013b) reports that several companies combined to produce about 20 000 gallons (only 76 m^3!) of fuels using cellulosic biomass (e.g., wood waste, sugarcane bagasse) from commercial-scale facilities in late 2012. However, they estimate that output could grow to more than 5 million gallons (nearly 19 000m^3) in 2013, as operations ramp up at several plants. Additionally, several more plants with proposed aggregate nameplate capacity of around 250 million gallons (circa 950 000m^3 or 5.2 TWh) could be in production by 2015 (US EIA, 2013b). As such the coming 2 or 3 years appear to be pivotal for the emergence of advanced technology platforms in the US.

5.5.3 Infrastructure bottlenecks for further expansion of the U.S. biofuels sector

In addition to the bottlenecks within vehicle fleets, there are infrastructure issues that place constraints on the US biofuels expansion. Two examples are provided here.

[63] Note that biodiesel qualifies as an advanced biofuel in the US because of its nominal >50% GHG saving potential.

Considerable uncertainty remains regarding the development of the infrastructure capacity (e.g., trucks, pipelines, pumps, etc.) needed to deliver the expanding biofuels mandate to consumers (Schnepf & Yacobucci, 2012). At present ethanol is not blended with gasoline at the refineries, as it can easily absorb water and it is corrosive for the existing gasoline supply pipes. Hence ethanol needs to be transported by road/rail to the filling stations and blended with gasoline (AAAS, 2011). In order to hasten the process of improving the situation, the Federal government has provided loan guarantees for pipeline upgrades, and to make other infrastructural changes at filling stations. In 2009 DOE announced to award $30 million in biofuel infrastructure grants (AAAS, 2011).

An additional efficiency challenge is also posed by long distance transportation infrastructure. While petroleum has traditionally flowed in pipelines from the coast into the interior in the US, the flow of ethanol has been in the opposite direction, and has been predominantly achieved via road and rail based transports – a markedly less efficient system (US DOE AFDC, 2013a). Again, existing infrastructure is unsuitable for ethanol. Most ethanol leaves the production plant on trains. Rail shipment is deemed most efficient when a train of approximately 100 cars (a so-called “unit train”), is loaded entirely with ethanol and sent to a single destination. Over the last few years, the development of unit train terminals has been focused on the Northeast, California, and Texas (US DOE AFDC, 2013a). While a major plan for a pipeline (US$ 3.5 billion in scale) to deliver ethanol from the Midwest to the Northeast was being developed by a partnership including one of the largest ethanol producers (Parker, 2012) this has been dropped as the potential for Federal funds was withdrawn during 2011 (US EIA, 2012e).

5.5.4 The legitimacy of the RFS2 may erode

With some 40% of the US corn crop dedicated to ethanol production, the scale of the industry and its environmental implications have increasingly attracted attention from critical social actors (Moschini et al 2012; Schnepf et al 2012) and placed it as a central position within critical discourses – not least the “food versus fuel” debate. Schnepf et al (2012) indicate that emerging resource constraints related to rapid expansion of U.S. corn ethanol production have provoked questions about its long-run sustainability and the possibility of unintended consequences in other markets as well as on the environment.

As has been mentioned in a number of areas in this discussion, a good deal of the social and political legitimacy of the US biofuels industry is founded in its contribution to fuel self-sufficiency and its contribution to the rural economy. Two issues at least can be associated with the nexus of renewable fuels and these prerequisites for socio-political legitimacy.

With the RFS2, a new situation is arising as a first issue – the environmental and sustainability concerns have led to a cap on corn ethanol. In essence this means that nearly all growth the biofuels market must be supplied by “advanced fuels” (those with greater than 50% GHG savings), of which the major part is to be cellulosic ethanol. Corn ethanol in excess of allowable amounts will presumably be exported, as was the case in 2011. Yet the cellulosic technology systems are not yet delivering yet – and may not deliver for some time forth. As a result, the issue of reliance on the import of foreign “advanced fuels” in order to meet the demands of the RFS2 mandates is raised.

This could fly in the face of both fuel “autonomy” and rural development.[64] Yet, Moschini *et al* (2012) indicate that the role that international trade can play in the path toward fulfilling biofuel mandates (in the United States, the EU and elsewhere) remains to be clarified.

Important considerations in this context are the implications of the sustainability standard within the RFS. For example, the provision of the unspecified portion of advanced biofuels (i.e., apart from cellulosic biofuels and biodiesel) of the RFS mandates in the United States, (to rise to 4 billion gallons by 2022), may well have to rely on sugarcane ethanol that has been imported from in Brazil (Moschini *et al* 2012). As indicated above, this may take place while US ethanol is exported.

As such the apparently perverse prospect of the United States importing sugarcane ethanol from Brazil to meet low-carbon standards, while at the same time exporting corn-based ethanol (even to Brazil!) could arise. Also, lack of international harmonization of sustainability standards, and lack of uniform guidelines and institution for the certification and enforcement of these standards, holds the potential for such standards to become serious impediments to trade. The plethora of biofuel programmes and subsidies is held to create situations ripe for trade conflicts (de Gorter, Drabik and Just, 2011).

While import of ethanol from abroad to meet RFS targets is discussed seriously by mainstream sources examined in this (cf. de Gorter et al, 2011; Moschini et al, 2012; Irwin and Good, 2013a; 2013b) the picture remains unclear at present. As has been discussed earlier in this analysis, challenges facing the expansion of biofuels via ethanol pathways are limited by the fact that the blend wall has essentially been reached.[65] Irwin and Good (2013a, b) estimate the blend wall at 12.9 billion gallons of pure ethanol (4.88 x 10^7 m^3; 269 TWh) – a figure at the level of domestic consumption in each of the previous three years. Total gasoline consumption has stagnated hence the market for standard E10 will not accommodate mandated volumes; E15 pumps and E15 cars are not available across the market hence that pathway has not yet grown; the E85 market is only about 100 million gallons ((3.79 x 10^5 m^3; 2.08 TWh) and in optimistic estimates is only anticipated to expand to 300 million gallons in 2014 and then 600 million gallons in 2015 (Irwin and Good, 2013b)). These authors indicate that this is unlikely, as it requires a coincidence of high gasoline prices and low corn prices (bumper crops) for ethanol production to be profitable.

Their analysis lead them to conclude that full implementation of the RFS in 2013-2015 would drive a boom in domestic biodiesel production. However, they point out that this is problematic for two reasons. Firstly, while the US has over capacity for biodiesel production, it is insufficient to fill the required gap. Substantial capacity would need to be added in a very short period of time to meet the

[64] Should corn ethanol be exported, then presumably that industry also benefits the rural sector. However, this issue presumably also brings with it a constraint on further expansion of the sector – that may be unpopular, or even detrimental to the rural economy.

[65] Irwin and Good, (2013a) report that the difference between the blend wall and the RFS mandate could be met for a short time via the use of RINS credits accumulated by obligated blenders as they have blended in excess of the RFS in previous years. However, they project that this stock of RINS credits will be used up by early 2014, so this is not likely to be a longer-term solution the E10 blend wall. Another manner in which the blend wall problem could be surmounted is if some of the RFS for renewable biofuels (ethanol) can be met with discretionary blending of advanced biofuels in excess of the RFS mandate for this category of biofuels (e.g. with Brazilian ethanol or US biodiesel). That alternative is currently limited by the bounds on the RFS for advanced biofuels – but also entails an economic loss associated with blending those biofuels (biodiesel and Brazilian ethanol).

biodiesel requirements stemming from the current RFS and the ethanol blend wall. Second, Irwin and Good (2013b) argue that the increase in biodiesel feedstock requirements would overwhelm feedstock markets.

A second issue is the rapidly increasing production of oil and gas from non-conventional reserves such as shale and tight rock sources. As discussed in the opening chapter of this report, leading analytical institutions around the world are now projecting the prospect of self sufficiency in oil from the US by 2030. Indeed, gas prices have already dropped markedly in the US as a result of a surge in the availability of natural gas from fracked shale deposits. As such, the prospect of the "need" for biofuels in order to improve US energy security becoming quite rapidly redundant is also present.

While difficult to speculate how these issues can affect the further expansion of the sector, it does appear worthy of examining the real potential that political support for the expensive and difficult process of bringing cellulosic ethanol production online may wane. Similarly, the prospect of importing foreign biofuels to meet mandates may raise critical voices. Both such factors could conceivably result in a winding back of fuel mandates in coming years.

5.5.5 Concluding words

A significant lesson that can be taken from the US is that a mixture of policy measures such as blend mandates and tax credits can instigate massive expansion of renewable fuels – even in a country where the pump cost of fuels is much lower than in essentially all developed economies. The central policies have been supported with various Federal and State incentives in the form of grants, awards and loan guarantees to prepare the existing market to incorporate biofuels.

Undoubtedly, the US biofuel policies revolve around tax credits and compulsory blend mandates set by the Renewable Fuel Standard under Energy Independence and Security Act (EISA) 2007. Compulsory blend mandates set under the RFS2 are leading the production of biofuels especially ethanol and second generation biofuels in the US. In absence of mandates and supporting Federal as well as State incentives, the biofuel market lacked the stimuli required for rapid growth to the scale where it comprises a significant share of the national fuel mix. It must also be recognised that the unprecedented growth of the sector over the past decade has also been supported by extremely large support for capital investment – both as grants, and as loan guarantees.

At this point in time, there is still continuing interest in expanding the U.S. biofuels industry as a strategy contributing to both energy security and environmental goals. However, it is possible that increased production may place desired policy objectives in conflict with one another (Schnepf et al, 2012). There are limits to the amount of biofuels that can be produced from current feedstocks such as corn and soya, and questions about the net energy and environmental benefits they actually provide. Further, rapid expansion of today's dominant biofuels is increasingly expected to have a number of unintended and undesirable consequences for agricultural commodity costs, fossil energy use, and environmental degradation. While very significant efforts are being made to expand the industry into fuel production pathways that do not compete with agricultural commodities, and are expected to have demonstrably reduced life cycle impacts (e.g. cellulosic ethanol), the pursuit of such technology platforms remains slower than desired.

Owing to these concerns, alternative strategies for energy conservation and alternative energy production are widely seen as warranting consideration. Among these are non-conventional oil and gas production pathways – and in recent years these have had a large impact in reducing US oil dependency, and in driving the price of gas in the US to much lower levels. Moreover and has been outlined above, the biofuels sector has reached a point where meeting mandated RFS volumes is constrained by several structural issues. While the US EPA has only chosen to write down the cellulosic component of the advanced mandate to date (but not the total RFS mandate or the total advanced fuel mandate) Irwin and Good (2013b) indicate that reversing this policy and writing down the totals at the same time that cellulosic is written down may be the only way to provide much needed breathing room for the markets. They hold that this may be the only realistic path for implementing the RFS in the next several years.

In closing, while the current scale of the industry appears assured, the “mandated” doubling of the US biofuels sector over the next decade does not. This analysis indicates that a significant slowdown of expansion – or even a stagnation of the sector – may be likely for the next few years.

6 REFLECTIONS ON THE HISTORICAL OVERVIEW

In the historical overview about the policy instruments directed at biofuels in Brazil, the European Union and USA in the previous chapters, there are things to be lifted for the following discussion:

- These three jurisdictions have been chosen as they produce and consume the vast majority of all the renewable transportation fuels produced and consumed globally.
- Policy instruments have been the key driver for the development of domestic production and consumption of biofuels in these jurisdictions.
- The extent to which policy instruments are needed to support an existing production-consumption chain depends on the development of the industry and local circumstances.
- A mix between blending alternatives for petrol and diesel for undedicated vehicles as well as pure biofuel alternatives for dedicated vehicles have been introduced in all studied countries/regions.
- Tax exceptions together with mandatory quotas, volumes or blending standards[66] are part of the policy instruments that have been applied in the studied jurisdictions, but to a shifting extent. A common trend has been to use tax exemption during a development phase and to use mandatory blending as the main tool subsequently.

Other things are harder to make direct conclusions about, such as the main drivers for the development of the domestic production-consumption chain for biofuels. Three factors that have been important are energy independence, rural development, and the abatement of greenhouse gas emissions, but to what extent one is a leading driver is more difficult to clarify, since they all are desirable. To objectively assess this is difficult, except in some cases, e.g. climate change mitigation may be the key driver in a country where the biofuels to a large extent are imported, since this neither gains rural development nor energy independence.

The changing landscape for policy instruments brings about insecurity that commonly is harmful for industrial development, but it is worth to remember that the biofuel industry is young. Most of the development of production volumes worldwide has been achieved since the turn of the century and this is also true for the country with the longest history in the field – Brazil. This means that decision takers to some extent has to test different options in the support of the biofuel industry, since policy instruments that have worked in one field not automatically will work in another. Presently, mandatory quotas/volumes/blending standards have become the most significant policy instrument(s) in the countries/regions studied, which could also be expected when the production has grown to noteworthy volumes in comparison with conventional transportation fuels. It is observed that application of interventions such as common tax exemptions serves a purpose in the build-up of the industry, but the continuation of tax exemptions as the prime policy instrument, will sooner or later reach a limit when the tax losses are too large for a state to tolerate. This limit seems to have been reached in the studied jurisdictions. The extra cost for biofuel production will with mandatory quotas/volumes/blending standards not be directly taken by the state and in most countries

[66] Mandatory quotas, mandatory volumes, and mandatory blending standards are technically different options, see section 2.1, but may in the absence of tax reductions lead to similar results, i.e. the dominance of blended biofuels, since pure biofuels in this case will be too expensive to market, see Section 4.4.

there are possibilities to pass on the extra cost for blending to consumers, since the road-based transportation sector not have good possibilities to fill the tank in other countries. It is rather the political circumstances that limit this possibility, since higher fuels prices not always are popular among the public.

Among the countries that have experienced significant losses in taxes through tax exemptions are Germany in 2007 and, more recently, Sweden. Germany changed the policy from tax exemptions to mandatory volumes with some remaining possibilities for tax exemptions as described in Section 4.3 and Sweden is about to do a shift from a pure tax exemption system to a combined tax exemption mandatory quota system in 2014 (Ministry of Enterprise, Energy and Communications, 2013), see Section 7.2. As described in Section 4.4 about Germany, a total shift from tax exemptions to mandatory quotas will lead to a higher share of blended biofuels on the expense of pure biofuels. The proposed change in Swedish policies will still leave all the pure and high-blended biofuels with the previous tax exemptions[67], and they are not part of the mandatory quota fuels. One likely outcome of such a change is that a similar decline in pure biofuels as has been experienced in Germany not will occur in Sweden, see Section 7.2.

There are also other factors that work in the favour of mandatory quotas, volumes, and/or blending standards. Within the EU, countries are to some extent limited in their choice of policy instruments, since the EU regulations allow for exemption or reduction in tax for biofuels, but not to over-compensation of the extra costs of production in comparison with the fossil counterparts (Council of the European Union, 2003). Hence, there are limits to the extent to which tax exemptions may be applied and this will favour mandatory quotas, volumes, and/or blending standards as the main incentive for the development of the biofuel industries in the EU countries.

However, there are technical limitations for the use of blending standards, since this policy instrument not will work without effort for all renewable energy carriers for transportation. Examples of such energy carriers are biogas, dimethyl ether (DME), and electricity. These energy carriers cannot be directly mixed with petrol or diesel and this means that the policy instruments cannot be technology neutral as long as mandatory blending standards are applied. To include these energy carriers in a mandatory volume system is possible, at least in theory, but since they demand both a dedicated infrastructure as well as dedicated vehicles they are not competing on a level playing field with the energy carriers that may be blended with fossil fuels. Other types of policy instruments, such as, R&D support, investment support, public procurement, and tax exemptions, are therefore needed if there is a political will to develop these options as well.

[67] This means a full relief from energy and carbon dioxide taxes while VAT is paid for biofuels.

7 THE FUTURE FOR SWEDEN

7.1 POLITICAL INTENTIONS REGARDING THE USE OF RENEWABLE TRANSPORTATION FUELS IN SWEDEN

As is revealed in Figure 4, the consumption of oil and oil products in Sweden has almost halved during the last forty years, but while the consumption has been substantially reduced in the industry, energy utility[68], and residential sectors (Swedish Energy Agency, 2012a), it has increased in the transport sector, see Figure 6. Previous efforts to reduce the oil consumptions has not affected the transport sector anywhere near as much as it has affected other sectors, despite an increase in taxes for oil products in the transport sector that has not occurred in for instance the industry sector, see Figure 5. The most likely explanation for why the development towards less oil consumption has yet to reach the transport sector is that there until recently has been no obvious alternatives to fossil fuels for road transports[69] acting in combination with the fact that the price elasticity for transportation fuels is relatively low, which studies of price elasticities of transport fuels indicate (Dahl & Sterner, 1991; Sterner 2006). The problems of reducing the oil consumption in the transport sector may also explain why there is an emphasis on the transport sector when reduced consumption of fossil fuels are discussed in Sweden and elsewhere.

As a member state of the European Union, Sweden has had obligations to reach targets for the amount of biofuels in comparison with all petrol and diesel used for transportation purposes. This share to be fulfilled by the end of 2005 was 2% and by the end of 2010 5.75% (European Parliament and the Council, 2003)[70] and Sweden managed to reach beyond both these targets[71]. The target for 2020 has been set to 10%, but this is for the total amount of renewable energy sources, not for biofuels alone, and emphasis is also put on the sustainability of the renewable energy sources (European Parliament and the Council, 2009a). Added to this is the proposal from the European Commission that the share of renewables originating from edible feedstock not should exceed 5% (European Commission, 2012a), thus putting pressure on other production routes.

The development of Swedish policies to promote renewable energy sources in the transport sector should be seen as part of the EU context, but Sweden has also an own agenda in this field. The Swedish government has for several years expressed the ambition that the vehicle fleet should be independent of fossil fuels by 2030. This ambition was first expressed in a governmental proposition (Ministry of the Environment, 2009), where three technical options were mentioned for how this could be achieved: plug-in hybrids, electrical vehicles, and biofuels. The term independent (in Swedish: oberoende) is not defined in the proposition, but should been seen as part of the vision that Sweden not should generate any net emissions of greenhouse gases by 2050[72]. It is also stated the goal will be a challenge to reach independence (irrespective of what it means), since the transport system in Sweden is almost totally dependent on fossil fuels. The transport sector’s share of the Swedish greenhouse gas emissions was almost 32 percent in 2007, which is a high figure inter-

[68] Electricity and district heating production.
[69] Among other things, the functionality of liquid energy carriers with high energy density that are available at (relatively) low cost has not been matched by alternatives.
[70] These targets are expressed as reference values on the basis of energy content for every member states.
[71] Only Germany and Sweden managed to reach the target for 2005 (European Commission, 2007).
[72] This vision should, accoring tot he proposition, be reached by powerful policies inside and ouside Sweden.

nationally. For EU15, the corresponding figure was 21 percent and the main reason for the high share in Sweden is the low share of fossil fuels in the energy utility sector (Ministry of the Environment, 2009). In contrast to the goal for the transport sector, the proposition entails a well-defined goal regarding another application for fossil fuels on the way to the vision for 2050: fossil fuels should not be used for residential heating by 2020.

The government states in the proposition that general policy instruments should be the foundation for the change towards abatement of greenhouse gases from the transport sector and is referring to policy instruments that set a price for greenhouse gas emissions. However, it is further stated that the general policy instruments are to be combined with more targeted policy instruments and describe such policy instruments in use in Sweden. These are research, development and demonstration (RD&D) support to companies and academia, tax exemptions for green cars, obligations to supply biofuels for filling stations, blending standards, emissions standards for vehicles, sustainability criteria for biofuel production, greenhouse gas emission demands on suppliers of transportation fuels, tax reliefs on biofuels, investment supports directed at biogas and second generations biofuels, and support for development of electrical cars and plug-in hybrid electric vehicles. Sweden should also work for a removal of the EU ethanol toll used for blending according to the proposition and it is announced that the Swedish Energy Agency should investigate the use of blending quotas instead of tax reliefs, see below. These general and targeted policy instruments should also be combined with information campaigns about fuels efficiency (eco-labelling) and efficient driving, together with changed speed limits and increased speed controls.

Following the vision that Sweden not should generate net emissions of greenhouse gases by 2050 as presented in the proposition, the government commissioned the Swedish Environmental Protection Agency to investigate how this could be achieved in July 2011. A report in the form of a road-map for such a development was delivered to the government in December 2012 (Swedish Environmental Protection Agency, 2012). According to this analysis, the goal with zero net emissions could be achieved by large domestic abatement of greenhouse gas emissions, by the utilisation of terrestrial sinks, and by creating emission reductions in other countries to balance the remaining Swedish emissions. The analysis was general in its character and it was also stated that to suggest a complete list of policy instruments until 2050 not is meaningful, since we not can be sure about future technologies, behavioural patterns, and international policies. Still, suggestions were made and the proposed changes for policy instruments were mostly aimed at affecting investments in technologies and infrastructure that have long lifetimes or demand development, demonstration, or new markets. Regarding general policy changes, it was suggested:

- that all relevant public documentation should be judged regarding the impact on the climate,
- that Sweden should work for decreased limits within the EU ETS,
- that the energy and CO_2 taxes should continue to be pillars of the Swedish climate strategy,
- that Sweden should work for increased funding of research and innovations within the European Union, especially regarding technologies that are strategic for mitigation of climate change,
- that the regulatory framework for energy efficiency should be developed and, specifically, development of the Ecodesign Directive (European parliament and the Council, 2009c) as well regulations for energy savings in the residential sector, and

- that the connection between consumption and greenhouse gas emissions should be visualized by developed official inventories and reporting.

The suggested policy instruments directed at the transport sector were also relatively general in their character and it was recommended that:

- Sweden should work for a stepwise development of the EU emission standards for new vehicles,
- a national bonus-malus system for registration tax on new cars should be investigated,
- a geographically differentiated system for infrastructure fees for heavy transports should be investigated,
- regulations regarding infrastructural planning at different levels should encompass analysis of how to reduce transports and visualization of the conflicting goals between increased transport capacities and climate goals,
- funding should be provided for research and pilot/demonstration plants for second and third generation biofuels,
- policy instruments directed at both production and demand are necessary to stimulate the development of second and third generation biofuels,
- the knowledge about policy instruments has to be developed,
- the knowledge about structures for a less transport-demanding society has to be developed,
- research on energy efficient vehicles should be directed at areas where Sweden could develop its competiveness, and
- the use of policy instruments with other primary aims, such as congestion taxes and infrastructural fees, should be increasingly used for climate purposes.

As can be seen from the suggestions above, the Swedish Environmental Agency suggested a wide range of policy instruments for how to achieve the vision of a Sweden with no net emissions of greenhouses gases by 2050. Among the discussed changes in the transportation sector, energy efficiency measures through more fuel efficient engines and a transition to hybrid and electrical cars are mentioned. However, no other policy instruments than the ones listed above are mentioned explicitly for the support of such energy efficiency measures.

It is evident that the ambitions for climate change mitigation, as described in the governmental proposition, are high and that an important part of this is the transportation sector. It is also clear that the measures as listed in the proposition and in the roadmap from the Swedish Environmental Protection Agency above are not sufficiently specified, at least not to reach the ambition for 2030; hence, a public inquiry about how to reach the goal with a vehicle fleet independent of fossil fuels by 2030 was commissioned by the Swedish government in July 2012 (Ministry of Enterprise, Energy and Communications, 2012). Since this goal has not been specified previously, part of the work will be concentrated towards establishing different alternatives for what independent of fossil fuels mean to be a relevant step on the way towards the vision of no net emissions of greenhouse gases by 2050 (ibid.). The results from the public inquiry are to be reported by the end of October 2013.

7.2 THE NEW SYSTEM FOR MANDATORY BLENDING IN SWEDEN

A system for blending quotas of ethanol and biodiesel was investigated by the Swedish Energy Agency (2009) and this subsequently lead to a proposed system for mandatory blending quotas presented in a memorandum from the Swedish government during the work with this report (Ministry of Enterprise, Energy and Communications, 2013). It is a hybrid between tax exemptions and mandatory blending where the previous full tax exemptions are limited to pure and high-level blended biofuels. Full tax exemptions means a complete relief from energy and carbon dioxide taxes while value added tax (VAT) is still paid by the consumer. The biofuels used for blending in the mandatory quotas will be given exemptions for the carbon dioxide tax but not for the energy tax. The pure and high-level blended biofuels are to be treated separately from the mandatory quota system and this means that the mandatory quotas have to be fulfilled with low-level blends of biofuels. As described in Section 4.4, a shift from tax exemptions to mandatory quotas/volumes will commonly lead to a higher share of blended biofuels on the expense of pure biofuels, but one probable outcome of the Swedish system is that a similar decline in pure biofuels as has been experienced in Germany not will occur due to the sustained tax exemptions.

The motives for this hybrid design are not explicitly expressed, but it is reasonable to assume that the main reasons are to create a system of policy instruments where the share of biofuels is more easily controlled, to avoid most of the tax losses encountered with the previous tax reliefs for blended biofuels, and to keep the market for high-level blended and pure biofuel. Another plausible reason why the Swedish government has chosen to treat pure biofuels separately is that a pure mandatory quota system without tax exemptions not is suitable for renewable transportation fuels that not are possible to blend, e.g. biogas which is an emerging biofuel in Sweden, see Figure 3.

The Swedish tax exemption has been relatively successful, but there are limits in how the tax exemptions could be used to further promote biofuels. The Energy Tax Directive (Council of the European Union, 2003) does not allow tax exemptions that over-compensate the extra costs for the manufacture of the renewable transportation fuels, as was previously mentioned in Chapter 6. Over-compensation is in this case when biofuels on the market would be cheaper than fossil fuels because of support systems, thus generating state aid. Hence, there are limits to the extent to which tax exemptions may be applied and this will favour mandatory quotas, volumes, and/or blending standards as the main incentive for the development of the biofuel industries in the EU countries. Thus, seen in the light of the risk for over-compensation, the shift towards a mandatory quota system in Sweden is logical.

Since the profitability of a biofuel in comparison with a fossil counterpart is dependent on the relative price of the feedstocks, the taxation system needs to be flexible to avoid over-compensation according to the Energy Tax Directive. How flexible the taxation system needs to be to avoid over-compensation is not specifically stated, but it is unlikely that fluctuations in the price for crude oil over some weeks will trigger actions towards a Member State[73]. The European Commission has approved the current Swedish tax exemptions until the end of 2013 and the new hybrid system will almost certainly not be considered as over-compensation (Ministry of Enterprise, Energy and Communications, 2013). A factor contributing to this opinion is that pure and high-level blends of biofuels will be considered as separate product categories since they demand dedicated vehicles

[73] Personal contact, Martin Palm, Ministry of Enterprise, Energy and Communications, Stockholm, Sweden.

and in many cases also dedicated infrastructures for fuel distribution. Contrary to this, low-level blends are in direct competition with conventional transportation fuels.

The suggested mandatory quotas for petrol are 4.8% biofuels (by volume) from May 2014 and this figure will be changed to 7% in May 2015. For diesel the mandatory quotas are 9.5% biofuels (by volume) of which 3.5% should be biofuels with additional benefits. The fuels with additional benefits are in accordance with the fuels considered to give additional benefits in the Renewable Energy Directive (European Parliament and the Council, 2009a), e.g. fuels made from wastes, residues, non-food cellulosic materials, and ligno-cellulosic materials. The biofuels that are to be blended with petrol and diesel are not specified except for the share that should provide additional benefits and that they all should fulfil the sustainability criteria, all in accordance with the Renewable Energy Directive[74]. Nevertheless, the options are in the short run realistically limited to ethanol for petrol and fatty acid methyl esters (FAME) and hydrotreated vegetable oil (HVO) for diesel.

The quota for petrol is for the first year set so that it will not generate any additional problems for fuels suppliers as the quota actually matches the current share; the quota for diesel is higher than the current share. One reason why the quota for diesel is higher than what is sold today is that the higher-level blend in diesel not requires technical modifications for the suppliers. Contrary to this, a blend with between 7 and 10 percent ethanol by volume in petrol will require some technical modifications at filling stations, etc. It may be seen as a contradiction that 6% of the quota for diesel may be reached by biofuels that not bring about additional advantages and that no such limitations are set for the biofuel share in petrol, since the EU has proposed that first generation biofuels should be limited to 5% of the total (European Commission, 2012a). However, it is important to notice that the limit in EU is set on energy basis while the suggested limits in Sweden are set on volume basis. This difference is important since for example ethanol has a much lower energy density than petrol.

7.2.1 Side effects of the Swedish quota legislation

The greenhouse gas emission savings as required for the sustainability criteria in the Renewable Energy Directive will be changed from 35% to 50% from January 1, 2017 (see Section 4.2). Most of the FAME used for blending in Sweden emerges from rapeseed and this biofuel does not generate enough greenhouse gas savings to qualify as sustainable according to default values in the Renewable Energy Directive.[75] This will – together with the relatively high quota for biofuels with additional benefits – put extra pressure on biofuels produced from non-edible feedstock. In Sweden the most used and most likely alternative is in this case HVO from tall oil, which also is mentioned indirectly in the memorandum (Ministry of Enterprise, Energy and Communications, 2013). Tall oil is a rest product from the pulp industry and is used for different purposes, e.g. as a fuel oil or as feedstock for a variety of relatively advanced chemical products.

The tax exemptions for industrial fuel oil (c.f. Figure 5) commonly make it less costly to use conventional fuel oil than tall oil in e.g. the lime kiln in kraft pulp mills. The high tax on fossil trans-

[74] More specifically: the sustainability criteria as set out in the requirements in the Swedish law for sustainability critiera of biofuels (In Swedish: Lag (2010:598) om hållbarhetskriterier för biodrivmedel och flytande biobränslen) created to implement the requirements of the Renewable Energy Directive.

[75] Parts, or even a large share, of the FAME production may qualify as sustainable according to RED when calculations are performed specifically for the Swedish production.

portation fuels in combination with low taxes on fossil fuels oils used in industrial production has together with the tax exemptions for biofuels also made the production of HVO from tall oil an interesting option. Here it is worth noting that the asymmetrical tax on fuel oil between different sectors not is a new phenomenon in Sweden, but the use of tall oil for HVO production is. The production and consumption of HVO has rapidly increased during recent years and it is estimated that its share of the total amount of diesel consumed in Sweden was 1% in 2011 and 2% in 2012, but the feedstock for the HVO consumed in Sweden is also e.g. rapeseed and animal fats (Ministry of Enterprise, Energy and Communications, 2013). Naturally, this raises questions whether it is optimal to use tall oil as feedstock for biofuel production instead of using it as a fuel oil in internal industrial applications where conventional fuel oil is used. The consumption of fossil oil will be similar; it only implies that fossil oil is used as fuel oil in industry instead of as feedstock for transportation fuels.

The use of tall oil for biofuel production instead of using it for fossil fuel replacement in industrial applications is merely a question whether this practice is efficient considering the mitigation of climate change. The tax exemptions for fuel oil used in industrial applications is also supporting the use of tall oil in the chemical industry that produce other types of chemical products, but this ought to be less controversial if these products are advanced products used in applications where they not are readily replaced. However, the new quota system will possibly lead to a shortage of feedstock for the chemical industry, and this is an outcome of the new quota system that is not discussed in the memorandum. The above mentioned stricter demands for greenhouse gas savings in 2017 as specified in the Renewable Energy Directive will put additional pressure on the tall oil market and thus add to the effects as described here, since the possibilities for rapeseed-derived FAME will be limited. This not unlikely development may be described as an unintended outcome of the policy instruments used to promote production and consumption of biofuels.

One effect that is discussed in the memorandum (Ministry of Enterprise, Energy and Communications, 2013) is the problems a decreased toll on ethanol used for low-level blendings may cause for domestic ethanol productions. Due to the risk for the previously discussed over-compensation, the Swedish legislation only allowed for undenatured ethanol to be used for low-level blendings. The EU has high tolls for undenatured ethanol[76] to the union and this has had the effect that almost all the ethanol used for low-level blendings in Sweden has been from Sweden or other countries within the EU. With the new system where the possibilities for tax exemptions are limited, there is less risk for over-compensation and the Swedish government has decided to decrease the tolls on ethanol by allowing the ethanol used for low-level blending be tolled as denatured ethanol[77]. This will – at least in periods – put an extra burden on the domestic ethanol production and Swedish ethanol production will also be more sensitive to exogenous factors, such as, international harvest yields, currency fluctuations, changes in policy instruments in other countries, etc. The ethanol quotas as set from May 2015 will, however, bring about an increased demand for ethanol in Sweden and this in combination with the higher demands for greenhouse gas savings in 2017 may work beneficially for the Swedish production of ethanol. The latter since calculations indicate that the greenhouse gas saving from Swedish ethanol may be relatively high in comparison with several on the world market existing qualities of ethanol Swedish Energy Agency (2012b).

[76] At the end of 2013, this is € 192 per cubic metre.
[77] At the end of 2013, this is Currently € 102 per cubic metre.

7.3 HOW DIFFERENT OPTIONS MAY AFFECT THE AIMS

In this section we will discuss how strategies with regard to production and consumption of biofuels in Sweden will affect different societal aims. The following potential aims will be discussed:

- Climate mitigation (global view)
- Energy security
- Competitiveness

Many strategies may be imagined. Here we use a couple of rather basic scenarios to illustrate some consequences of the choices to be made in the bioenergy sector.

Scenario 1

In this scenario the potential of synthetic diesel from tall oil (HVO) is utilised in the short term. As technology matures – due to significant public funding of research and pilot plants – synthetic diesel (gasification or pyrolysis) made mainly from forest residues start to replace large shares of conventional diesel. In addition the use of biogas from residues and manure has increased significantly. In 2010, 40 TWh diesel was used in Sweden, a figure which is increasing rather quickly (see Figure 6).

Scenario 2

This scenario is similar to scenario 1 except that DME, methanol or biomethane is produced instead of synthetic diesel but with the same feedstock as in scenario 1.

Scenario 3

Some synthetic diesel is produced from tall oil, but little (if any) synthetic diesel is produced from other types of biomass before 2030. Instead substantial quantities of biomass (mostly forest residues) are exported to e.g. Germany and Denmark to replace coal and lignite in power production. Thus less renewable fuels are used in the transportation sector. As in scenario 1 the use of biogas from residues and manure has increased significantly.

Scenario 4

This scenario is similar to scenario 3 in that woody biomass is primarily used to replace fossil fuels outside the transport sector. The difference is that here a large volume of biomass is used to replace coal in the Swedish industry. The industrial coal use was 16 TWh in 2010 (Swedish Energy Agency, 2012a), but only part of this may be replaced by bioenergy. This means that the export of biomass is smaller than in scenario 3, although still higher than in scenarios 1 and 2.

Common for the four scenarios is that the approximately 3.2 TWh coal, 7.1 TWh oil, and 5.3 TWh natural gas used for heat or combined heat and power (CHP) production in Sweden in 2010 (Swedish District Heating Association, 2011) have been replaced by bioenergy. The amount of fossil fuels used for electricity production in condensing mode in Sweden is almost negligible. Since all the fossil fuels used today are used for heat with or without electricity production, this assumption is in line with the Swedish goal that no fossil fuels should be used for residential heating by 2020, see Section 7.1.

If energy security is in focus, the aim would be to match domestic energy production as well as possible with domestic use of different energy carriers. The residential and services sector and the industry sector (to a lesser extent) are already relying on domestic energy sources for most of their energy supply. Therefore producing substitutes for fossil transport fuels would be a key if energy security is to be improved. This strategy is reflected in scenarios 1 and 2, and consequently these scenarios score high on energy security. Replacing fossil diesel rather than gasoline would entail the advantage of making large part of truck transport independent of fossil import. It may be argued that truck transport in general is more vital for society than passenger car transport (perhaps with the exception of sparsely populated areas). Scenarios 1 and 2 may also score highly on industrial competitiveness. A precondition is that the development of second generation biofuel technology has generated a thriving Swedish industry. It is worth noting that although scenario 1 contains widespread use of second generation biofuel production within Sweden, the technology used is not necessarily developed and marketed by Swedish companies.

Scenarios 1 and 2 do, however, score more modestly regarding climate mitigation. This is due to the comparatively poor energy efficiency in converting cellulosic biomass to transport fuel and also because replaced oil has a lower emission factor than replaced coal. The well-to-tank energy efficiency of producing synthetic diesel from woody biomass via gasification and Fischer-Tropsch synthesis is at best 50% (Concawe et al., 2007). If black liquor is used the efficiency will be higher, around 55%. Scenario 2 is in this respect somewhat better due to the less energy intensive processes associated with producing DME, methanol and biomethane. DME produced from black liquor may entail an energy efficiency of 65% (Concawe et al., 2007). Biomethane produced from salix by pyrolysis may yield a plant energy efficiency of up to 70% (Bojler Görling et al., 2013). If cultivation and transport of the biomass is included the efficiency is somewhat reduced. There are also, especially for biomethane, energy losses associated with compression and distribution of the processed fuel.

A considerable threshold for DME and biomethane is that both dedicated vehicles and dedicated infrastructures for fuel distribution are necessary. Methane vehicles are available, but more costly than liquid fuelled vehicles. The development of biomethane vehicles is, however, assisted by the fact that the same vehicles also run on natural gas, i.e. fossil methane. DME vehicles are not available on the market, although Volvo has a small test fleet with trucks. Furthermore, almost all current methane vehicles use the otto-cycle, which basically means that the efficiency advantage for biomethane in the fuel production process is counteracted by lower vehicle efficiency. There is technology under development for using methane in a diesel-cycle (with some injection of conventional diesel), but the outcome regarding feasibility and costs is still uncertain. Another development trend is that future otto-engines may have comparable efficiencies to that of diesel engines.

On the other hand it should be kept in mind that the processes for producing DME and biomethane from woody biomass in general are less complex than the processes for producing synthetic diesel from biomass. This means that the fuel cost probably is likely to be lower than for synthetic diesel and that the technological barriers for a full-scale production plant thus would be somewhat lower.

With regard to climate mitigation, scenario 3 and scenario 4 scores better than scenarios 1 and 2. The amount of GHG mitigated per energy unit of primary biomass is almost twice as high in these scenarios. There are two principal reasons. First, as mentioned above, producing second generation transport biofuels entails a life-cycle energy efficiency of only 50-65% at best, while bioenergy replacing coal entails very low energy losses. Secondly, coal has a 26% higher carbon content per energy unit.

The potential for replacing coal by bioenergy is large outside Sweden. Only in Germany, 712 TWh coal and lignite was used for electricity production in 2010 (Weltenergierat – Deutschland, 2011). Hansson et al. (2009) has assessed the potential for co-firing biomass in coal power plants in EU - 27. Assuming that biomass may replace 10-15% of the coal, they conclude that the technical potential for co-firing biomass in EU-27 amounts to between 140 and 250 TWh of primary biomass. Almost half of this potential stems from coal plants in two countries, Germany and Poland. In the longer time perspective where completely new plants need to replace old ones the potential for biomass use is even larger.

An important factor when facing choices between different uses of bioenergy is the feasibility of the respective scenarios. Although no definite conclusions may be drawn, some observations can be made. Both scenarios 1 and 2 are dependent on significant technology breakthroughs. While the challenge regarding fuel production technology is slightly smaller in scenario 2, the barriers regarding distribution and vehicles are higher. Scenario 3 does not seem to involve major practical or technological challenges. At present there exist, however, an economic barrier, since the price of carbon dioxide in the EU ETS is only about 4 Euro per tonne (17 May, 2013). Scenario 4 will require more technological development and plant retrofitting than scenario 3.

A factor that may increasingly receive public attention is food security. The four scenarios here discussed do not differ in this respect since agricultural land is not supposed to be used for energy purposes. This precondition is realistic in that it is in the direction of both the suggested limitation on first generation biofuels suggested by the European Commission (2012a) and the new quota system for biofuels in Sweden, see Section 7.2. If other scenarios are conceived the conclusion may be different. For instance, energy forests may be grown on agricultural land. According to Baky et al., (2009) there is 300 000 to 400 000 ha of unused agricultural land in Sweden. If 250 000 ha of this was used to grow Salix, it is estimated that about 5.8 TWh of biogas could be produced annually by pyrolysis (Bojler Görling et al., 2013). By using such land, it may be argued that food security is not compromised. This argument seems to have some relevance, but it may also be put forward that what presently is unused land should be used to increase domestic food production, given that Sweden is a net importer of food commodities.

7.4 BIOFUELS – A REVITALIZATION PATHWAY FOR THE NORDIC PULP AND PAPER SECTOR?

The maintenance of a vibrant Swedish commercial forestry sector is an important social and economic issue for the country. This has many facets: a significant proportion of the forests is owned by private persons and thus the sector is directly linked to family and rural economies as "owners" as well as workforce; the ongoing husbandry of the country's forests are integral to management of natural environmental systems; the forestry sector constitutes an important pillar for the export economy supplying some 10% of the world's sawn timber, while pulp and paper provides net positive export earnings of around 100 billion SEK (KSLA, 2009); Swedish forestry companies are world leaders in technology development and leading actors on the world market and the forestry sector activities, and forest by-products are absolutely integral to the energy balance of Sweden (Elforsk, 2008) – these being just a number of relevant parameters.

Moreover, the resource is growing – as in the rest of Europe, the standing volume of timber in Sweden has been increasing steadily since the 1920s and has almost doubled since that time (Jonsson et al., 2011). This increase suggests that the commercial sector and its management regimes, as they are developing, are assuming a sustainable pathway. Pursuant to such points, there is a broad consensus in Sweden that if managed well the sector's role in the energy mix can increase without endangering ecological systems, and can also contribute to national goals to become independent of fossil fuels in transportation (Swedish Board of Agriculture, 2009; Emanuelsson, 2007; Egnell, 2007). Such developments however, do increase the competition for biomass. Among other things, this can add to competitive pressures that challenge traditional biomass users. The pulp and paper sector in Sweden is a leading example in this instance, and competition, or the potential for competition, with the bioenergy sector is just one challenge the sector must live with.

7.4.1 The globalisation of the forestry sector – an inevitable scale economy issue

The forestry sector – in particular the pulp and paper actors have been challenged in many ways over recent decades. While the forest sector market is cyclical with upswings and downswings, relative real price developments have been negative since at least the 1990s in key areas such as panels, paper and board, sawn wood and industrial round wood (cf. Jonsson et al. 2011, p4). Paper and board prices fell some 40% in the period 1990 to 2006. While continued efficiency and productivity improvements have maintained overall profitability in the sector for many years – the pulp and paper sector in the Nordic region is pressured from several fronts and the low margins in the sector do not provide room for the sector to pay (significantly) more for raw materials. Elforsk (2008) indicate that depending upon circumstances at any one time, threats to the sector include high biomass prices, high electricity prices, periods with a weak US dollar, as well as the aforementioned stagnating or declining price trends for pulp, paper and sawn timber. High biomass prices in Sweden have been exacerbated by competition for "biomass-for-energy" – that at times competes directly for pulp wood (Elforsk, 2008).

Central to such issues are the economies of scale and plantation productivity in sub-tropical and mild temperate zones – such as in Latin America. Bael and Sedjo (2006) report that from a global perspective, intensively managed forest plantations are increasingly replacing natural forests as the raw material resource. Not only do such changes eliminate the traditional ties between forest processing and locations with abundant natural forests (Bael and Sedjo, 2006) such as those mentioned above for Sweden but they facilitate the spatial separation of forest industry production functions. This increasingly allows companies to utilise materials from various sources, and site manufacturing plants at different locations along the value chain (United Nations, 2005).

While the forest products sector "at home" is clearly affected, the Nordic paper and pulp sector has not been passed by such developments and have invested significantly abroad "where trees grow quickly". Indeed, European actors have been some of the largest investors in the pulp and paper sector in Asia and Latin America. The European companies have applied their technologies, marketing and managerial systems to regions with high forest-growth rate/low labour cost settings, rapidly expanding plantations and growing demand (FAO, 2009). For example, in the 10-year period to 2008, the production of pulp and paper in Latin America expanded to deliver a six-fold increase in net exports (Aulisi et al, 2008).

It seems logical to assume that trends that pursue economy of scale effects provided by enormous facilities, co-located with fast growing forest plantations, can paint a picture of an inevitable withering decline of the traditional pulp and paper sector in northern hemisphere countries such as Sweden. Such views are supported by analysts that hold that the competitive advantage in paper production that has long been based on close-by high-demand markets, the availability of recovered paper, and technological sophistication for producing high-quality paper will gradually be eroded by long-term real price reductions and technological development in competing regions (MBendi, 2012). There are ameliorating factors however. For example, Nordic pulp is predominantly long-fibre, while much of the South American pulp production is short fibre and as such these products do not compete directly. Elforsk (2008, p.9) adds that ameliorating effects are also provided for the competition from the energy sector: firstly that the large potential for increased biomass supply from other countries can reduce the competitive pressure from the Swedish energy sector; and secondly cost increases for biomass are also expected in low cost production countries (Elforsk, 2008, p.9). However, trends for the focus of production to gradually shift closer to the regions of faster paper consumption growth are expected to continue (MBendi, 2012).

7.4.2 A shift to biorefining – a pathway beyond simple scale economies

In the light of developments such as those described above, the Nordic forest sector/pulp and paper sector recognises the imperative for a shift to ever more sophisticated portfolio of specialised products and a marked shift to the so-called bio-economy is called for (Rushton, 2012). While some describe such moves simply; i.e. in terms of biofuels, bioenergy, and efforts to lower the carbon footprint of production (cf. Hawkins Wright, 2008), others describe more complex mixes. van Ree and Annevelink (2007) for example, describe the transformation of pulp and paper units into bio-refineries that deliver biofuels, starch, organic acids, polymers, oleochemicals, bioplastics and various foods and feed ingredients. They portray these bio-refineries as potential key features in the creation of a "green economy" (van Ree and Annevelink, 2007). Söderholm and Lundmark (2009) argue that such developments should also benefit the profitability of the pulp and paper industry, as the primary goal of converting a (chemical) pulp mill into an integrated bio-refinery is to create more value from forest feedstocks.

Progress in achieving change in the Swedish pulp and paper sector has however been slow. While high sunk costs related to the capital infrastructure intensive nature of the sector naturally dictates a slow rate of change (Elforsk, 2008), other issues, both internal and external also seem to constrain progress. The Nordic Paper Journal (Papernet.se, 2013) for example reports that the absence of a global CO_2 tax, increasing opposition to the sourcing of biomass from forest and field, and the dissipation of "end of oil fears" and cheap natural gas (as a direct result of rapid increases in shale and other non-conventional oil and gas extraction) are posing significant exogenous barriers to development. They also hint at internal discord on whether pathways forward should involve a deep cooperation between the forest industries and the petrochemical sector, which types of transportation fuels should be produced from the sector (e.g. ethanol, methanol, DME, FT-diesel, etc.), and whether focus should be placed upon (only) the inherent functions that exist in wood chemicals such as lignin[78] and extractive-substances such as tall oil.

[78] It should be noted however, that despite significant research efforts over many years, we observed that there remain significant doubts that valuable products can be derived from lignin.

7.4.3 An emerging forest sector preference for (Black Liquor) gasification pathways

While views are mixed, some analysts within the forestry sector describe promising opportunities for pulp producers to be the development of the energy potential of black liquor (cf. Papernet.se (2013) and Hawkins Wright (2008)). Internationally, Hawkings Wright (2012) indicate that while kraft pulp mills are already major producers of bioenergy, new black liquor gasification technologies promise to capture the energy values of black liquor far more efficiently, turning a pulp mill into a true biorefinery producing transport fuels and bio-chemicals along with electricity, heat and wood-pulp. With direct reference to Sweden and transport fuels, KVA's (The Royal Swedish Academy of Sciences) Energy Committee (Royal Swedish Academy of Sciences, 2013) present arguments that Sweden can largely replace its requirements for gasoline and diesel via gasification of forest biomass – with a major focus on black liquor gasification pathways. Energy carriers included in presentation of such scenarios focus on syngas – methanol – DME pathways. In fuel utilisation, it is argued that methanol can be blended at low concentrations, precisely as ethanol is today; and that M85 (instead of E85) can be supplied to vehicle fleets (cf. Swedish Knowledge Centre for Renewable Transportation Fuels, 2013, for an EU methanol fuel summary). With the success of the Volvo/Chemrec/Preem DME trial in Norrland, evidence of the eventual feasibility of large-scale heavy goods fleets running on DME has been gathered. Volvo reported a reduction of GHG emissions of up to 95% from the project. Presumably, if diesel engine buses can be run effectively and efficiently on ethanol (as Scania has produced compression ignition (CI) engines for buses have since the late 1990s)[79], then it seems logical that mainstream engines can also be produced to run on methanol as well. Mainstream market-ready methanol engines have not however, been found in this study.

The Royal Swedish Academy of Sciences (2013) argue that thermodynamic principles dictate that methanol/DME presents a markedly superior pathway to those offered by ethanol (be it cellulosic or first generation)[80] or first generation biodiesel. As such the Academy analysts portray the key to a sustainable solution as 'energy efficiency' – and as such they indicate that, "methanol and DME as final products stand out as quite superior in comparison to other liquid transportation fuels such as ethanol and biodiesel".[81] It is clearly recognized however, that very strong political support is required, that much research and development remains before large scale facilities can be put in place, and that extensive new distribution infrastructure is required (Royal Swedish Academy of Sciences, 2013; p 4-5). Such issues have significant implications for the prospects for emerging technology fields or businesses (cf. Aldrich and Fiol, 1994; Bergek, Jacobsson, Carlsson, Lindmark and Rickne, 2008; Bergek, Jacbobsson & Sandén 2008).

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[79] By 2008, Scania had built more than 600 ethanol-powered city buses over a 20-year period and consider the technologies mature. The ethanol used for compression ignition engines contains 5-7 per cent additives that improve ignition and lubrication (cf. Scania, 2008). As of 2013, the IEA reports (see: IEA-AMF (2013) that as of 2013, around 1000 CI engines are used in heavy-duty vehicle engines. While the efficiency of these engines are some percentage points lower than an equivalent diesel engine, they are considered mature and are present in both bus and truck fleets around the world. The GHG performance depends upon the ethanol production chains. See: Scania Group (2011).

[80] Note however, that these views are not necessarily accepted by all analysts – or for all fuel chains – or for all motor technology developments. This citation is intended to show the views of the analysts involved, and not to represent a scientific 'consensus position'.

[81] In the original Swedish: "framstår slutprodukterna metanol och dme som överlägsna jämfört med andra flytande drivmedel som etanol och biodiesel".

While black liquor pathways have been given attention in the discussion above, they are by no means the only technology systems under consideration. A number of biomass gasification pathways are under consideration (Linné and Jönsson, 2004; Magnusson, 2012). Linné and Jönsson (2004) estimated that forestry waste potential (including black liquor) via gasification could be as high as 74 TWh by 2015. These authors also underline however, that in general gasification pathways to fuel remain further from the market. One technology that is already market proven however is biogas via anaerobic digestion. This is also relevant to the pulp and paper sector – and biogas production from wastewater at pulp mills is an area with modest but still significant potential. Work by Magnusson (2012) indicates that applying anaerobic wastewater treatment at Sweden's pulp and paper mills may render as much as 1 TWh/year. If this were to be fully exploited it has the potential to increase Swedish biogas production of 1.4 TWh (2010 figures) by some 70%. As these pathways generally fill a smaller place in the broad debate at the current time, these are not discussed further here.

7.4.4 Forest derived biofuels – achieving a fit with the Swedish fuel market and infrastructure (?)

While thermodynamic imperatives underlie the design of any fossil fuel independence strategy to be viable in the long term, vested interests, consumer preferences and existing "locked in" fuel infrastructure pose some very real constraints upon the immediate pursuit of any pathway based on maximized efficiency. In the context of this discussion, a holistic view of "which fuel pathway to pursue" also requires detail consideration of infrastructure requirements; the degree of alignment of the technology with existing infrastructure; and overlap and synergies (or competitive issues) with incumbent industries in the sector (cf. Aldrich and Fiol, 1994; Bergek *et al*, 2008b, Bower and Christensen, 1995). Parts of the syngas – methanol – DME pathway may face considerable challenges when viewed from such perspectives.

As a first issue one can examine the conservative nature of European vehicle manufacturers and drivers. At present, up to 3% methanol is allowed by regulations in the EU (European Parliament and the Council, 2009d)[82] but uptake is limited. Moreover, Preem (Eriksson, pers. comm., 2013a) indicates that there that they perceive that a number of EU car manufacturers do not support blending of methanol.[83] Even with ethanol – a thoroughly established fuel – there remain such issues to be overcome. E10 in Europe is one such example – regardless of whether countries such as the US approve, warranty and manage 10% ethanol content in gasoline, in Europe acceptance of such is still limited among some industry actors. Indeed, there is even tangible opposition to E05 (ibid.), let

[82] The amended Fuel Quality Directive 2009/30/EC adopted in 2009 allows up to 3% v/v blend-in of methanol in petrol (European Parliament and the Council, 2009d).

[83] Such comments however must be viewed in the light of potential vested interests from the fuel suppliers as well – not least as higher concentrations of alcohols in gasoline fuels may not be compatible with materials prevalent in their fuel depots or fuel dispenser pumps. For instance, according to ePure, an EU industry association for renewable ethanol E10 can be used in about 90% of all petrol-driven cars used in Europe and 99.7% of the petrol vehicles constructed in 2010 are E10 compatible, see European Renewable Ethanol (2013). Mixes known as 'protection grades' – namely gasoline with very low concentrations of alcohol are to be maintained so that fuels are available for older vehicles (ibid.). Moreover, all manufacturers that export gasoline vehicles or engines to the US have already adapted these engines to match the prevalent E10 fuels prevalent in that market.

alone E10 or E15 (ePURE, 2012).[84] German consumers in particular were reticent to adopt E10 at the time of its introduction Germany in 2011 being particularly concerned about vehicle warranties [cf. GAIN (2012)].

A second issue to consider is the match between the apparent "forest sector offering" (DME and methanol) and the Swedish fuel mix developments and scale. Roughly speaking, Sweden consumes some 8 million m^3/year of domestic road transportation fuels (Swedish Energy Agency, 2013) – thus circa 84TWh fuel energy[85] – with roughly 45% as gasoline, and 55% as diesel (Eurostat, 2012). Diesel has traditionally been utilised mostly in heavy-goods transportation and industrial vehicle fleets, but in recent years Sweden has witnessed a rapid shift to diesel vehicles for personal transportation. This marked change has not only displaced gasoline vehicles, but has also reduced the sales of "biofuel" ready vehicles. Only a low percentage of cars sold in Sweden at the present time are suited for E85 or high-level blended biodiesel.

Due to the thermodynamic superiority of diesel engines over otto-type engines (resulting in circa 20-25% better fuel efficiency) a trend to more diesel appears both logical and desirable – but one major difficulty faces the entire transport sector in Europe in this regard. Preem 2012) (Sweden's largest oil refining company[86]) reports that there is currently, a shortage of diesel in Europe of some 30-40 million m^3/yr. The deficit is currently being met by imports from countries such as Russia and the US but as the shortage of diesel increases, this is projected to lead to (markedly) increased diesel prices.

As such, the urgent fuel need in Sweden and Europe appears to be fuels that seamlessly fit with the existing diesel infrastructure. At present, only hydrogenated vegetable oil (HVO) fuels and Fischer Tropsch produced fuels (after gasification) appear to be capable of delivering such. Only HVO fuels are delivering. FT technologies fitted to black liquor are seen as technically viable – but costly; a cost of circa 4 billion SEK for 1 million tpa capacity is indicated (Eriksson, pers. comm. 2013a).

Here growing faith in so-called "look-alike" molecules from the incumbent petrochemical sector can be observed. The HVO efforts of Neste in Finland (involving a range of vegetable oils including palm oil, and tall oil) and Preem in Sweden (tall oil) are leading examples. By following hydrogenation pathways, a paraffinic diesel look-alike is delivered that can be mixed with existing diesels and used in existing diesel engines at high concentrations (23% at present for Preem's diesel product in Sweden).[87] Minimal or no changes to refuelling infrastructure are required. As an

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[84] Epure (2012) reports that E10 has been available in countries such as France and recently Finland, Spain and Germany. Also it is being used in the USA, Australia and New Zealand. In Brazil the percentage of ethanol used in petrol can be even as high as 25%. In France E10 has been sold since April 2009 and the current market share is 17.6%. In the USA E10 has been used for many years now and they are now moving towards E15.

[85] According to the Swedish Energy Agency (2013) the consumption of transportation fuels in Sweden for 2012 was as follows: a total of 3.916 x $10^6 m^3$ petrol (of which 407 x $10^3 m^3$ ethanol); and 4.939 x $10^6 m^3$ diesel (of which 404 x $10^3 m^3$ biodiesel). Using conversion figures of diesel (35.28GJ/m^3 and Petrol 32.76GJ/m^3 this yields circa 48.4TWh of diesel and 35.6TWh petrol).

[86] Preem is the biggest oil company in Sweden, with refining capacity of more than 18 million m^3 of crude oil every year. Their two refineries are reportedly among the most modern, efficient, and cleanest in Europe and the world (Aleklett, 2012).

[87] According to Preem 2012) Through hydrogenation – i.e. the addition of hydrogen – in a Hydro Treater facility, the raw bio-material (tall oil) is converted into diesel in accordance with Swedish standards. This is then processed to produce a

addition to an existing refinery complex, a production facility with capacity of some 100 000 m^3/year (circa 2.5% of Swedish diesel consumption) was achieved this for about 250 million SEK.[88] A fundamental challenge with a tall oil strategy is that oil volumes are limited by the production of kraft pulp – in Sweden available at only circa 200 000 m^3/year.[89] While more than current production, utilisation of tall oil for fuel is in direct competition with other value-adding chemical production pathways – and raw tall oil is also a substitute for heavy fuel oil used in Swedish industry. While HVO does contribute to fossil transportation fuel replacement these limitations are significant. In contrast to HVO strategies, other pathways such as methanol or DME all require very significant infrastructure investments along the whole production and distribution supply chain.

7.4.5 Potential petrochemical industry strategies – drop in fuels via new technology pathways

The shortage of diesel in Europe mentioned in the previous sub-section adds the potential for additional dynamics from the traditional petrochemicals sector. In this context one issue is investment in new "traditional" infrastructure that may also include new innovative processes with renewable feedstocks that deliver paraffinic diesel fuels with substantial renewable content. The construction of a new large-scale coker plant that can convert higher proportions of heavy fuel oil to distillate (diesel) and petroleum coke has been discussed for some time in Sweden but has not proceeded.[90] In recent times, the potential for the evolution of a "fossil free refinery" has been brought forward as a concept in communications from Preem[91] (Eriksson, 2011; 2013a; 2013b) that are related to revival of the coker project. The concept involves feeding lignin-derived bio-oils or pyrolysis oils, or both, into the coker process.

At present however, such plans are at an early stage and remain uncertain for a number of reasons. Firstly, volatility in the policy field, with the Fuel Quality Directive just the latest intervention in a long string since circa 2008, is not conducive to an investment of such scale at the current time. Not least as the scale of investment for a plant that can process some 2.8 million tonnes/year (Preem, 2007) is approximately 8-10 billion SEK (Eriksson, 2013a; 2013b; Preem, 2007). Secondly, one of the technology pathways (conversion of lignin precipitate to a bio-oil that in turn can be fed into the plant) remains between the laboratory and pilot scales (Eriksson, 2013b). Thirdly stabilizing oil prices also engender conservatism in biofuels investment from the petrochemicals sector. However, should such developments move to pilot scale by 2015 as indicated by Eriksson (2013a, 2013c, then this may represent a new and significant impetus towards Swedish goals to reduce fossil fuel

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diesel with a 23% renewable proportion (for summer mixes – winter fuels have a lower renewable content). This in turn is mixed with 7% RME; the end result being a diesel with a 30% renewable content. (Preem ACP Evolution Diesel).

[88] According to Preem, Neste invested about 1 billion SEK for a smaller plant that was more "stand alone" (Eriksson, 2013a).

[89] Raw tall oil is produced at 30-50kg per tonne of kraft pulp – indicating a Swedish chemical pulp production of circa 5 million tpa indicates some 200 000m^3 of raw tall oil per year available (see Swedish Forest Industries Federation (2010)). When raw tall oil is distilled, the greater part is refined to products, such as, tall oil fatty acids, tall oil rosin, and tall oil sterols, while the non-volatile remainder is 'tall oil pitch'. The last is mainly used as a fuel oil in stationary applications.

[90] The Preem Coker project, a circa 10 billion SEK investment, was originally scheduled for completion in 2012 but the project was placed indefinitely on hold in mid 2009. Reasons given were market and regulatory uncertainty. Refer to Preem AB (2007) and Highbeam Business (2010).

[91] Preem represents 80% of Swedish refinery capacity (which in turn is approximately twice Swedish consumption) and sells 50% of all refined oil products on the Swedish market.

dependence in transportation. One that also has large implications for the forestry sector as both lignin and pyrolysis oils from forestry or agricultural waste are under consideration.[92]

While at an early stage, such investment of the traditional petrochemical sector in new plant for large-scale production of biofuels is a scenario that must be taken into account by stakeholders – albeit with recognition that it has a time horizon in excess of a decade (Eriksson, 2013a).

At this juncture however; the traditional petrochemical sector is predominantly represented in forestry sector-derived transportation biofuels by its processes that hydrogenate bio-oils. As described above, this is both proven and implemented at significant scale the volumes (relevant to the forestry sector) are limited by the scale of kraft pulp production. While added competition for tall oil drives up prices and adds value to the Swedish pulp and paper sector – it apparently has distortionary effects on other parts of the economy as it competes with production of value-added chemicals (e.g. by tall oil distillers) with the help of policy support for renewable transportation fuels (de Guzman, 2007; de Jong et al, 2012). In this light, HVO fuels do have a place within future biofuels scenarios, but their ongoing expansion would likely be tied to utilisation of other vegetable oils – a pathway made increasingly untenable by in the EU by policy developments such as the Fuel Quality Directive.

7.4.6 Biofuels as a valuable diversification pathway for the Swedish pulp and paper sector?

The analysis above presents a number of potential challenges for actors in the pulp and paper sector should they wish to leverage biofuels – or "biofuel-platform biorefineries" – as an important new diversification option that can contribute to long-term survival.

At present, there appear to be some fundamental barriers for the sector to deal with that limit the degree to which the pulp and paper sector can derive additional value from biofuels. Among others, these include:

- There does not appear to be consensus within the forest sector regarding whether they should be deeply involved in fuels production in the future;[93] among those actors engaged in fuel production endeavours, there does not seem to be consensus regarding which fuels are most desirable.
- Potential biofuels from the pulp and paper sector such as high-level blended methanol, DME and biogas, will require special engines or special fuel distribution infrastructure, dedicated fleets, or even all of these.[94]
- Whatever pathway is pursued by the pulp and paper sector, they need very significant investment in new infrastructure. While low-level blends of methanol can largely be accom-

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[92] Eriksson (2012b) indicates that pyrolysis pathways require greater investment.
[93] One example of an area of discord being related to the additional requirements for biomass for the plant energy balance if black-liquor gasification processes are undertaken. If transportation biofuels are produced by the plant in large quantities, then additional biomass feedstock must be available within the plant 'capture zone'.
[94] However, for low blend methanol and biogas there are both an infrastructure and available cars currently. One very significant challenge that remains is that half of the pulp industry is in the northern portion of Sweden (Norrland) where the number of filling stations for biogas currently is limited. See FordonsGas Sverige (2013) for an overview of Swedish biogas refuelling sites.

modated by existing infrastructure, other solutions involving fuels that do not "drop in" to the existing system entail very significant costs to build infrastructure that extends far beyond that required for production plants. Very substantial investment is required in fuel distribution and refuelling infrastructure as well.[95]

- Factors such as the uncertainty introduced by EU's fuel quality directive FQD (European Parliament and the Council, 2009d), apparent antipathy towards intensified forestry in a number of EU member states (particularly harvest waste utilisation (cf. Eriksson, 2013a; Papernet.se, 2013; Royal Swedish Academy of Sciences, 2013) remain as issues that are yet to be resolved. Current levels of political risk appear to be a prime constraint on large investments required for forest-derived biofuels.
- Biofuel production strategies under consideration from the incumbent petrochemicals industry appear increasingly separate from the pulp and paper sector except as a provider of feed-stock (tall oil), and potentially as a provider of lignin or pyrolysis bio-oils. The petrochemicals sector appears to be consolidating strategies to deliver new drop in fuels from standard refinery platforms but these developments remain many years in the future. Moreover, it seems that these can only eventuate if very significant petrochemical plant investments are made – investments that in the first instance will target the market opportunity presented by Europe's fossil diesel deficit. The political risks mentioned above, also place constraints on the petrochemical sector.

7.5 CONCLUDING REMARKS REGARDING THE SWEDISH WAY AHEAD

The long term intention for Swedish greenhouse gases set by the Swedish government is that there should be no net emissions of emissions by 2050. This does not necessarily require that all energy inputs to the transportation sector should be from renewable sources, as it is possible to utilise so called carbon sinks (e.g. terrestrial biomass) and to carry out projects that reduce greenhouse gas emissions abroad in order to offset the country's greenhouse gas emissions. As a separate but related issue, there is also the goal to make the transport sector independent of fossil fuels by 2030; this issue is currently under study in a current public inquiry (c.f. Section 7.1.for all of these issues). Renewable fuels for transportation will be part of the toolbox to reach both these goals and will need to constitute a major part of the latter.

Pursuant to the points above, and with the exception of the near term proposed changes in the legislation to create a hybrid quota based tax exemptions system for the promotion of transportation biofuels in Sweden (c.f. Section 7.2), there will probably be a need to reinforce the quota system in combination with tax exemptions. There shall also likely be a need to utilise other policy instruments on the way towards both these goals. Given this, it is relevant to consider the range of different instruments applied in the countries studied in this report, their manner of utilisation, and how well they have contributed towards the promotion of biofuels utilisation in manners that contribute (effectively, efficiently, or both) to important policy goals such as GHG emission reductions, rural development, and energy autonomy. It is also important to keep in mind that there are differences

[95] There may however be situations where the location of a pulp mill would allow delivery of synthetic biogas direct to existing distribution and refueling infrastructure.

between the different countries that will affect the possibilities to copy systems that have worked well in a specific context.

One of the conclusions from the expansion of biofuel production and consumption in Brazil is that there are marked synergistic effects and increased overall benefit if several sectors are involved, and if all gain in some way from the development. This case also highlights how biofuels development can be utilised to strengthen and diversify incumbent sectors (e.g. sugar and agriculture) while delivering tangible macro-economic benefits in other areas (e.g. contribution to balance-of-payments challenges related to oil import). Indeed, the need for multi-sectoral benefit is to some extent inevitable for a biofuels programme to be perceived as successful, at least if the full chain from production of feedstock to consumption of biofuels is considered. This, not least as the fuel distribution and transport sectors always have to be involved and interlinked in new ways with the agricultural or forest sectors, or both. Despite this the deep involvement of the energy utility sector is not always a given, albeit this can offer benefits. There are several examples of synergetic advantages associated with the energy utility sector. One area of importance is the logistic advantages that can be achieved – as large quantities of biomass are already used for energy purposes in Sweden. This advantage is similar to that which may be achieved by involvement of the forest industries (c.f. Section 7.5). There may currently be a relatively positive business climate for integration of biofuel production with processes in the Nordic forest industry, as this offers diversification opportunities that may help ameliorate the decreased profitability in core business areas experienced in recent years. Problems with decreasing profitability are also noted in the Swedish energy utility sector, but the well-developed sectoral infrastructure for district heating will offer an additional advantage for integrated biofuel production. While not found at present in many regions globally, the possibility to utilise surplus heat from biofuel processes for the production of district heating is both well recognised and emerging in the Swedish context. As most second generation biofuel processes generate large amount of waste heat, there may be possibilities to utilise this to save fuel used for district heating production – a combined solution that is more profitable than two stand-alone units. In reality however, there remain obstacles that obstruct the utilisation of waste heat. One being consistent trends towards reduced district heating demand;[96] another being competition with heat production processes or technologies – some that are directly supported by other types of policy instruments – such as combined heat and power (CHP) production from biomass and incineration of wastes with or without CHP (Swedish Energy Agency, 2008). This is just one example of when two desirable (from an overall resource saving perspective) energy conversion processes may compete and when different policy instruments heavily influence such competition.

Sweden has long been a world leader in the utilisation of industrial waste heat for district heating production (Euroheat & Power, 2006). One important facilitator for this has been the well-established culture of co-operation between sectors, especially in smaller cities and towns that is related to awareness of mutual dependence (Grönkvist and Sandberg, 2004). This culture of co-operation may also bring about advantages for biofuel production in similar ways as cross sectoral co-operation and mutual dependence has brought about benefits for the development of ethanol production in Brazil, see Chapter 3. One important difference however, is that the intervention on the Swedish national level considering waste heat co-operation(s) has essentially been limited to some relatively

[96] In turn mainly due to energy efficiency measures in the residential sector, the increased use of heat pumps in Sweden, and a warmer climate.

minor investment programmes (Swedish Environmental Protection Agency, 2010). The involvement of governmentally controlled policy instruments has therefore not been the major driving force behind the Swedish waste heat co-operation efforts. Nevertheless, the many examples of successful cross-sectoral waste heat co-operation may also set important precedents and form foundations for cross-sectoral biofuel production arrangements, irrespective of whether these need national support or not.

An immediate deduction that may be drawn from the German biodiesel experience is that rapid changes of policy instruments or regimes can be very detrimental for the development of the sector. The change from tax exemptions to mandatory quotas in 2007 quickly created over-capacity for the production of biodiesel by knocking actors out of the markets and putting their plants into "care and maintenance" even when the tax exemptions were removed progressively over several years, (c.f. Section 4.3). Most drastic changes of policy instruments or regimes will cause immediate problems as well as challenges in the longer run. An important example of the latter is the inherent climate of distrust that such moves engender among (potential) investors. While the relatively modest progressive change in Germany that so significantly disrupted their biodiesel sector may well indicate that the whole industry lacked financial robustness and long-term viability, the long-term trust related effects will doubtless affect several future technology pathways reliant upon policy support in their emergent phases. Another result of the change to a quota-based system was that the pure biodiesel almost disappeared from the market, despite the gradual reduction of tax exemptions in Germany. A pure quota-based system will be a barrier for biofuels other than blendable types to reach the market. With the relatively low targets for the total share of biofuels that are currently included in quota-based systems in the EU, it is not relevant to have a market for pure biofuels. When (and if) goals involve higher shares however, this may constitute a crucial aspect since high-level blends and pure biofuels often requires adapted or dedicated vehicles and separate supply-chains – a development that can take considerable time to develop and be accepted by the market.

The Swedish government seems to have taken note of the German experience when the new proposed quota system was created. A change is almost inevitable in any country when tax losses resulting from tax exemptions reach a certain level. The quotas are set so that no over-capacity in the production chain is likely to be created. Here there may be some questions about the production capacity for ethanol because of the reduced tolls on ethanol that will be introduced in parallel with the quota system (c.f. Section 7.2.1) but the outcome is difficult to predict. The tax exemptions will be untouched for pure or high-level blended biofuels, so the market for the existing biofuels will be preserved and it will also leave the door open to other pure or high-level blends of biofuels in different stages of development – such as DME, biogas, and high-level blends of methanol. It thus appears likely that the suggested change from pure tax exemptions to a hybrid tax exemption and mandatory quota system will leave possibilities open for the future, reduce taxation losses significantly, and leave production chains relatively untouched.

The low tax burden placed on transportation fuels in general in the US should always be considered when deductions are drawn from experiences there. Low tax levels diminish possibilities for the use of tax reductions as a stand-alone policy instrument to promote biofuel production. Not least for this reason, US policy has thus pushed forward different forms of mandatory volumes in combination with import protections and investment programmes (see Chapter 5). The biofuel sector has expanded rapidly in the U.S. during the last two decades, but as its development has predominantly been pushed by a mandatory volume system in recent years, it is currently dominated by low-percentage blends. This reflects the form that the German biofuels market has moved towards after the shift to the mandatory quota system. The federal regulatory framework in the USA has thereby generally not been conducive to the development of markets and infrastructure for pure biofuels and this may be a constraint for higher targets regarding biofuel volumes. However, high targets for biofuels in the U.S. may also be constrained by other factors such as the access to feed-stock – both nationally where some 40% of the maize and 14% of soybean crops already goes to biofuels, and on the global market – as the market for transportation fuels in USA is so vast in comparison with all other countries.

Another lesson to be learned from experiences in USA is that the fulfilment of a mandatory volume does not occur automatically; a firm foundation of technical or economic development developed over time, combined with policy certainty and fiscal support, appear as key facilitators. The mandated volumes for cellulosic ethanol is an example when difficulties related to the development of the production has led to a situation when mandated volumes are unlikely to be fulfilled, see Section 5.2.4.

In a market as small as the Swedish, a deficit in domestic production capacity may be compensated by imports, given that imports are allowed in the mandated quotas, blends, or volumes. This may not always be possible for the market of the size of that in USA – for a specific product such as cellulosic ethanol the prospects to import from an international market are currently limited. The observation that mandatory quotas may not automatically bring about new products, such as cellulosic ethanol or biodiesel with additional advantages, may be relevant for the new quota system in Sweden where almost 37%[97] of the total required biodiesel share should be fulfilled with biofuels with additional advantages, see Section 7.2.1. Presently, the biofuels defined as biofuels with additional advantages are not a major share of the Swedish market and this may pose challenges to fulfilment of quotas; it may also lead to a number of unintended outcomes for other industries as discussed in Section 7.2.1.

Since the precise definition or "real meaning" of the Swedish goal "a transport sector independent of fossil fuels by 2030" is under investigation (see Section 7.1) it remains difficult to estimate the magnitude of biofuel volumes required for 2030, or any other future years for that matter. This makes most questions regarding requirements for future policy instruments difficult to evaluate. A key example of such questions appears to be: Will the new hybrid tax exemption quota system together with support programmes to RD&D and production be the most appropriate toolbox if high shares of renewable transportation fuels are desired or required? While this analysis can point towards a number of relevant issues within such a question, it remains impossible to answer definitively. This is not just due to the unspecified goal, since a vast number of factors apart from policy instruments affect the production of biofuels in Sweden. Examples of such factors include: the future of global, EU and national efforts to mitigate climate change, the oil price, progress with technical advancement in biofuel production, and the expansion and role of electrical vehicles and plug-in hybrids to name a few. With more stringent demands for biofuels that also provide additional advantages – or more specifically, the need to produce second generation biofuels – capital costs are expected to become a more significant part of the total production costs (see Section 4.4).

[97] 9.5% biofuel share and 3.5% of these should be fulfilled with biodiesel with additional advantages, i.e. almost 37%.

Given this, and that the Swedish goal for 2030 is likely to be in the direction of a large share of second generation biofuels, there will be a need for increased support for both R&D and for capital investment programmes. Moreover, the government cannot wait too long with the commencement of these if they are to contribute to goal fulfilment. Many of the promising processes remain at a relatively early stage of development and require time as well as support if they are to achieve mainstream market establishment. The failure of the US to fill its initial volumes for cellulosic ethanol in the past few years serve as an example of this – while very significant financial resources have been provided to the sector, and large and established (first generation) ethanol producers are involved, the path towards commercialisation of the second generation plants has been slow. US experiences underline how difficult it is to establish production of second-generation biofuels when production processes still require work before they can enter commercial scale production.

In both the European and Swedish contexts, properly designed quota systems are likely to deliver an intended share of biofuels and this is important for reaching goals for renewables or climate change mitigation. Tax exemptions have similar benefits, even if these are not as target specific. Experiences documented in this report indicate that other desired (or even “intended”) outcomes for biofuel production, such as energy self-sufficiency and rural development are much harder to address with cross-sectoral policy instruments such as these.

Investment support programmes may be more than just key instruments considering the aforementioned support to second generation biofuels and hence be a driver for technology development; they may also be a complement to the suggested hybrid quota system in areas of both energy self-sufficiency and rural development. As is possible to observe in Germany for example, quota systems can act as a clear stimulus for import of biofuels and can result in the concentration of production capacity with larger corporations. Investment programmes can however be applied so as to balance such developments as it is possible to direct them towards a range of national co-benefits. Import restrictions (e.g. tariffs) are possible to employ to improve energy self-sufficiency, but may also reduce the need or desire for technical development in the national biofuel sector; they can also cause problems for other branches and sectors in an export-driven economy such as that of Sweden. To decrease the tolls put on ethanol from outside EU in parallel with the introduction of the new hybrid quota system as suggested by the Swedish government may therefore prove to be beneficial in the long run, even for the domestic biofuel sector.

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APPENDIX: US ANALYSIS

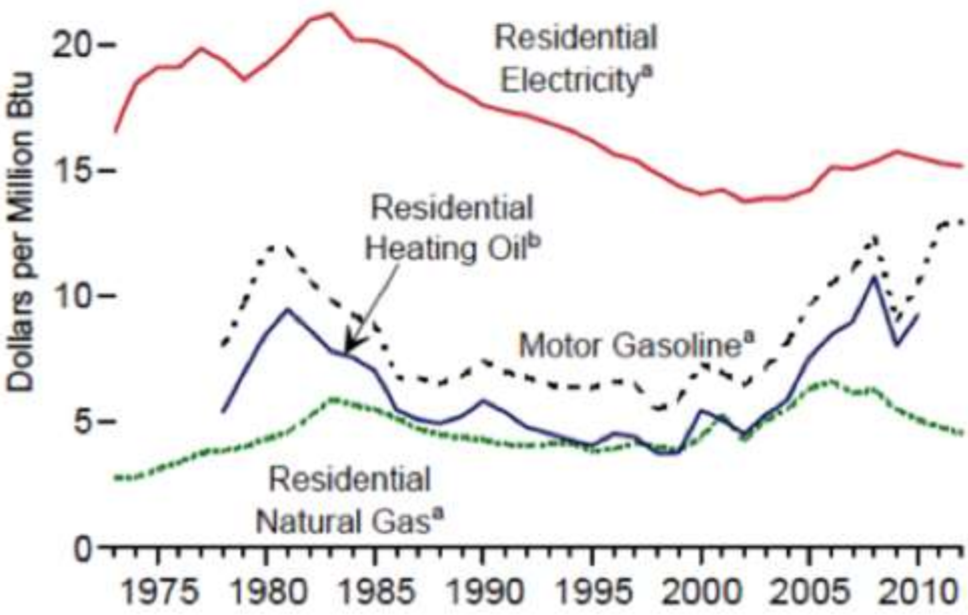

Figure A5-1. Cost of fuels to end-users in real (1982-84) dollars. Source: U.S. Energy Information Administration, March 2013 Short-Term Energy Outlook,
http://www.eia.gov/todayinenergy/detail.cfm?id=10451

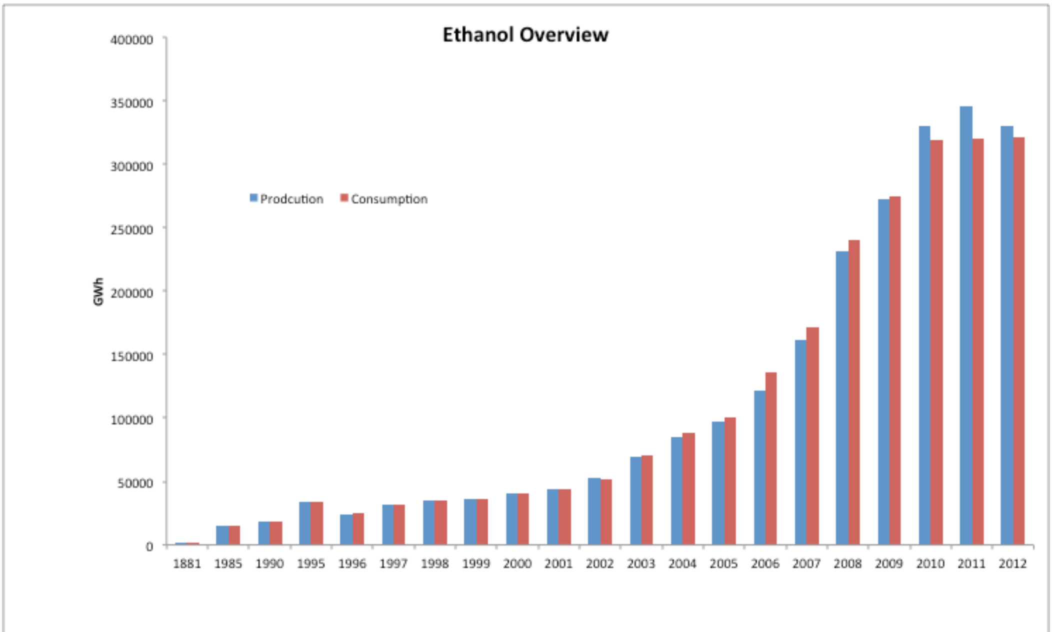

Figure A5-2. US ethanol consumption and production capacity 1980-2008. Source: Data from STS (2010).

Table A5-1. Ethanol Industry. Source: RFA (2013).

Year	Total Ethanol Plants	Ethanol Production Capacity (billion litre/year)	Plants Under Construction/ Expanding	Capacity Under Construction/ Expanding (billion litre/year)	States with Ethanol Plants
Jan-99	50	6.44	5	0.291	17
Jan-00	54	6.62	6	0.35	17
Jan-01	56	7.27	5	0.24	18
Jan-02	61	8.88	13	1.48	19
Jan-03	68	10.24	11	1.83	20
Jan-04	72	11.74	15	2.26	19
Jan-05	81	13.8	16	2.85	18
Jan-06	95	16.41	31	6.73	20
Jan-07	110	20.79	76	21.33	21
Jan-08	139	29.86	61	20.95	21
Jan-09	170	40	24	7.82	26
Jan-10	189	44.96	15	5.42	26
Jan-11	204	51.13	10	1.98	29
Jan-12	209	56.42	2	0.53	29
Jan-13	211	55.69	4	0.60	28

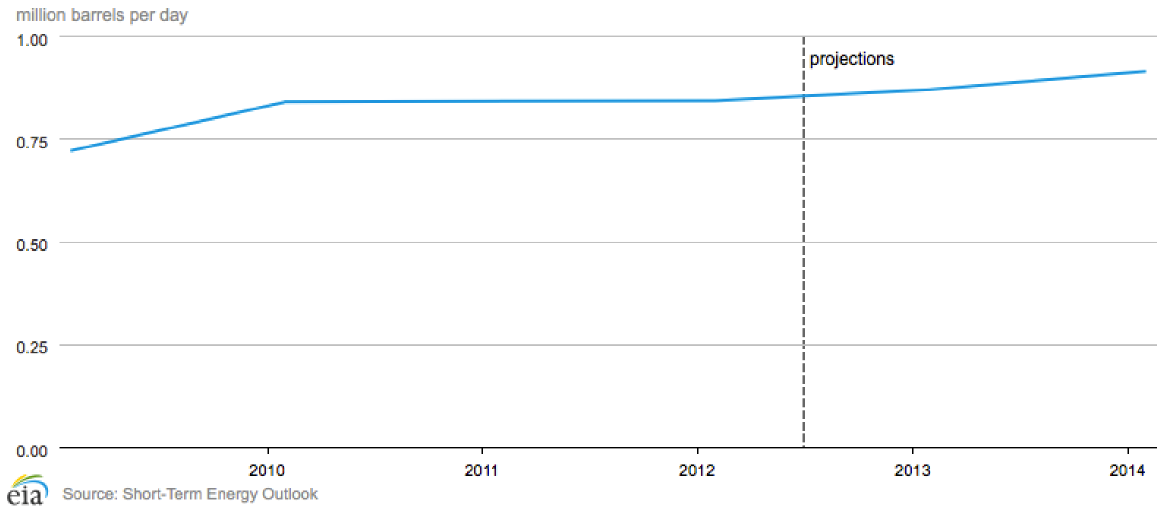

Figure A5-3. US ethanol production projections – short term. Diagram generated by author with data and graphing tool from the US EIA [http://www.eia.gov/forecasts/steo/query/.](http://www.eia.gov/forecasts/steo/query/)

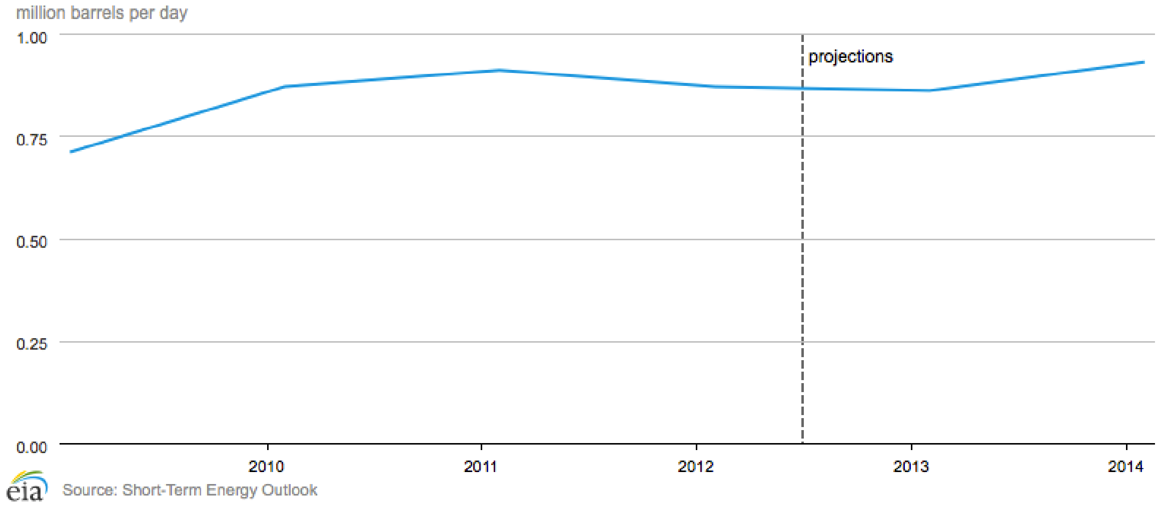

Figure A5-4. US ethanol consumption projections – short term. Diagram generated by author with data and graphing tool from the US EIA [http://www.eia.gov/forecasts/steo/query/.](http://www.eia.gov/forecasts/steo/query/)

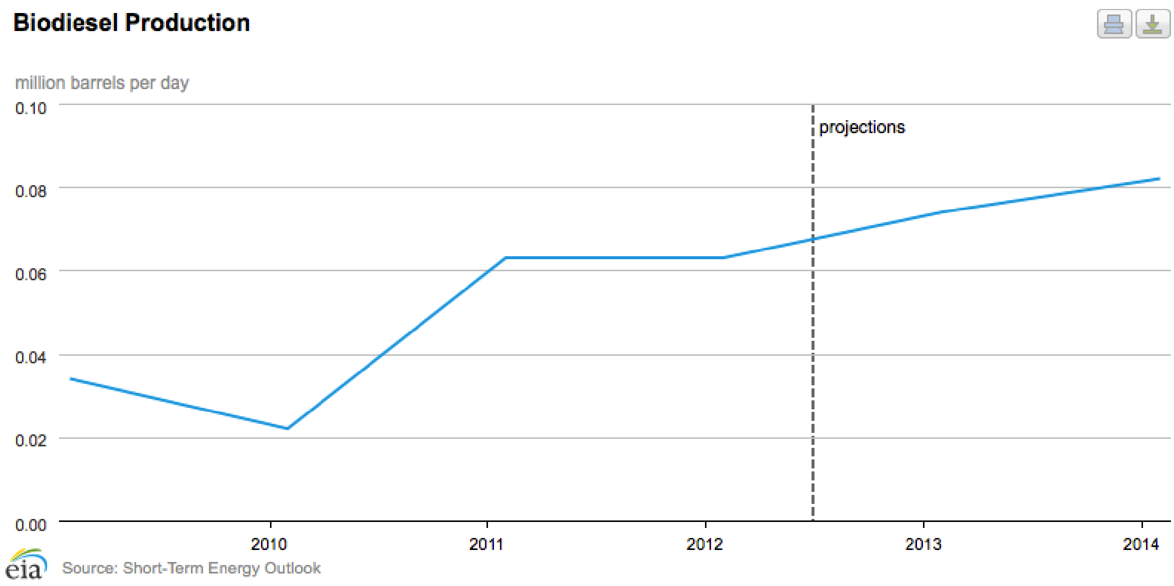

Figure A5-5. US biodiesel production projections – short term. Diagram generated by author with data and graphing tool from the US EIA http://www.eia.gov/forecasts/steo/query/.

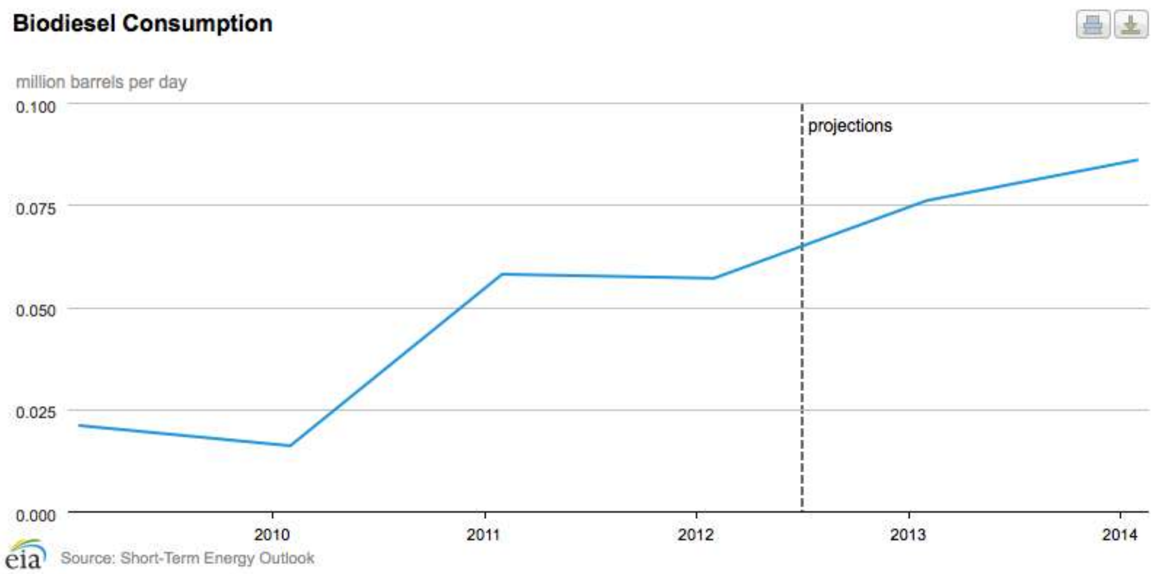

Figure A5-6. US Biodiesel consumption projections – short term. Diagram generated by author with data and graphing tool from the US EIA http://www.eia.gov/forecasts/steo/query/

Table A5-2. Overview of Commercial Scale US Cellulosic Ethanol Plants. Sources: Updated from Biofuels Journal (2010), Gardner (2009) and Biofuels (2010) with material from Barnett (2012), Fehrenbecher (2008), Griekspoor (2012), Lane (2012), Schiffer (2012) and Schill (2012).

Company	Location	Feedstock	Capacity (‘000s m^3/year (GWh))	Production status	
Abengoa Bioenergy	Hugoton, KS	Wheat straw	95 – 114 (523-627GWh)	Scheduled est. June 2013 – now to go online early 2014. Construction work still underway as of Nov. 2012 (Griekspoor, 2012)	1
DuPont	Nevada, IA	Corn stover	113.5 (630GWh)	Original estimate 2014 Construction underway.	2
Fulcrum BioEnergy	Reno, NV	Municipal solid waste	38 (209GWh)	Original estimate end of 2013. Conditional USDA loan guarantee received Aug. 2012. Construction yet to commence (Schill, 2012)	3
Mascoma	Kinross, MI	Wood waste	75 (413GWh)	Original estimate 2014. Mascoma moved to Bid Review status for construction in mid-2012 (Lane, 2012)	4
INEOS Bio	Florida	Solid biomass waste	30 (167 GWh)	Commissioning commenced June 2012.	5
POET LLC	Emmetsburg, IA	Corn stover	75 – 95 (413- 523GWh)	Original estimate late 2013 – the plant was still under construction as of April 2013 (Lane 2012)	6
Colusa Biomass	CA	Rice hulls	47 (260GWh)	No apparent progress since 2010 but still listed.	7
US Envirofuels LLC	FL	Sorghum/Sugar cane	76 (416GWh)	Delayed but still moving forward as of 2012 (Barnett, 2012): Note: 1st generation sugar fermentation plant.	8

Table A5-3. Key federal level policy measures to promote biofuels in the US. After: US DOE AFDC (2013). Key Federal Legislation. *Alternative Fuels Data Center*. http://www.afdc.energy.gov/laws/key_legislation.

Policy	Federal/ State	Type of support	Targeted at	Description	Applicability
Alternative Fuel Excise Tax Credit	Federal	Financial incentive	Retailer	A tax credit in the amount of $0.50 per gallon ($0.13/litre) is available for the alternative fuels that is sold for use or used as a fuel.	Between January 1, 2005, and December 31, 2013
Biodiesel Income Tax Credit	Federal	Financial incentive	Distributor of biodiesel or final user	A taxpayer that delivers pure, unblended biodiesel (B100) into the tank of a vehicle or uses B100 as an on-road fuel in the trade or business is eligible for an incentive of $1.00 per gallon ($0.26/litre) of biodiesel, agri-biodiesel, or renew-able diesel used.	Between January 1, 2005, and December 31, 2013
Advanced Biofuel Production Payments	Federal	Payment scheme	Biofuel producer	Through the Bioenergy Program for Advanced Biofuels, eligible producers of advanced biofuels, or fuels derived from renewable biomass are eligible to re-ceive payments to support expanded production of advanced biofuels.	
Ethanol Infrastructure Grants and Loan Guarantees	Federal	Loan Guarantee and grants	Agricultural producer & rural small businesses	The Rural Energy for America Program (REAP) provides loan guarantees and grants to purchase renewable energy systems or make energy efficiency im-proveements. The maximum loan guarantee is $25 million and the maximum grant funding is 25% of project costs.	Funding for this program is subject to congressional appropriations over fiscal year 2013.
Advanced Biofuel Feedstock Incentives	Federal	Payments	Biomass producer, landowner or operator	The Biomass Crop Assistance Program (BCAP) provides financial assistance to establish, produce, and deliver biomass feedstock crops for advanced biofuel production facilities. The payments of $1 for each $1 per dry ton paid by a qualified advanced biofuel production facility.	
Second Generation Biofuel Producer Tax Credit	Federal	Financial incentive	Advanced biofuel producer	A second generation biofuel producer is eligible for a tax incentive of up to $1.01 per gallon ($0.27/litre) of second generation biofuel that is: sold and used by the purchaser to produce a second generation biofuel mixture, or as a fuel in a trade or business, or as a motor vehicle fuel;	Between January 1, 2009, and December 31, 2013
Vehicle Acquisition and Fuel Use Requirements for Federal Fleet	Federal	Regulation	Federal fleet of vehicles	Under the Energy Policy Act (EPAct) of 1992, 75% of new light-duty vehicles acquired by the federal fleets must be alternative fuel vehicles. Federal fleets are also required to use alternative fuels in dual-fuel vehicles.	
Vehicle Fuel Economy & GHG Emissions Standards	Federal	Regulation	Vehicle manufacturers	Vehicle manufacturers must meet fuel economy and greenhouse gas (GHG) emissions standards for vehicles sold in the United States.	
Alternative Fuel Infrastructure Tax Credit	Federal	Financial incentive	Fuelling station owners	Fuelling equipment for natural gas, liquefied petroleum gas (propane), electri-city, E85, or diesel fuel blends containing a minimum of 20% biodiesel instal-led, is eligible for a tax credit of 30% of the cost, not to exceed $30,000.	Between January 1, 2006, and December 31, 2013

Table A5-4. Examples of state level policy measures to promote biofuels in the US. After: US DOE AFDC (2013). Key Federal Legislation. *Alternative Fuels Data Center*. http://www.afdc.energy.gov/laws/key_legislation

Policy	Federal/ State	Type of support	Targeted at	Description or example	Applicability
Vehicle Purchase and Infrastructure Development Incentives	State	Financial incentive	Private & non-profit organisations. Public and private entities in the area. City of Riverside residents & employees	Alternative Fuel and Advanced Vehicle Funding - New York, New York Alternative Fuel Vehicle (AFV) Grants - Houston - Galveston, Texas Vehicle Purchase Incentives - Riverside, California	
Renewable Fuels Mandates and Standards	State	Regulation	Blenders and retailers	Renewable Fuels Mandate - Portland, Oregon: According to the standard, all gasoline and diesel sold in Portland city must contain a minimum of 10% ethanol (E10) and 5% biodiesel (B5) respectively.	
Vehicle Acquisition Requirements	State	Regulation		Alternative Fuel Vehicle (AFV) Acquisition Requirements - Albuquerque, New Mexico Compressed Natural Gas (CNG) Use Requirement - Smithtown, New York Green Fleet Policy - Minneapolis, Minneapolis	
Idle Reduction Requirements	State	Regulation	Vehicle owners	Idle Reduction Requirement - Atlanta, Georgia: Atlanta city prohibits the idling of a truck or bus for more than 15 minutes on any street or public place. Idle Reduction Requirement - Denver, Colorado: Idling of any vehicle for more than five minutes in any one-hour period is prohibited in the city and county of Denver. Idle Reduction Requirement – Philadelphia, Pennsylvania: Idling of any heavy-duty diesel motor vehicle for more than two minutes is prohibited in the City of Philadelphia.	
Parking Incentives	State	Incentive	Alternative fuel vehicle owners	Alternative Fuel Vehicle (AFV) and Hybrid Electric Vehicle (HEV) Parking - New Haven, CT: The City of New Haven provides free parking on all city streets for HEVs and AFVs that have a rating of at least 35 miles per gallon (~ 15km/l).	

Table A5-5. Overview of CANCELLED Commercial Scale US Cellulosic Ethanol Plants (Sources as for Table A5-2)

Company	Location	Feedstock	Capacity ('000s m^3/year (GWh))	Production status	
BlueFire Ethanol	Irvine, CA	Multiple sources	14.7	No activity found on this project. Bluefire focused on a Korean project.	1
BlueFire Ethanol	Fulton, MS	Multiple sources	72	No activity reported since site preparation in 2011. Apparently searching for financing.	2
Coskata, Inc.	Boligee, Alabama	Wood waste	60.5	Original estimate 2013 – refocused on natural gas feedstock.	3
Gulf Coast Energy	Mossy Head FL	Wood waste	95 (520GWh)	Project cancelled. Gulf Coast concentrate on Alabama pilot plant.	4
Iogen Biorefinery Partners Inc.	Shelley ID	Multiple fuels	68 (375GWh)	Project suspended 2008 (Fehrenbacher, 2008).	5
Range Fuels	Truetland GA	Wood waste	76 (416GWh)	Closed CoM 2011.	6
Sun Opta Bioprocess	Little Fields MN	Wood chips	38 (208GWh)	Sold to Mascoma, terminated by Mascoma 2011 (Shaffer, 2012).	7
Verenium BP	FL	Sorghum/Sugar cane	136 (750GWh)	Project cancelled in 2012.	8
Xenthanol Corp/Southeast Biofuels	Auburndale FL	Citrus peel	30 (167GWh)	Cancelled	9