POLICY CHALLENGES IN REALISING BIOMASS GASIFICATION IN THE EUROPEAN UNION

Hans Hellsmark
Department of Energy Technology, SP Technical Research Institute of Sweden*

Staffan Jacobsson
Department of Energy and Environment, Chalmers University of Technology*

*Division of Systems Analysis (H. Hellsmark) and Division of Environmental Systems Analysis (S. Jacobsson)
Chapter reviewers: Maria Grahn, Daniel Johansson, Physical Resource Theory, Energy and Environment, Chalmers

INTRODUCTION

A core technology in biorefinieries is that of biomass gasification (see Chapter 2). Over the last three decades, experiments have been undertaken where different applications have been explored. In the 1980s, gasified biomass replaced oil in some lime kilns in the paper and pulp industry and experiments were later made with electricity production. The current focus (and the focus of this chapter) is on synthetic fuels from biomass gasification. Within the EU there are nine prominent demonstration facilities, centred on three dominant technological trajectories, in the process of being realized in Austria, Finland, Germany and Sweden.

Each demonstration plant is at the heart of an alliance consisting of a wide range of firms, institutes and universities. Whereas many of these plants are well under way, none of them have yet completed the initial demonstration phase for production of synthetic fuels. Moreover, this phase is followed by a dramatic, and very costly, up-scaling of the plants to full scale semi-commercial demonstrations and, eventually, commercial plants. The various biomass gasification technologies are, hence, largely untried.

In such early phases of development, there are generic uncertainties facing investors in terms of technology, markets and institutions.[1] These uncertainties also abound in this case and risk delaying or even jeopardizing progress towards commercial plants. This calls into question how policy may continue to support the development of a technological field which is seen as one, of many, that may help us reduce the threat of climate change.[2] They also raise questions about the realism of EU's expectations of the time scale involved in creating a substantial supply of biofuels from lignocellulosic feedstock (see Chapter 4 on biomass resources and Chapter 6, Figures 6.7-6.9, on conversion efficiencies). The purpose

1 Rosenberg, N., (1996). Uncertainty and Technological Change, in: Landau, R., Taylor, T., Wright, G. (Eds.), The Mosaic of Economic Growth. Stanford University Press, Stanford, California, pp. 334-355.

2 Our starting point is that synthetic fuels produced through gasifying biomass is an important technology for reducing emissions of GHG in the transport sector and it is, therefore, of great social interest to develop the technology (see also Chapter 7).

9

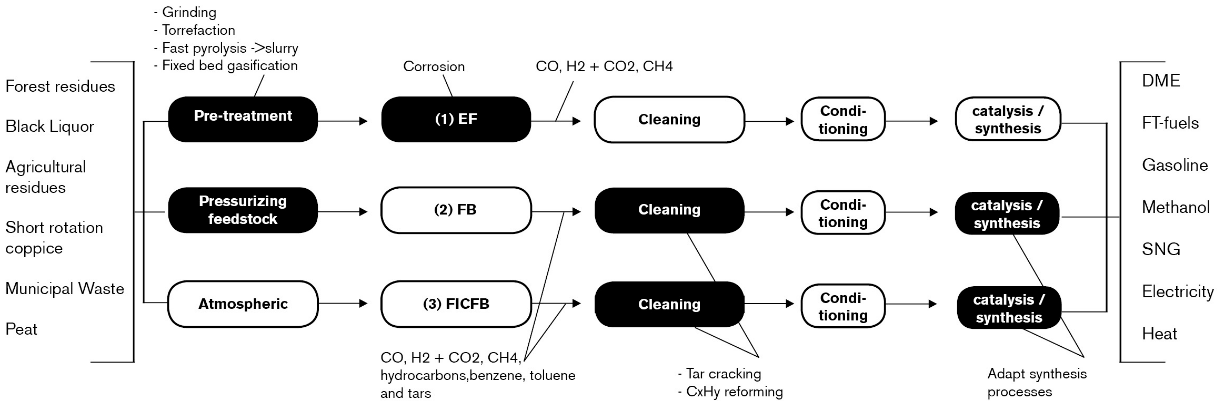

Figure 9.1 The three main trajectories for biomass gasification and main technical challenges (marked in grey and described in italics). The three main trajectories are: (1) Entrained Flow (EF) gasification, (2) Fluidized Bed (FB) gasification, and (3) Fast Internal Circulating Fluidized Bed (FICFB). Source: Hellsmark (2010).

of this chapter is, therefore, to identify policy challenges and discuss options for moving from the current small scale pilot and demonstration plants to a larger scale diffusion of gasified biomass in the EU in the course of the next decades.

Knowledge of the three technological trajectories and of the actors engaged in these is essential for our policy analysis. In the next section, we describe, therefore, the technologies associated with the current demonstration projects, identify the main technical uncertainties associated with these and the coalitions of actors that are formed around the plants. We then address the size of the financial risks for investors stemming from technical and market related uncertainties and discuss different policy instruments which can reduce the effects of these uncertainties for investors. [3]

TECHNOLOGY, DEMONSTRATION PROJECTS AND SUPPORTING ALLIANCES

Gasification technology rests on a set of technological capabilities associated with the thermal conversion of carbon based fuels to a gaseous product with a usable heating value[4]. Many types of feedstocks can, in principle, be used, e.g. municipal waste, oil, coal, natural gas and biomass, and a wide range of synthetic fuels may be produced from the gas, e.g. FT-fuels, hydrogen, dimethylether (DME), methane (i.e. substitute natural gas, SNG) and methanol, see Figure 9.1.

To some extent, biomass gasification can draw upon the knowledge base of fossil fuel gasification. However, both the physical and chemical properties of biomass are different from coal, oil and natural gas. The demands on the feeding system, reactor design as well as the downstream processes are, therefore, different. Producing a synthetic fuel based on biomass gasification consequently means that a set of additional competences related to feeding, reactor design, cleaning, conditioning and catalysis of the gas are required. Attempts to solve the technical challenges of biomass gasification, and associated uncertainties, are currently pursued along three trajectories - see Figure 9.1 where the technical challenges are marked in grey and described in italics. [5]

The Entrained Flow (EF) trajectory draws primarily on technologies that have been developed for oil and coal gasification. It involves gasifying biomass with oxygen under high temperature

3 This chapter is based on Hellsmark, H., Jacobsson, S., (2012). Realising the potential of gasified biomass in the European Union–Policy challenges in moving from demonstration plants to a larger scale diffusion. Energy Policy 41, 507-518.

4 Higman, C., van der Burgt, M., (2008). Gasification. Gulf Professional Publishing, Burlington, USA.

5 These nine projects were identified in 2008 through an extensive literature review and interviews with industry experts. This implies that that some important but more recent projects are excluded. See Hellsmark, H. (2010). Unfolding the formative phase of gasified biomass in the European Union – The role of system builders in realising the potential of second-generation transportation fuels from biomass. Doctoral thesis, Department of Energy and Environment, Chalmers University of Technology, Göteborg.

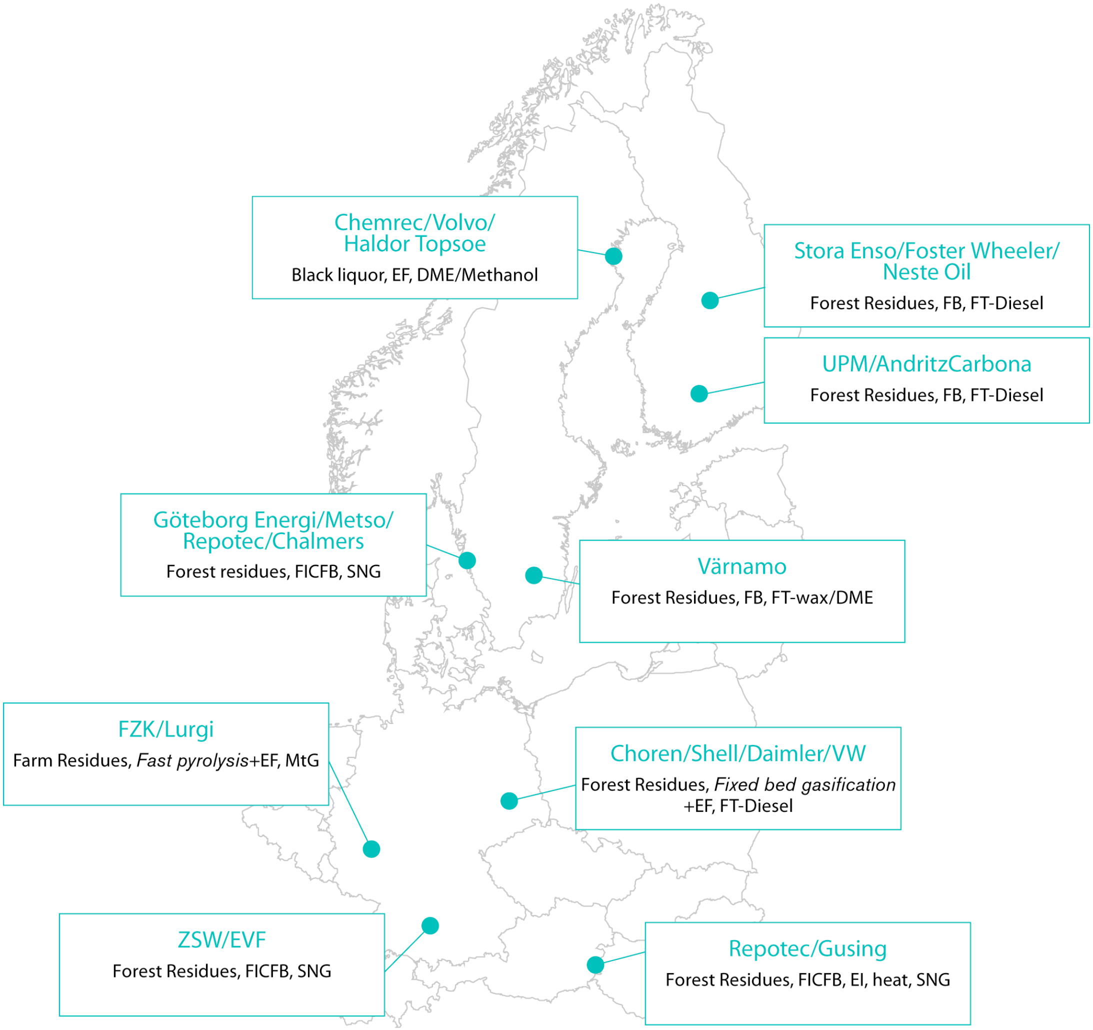

Figure 9.2 Overview of major gasification projects in Europe pursued for the production of synthetic fuels from biomass. When relevant, methods for pre-treatment are mentioned in italics. Acronyms used in the figure are: EF: Entrained Flow, FB=Fluidised Bed, FICFB=Fast Internal Circulating Fluidised Bed, SNG=Synthetic Natural Gas, DME= dimethyl ether, MtG=Methanol to Gasoline. Source: Hellsmark (2010), see footnote 5.

and pressure. The process results in a relatively clean gas that can be synthesised into advanced chemicals and transportation fuels with, more or less, existing downstream coal technologies. The drawback with this route, however, is that a system for pre-treating the biomass is necessary and such systems are currently not commercially available.

The two other trajectories have evolved from combustion technology into pressurized Fluidized Bed (FB) and atmospheric Fast Internal Circulating Fluidized Bed (FICFB) gasification. In the FB system, biomass reacts with a mixture of oxygen and steam. Since it is pressurized, it can be operated on a large scale, while the atmospheric process (FICFB) can be operated on a smaller scale without an external oxygen supply. Fluidized bed technologies are well suited to the physical and chemical properties of biomass and feeding biomass to the gasification reactor poses, therefore, few problems, although there are limited experiences with pressurized feeding systems. More importantly, the gas from both processes is more contaminated by tars, alkaloids, hydrocarbons, benzene, nitrogen and toluene, etc. than the gas from EF gasification. For transport fuels, ultra clean gas is required and there are limited experiences with producing such a gas with conventional cleaning methods. Producing transport fuel means, therefore, that competences related to cleaning, conditioning and catalysis of the gas are required. [6]

These competences reside not within the boiler industry (mastering combustion technology) but within the chemical industry, associated institutes and university departments. This means that firms have to acquire the required competences or operate in alliances. A feature of the technological field of biomass gasification for the production of synthetic fuels is, indeed, that such alliances are formed. [7] These alliances include actors along the whole value chain, e.g. actors in the agricultural and forestry sectors supplying the feedstock, the capital goods industry, suppliers of gas (including the petrochemical industry) and manufacturers of transport equipment.

Nine such alliances are found in Figure 9.2. Each of these focuses on a specific pilot or demonstration plant. These projects target different types of biomass as feedstock, employ different gasification technologies (all of the three trajectories discussed above are represented) and aim for different types of synthetic fuels such as FT-fuels, DME, methanol and methane. Some of the projects are in a pilot phase whereas others are in an early demonstration phase, see Table 9.1.

As the development of the technological field progresses towards commercially sized demonstration plants, we expect to see challenges for private actors to coordinate simultaneous investments along the entire value chain. These coordination and development activities range from increased biomass production to technology integration in the pulp and paper industry, in refineries or in other existing industries where potential synergies can be found (see Chapters 2 and 5), to the development of new infrastructure and vehicles. However, judging from the ability to form alliances hitherto, this coordination may not be a primary obstacle. A more significant obstacle arguably lies in managing the substantial technical uncertainties indicated above and the even more substantial market uncertainties.

TECHNICAL UNCERTAINTIES FACING INVESTORS

The nine projects described above are all in the process of moving from the pilot stage to constructing the first demonstration units. The cost of these plants ranges from 1 to 100 MEUR. However, not all of them include demonstration of the synthesis process, see Table 9.1.

The subsequent shift to pre-commercial demonstration plants and fully commercial plants involves dramatic up-scaling of the size and cost of the plants. For instance, for the Chemrec plant (EF gasification of black liquor in Sweden) this will involve an increase in output from less than 0.1 PJ per year[8] (28 MEUR) in a demonstration plant that was constructed (but not taken in operation) in 2010 to 4 PJ per year (300 MEUR) in a pre-commercial plant (originally planned to be ready by 2012-2013)[9] and to 8 PJ per year (400 MEUR) in a commercial plant to be ready for operation by 2015.[10] The investment costs would typically be between 400-800 MEUR for commercial plants with a production capacity in the range of 8 PJ per year (0.2 Mtoe per year).

Throughout the up-scaling process, uncertainties of a technical nature are likely to remain although they are expected to get smaller as the scaling process proceeds. On the other hand, the sums involved are much larger, so technical uncertainties will remain a serious obstacle to investment. Conventionally, demonstration plants receive investment subsidies from governments but

6 For a longer discussion of these matters, including sources, see Hellsmark, H. (2010). Unfolding the formative phase of gasified biomass in the European Union – The role of system builders in realising the potential of second-generation transportation fuels from biomass. Doctoral thesis, Department of Energy and Environment, Chalmers University of Technology, Göteborg.

7 There are also other reasons for forming alliances, such as political leverage and securing complementary products as well as funding.

8 Approximately 1.5 ktoe (tonnes of oil equivalent), 1 Mtoe equals 41.9 PJ.

9 Recent information indicates that this decision has not yet been taken which means the time-scale is shifted forward 2-3 years, at best.

10 Rudberg, J., (2008). Interview with Jonas Rudberg, CEO Chemrec, Stockholm, 2008-12-03.

Table 9.1 Industry estimates of costs and time line for the major development projects in the EU.

	Pilot			Demo			Pre-Commercial Demo			Commercial size		
	Year	Size (MW)	Cost (MEUR)	Year	Size (MW)	Cost (MEUR)	Year	Size	Cost (MEUR)	Year	Size (PJ)	Cost (MEUR)
TU-Vienna/Repotec	1995	0.1	NA	2002	8	10	2013	0.1PJ	75	2015-	3	150
Chalmers/Metso	2008	6	1.1	2008	6	1.1						
ZSW/EVF	2002	8	2.4	2010	10	18	2013-	10 MW	NA	2015-	3	150
Chemrec	2005	5	7	2010	5	28	2013	4 PJ	300	2015-	8	400
Värnamo				1993	18	45				2015-	8	400
Carbona/UPM	2005	6	10				2012	8 PJ	400	2015-	8	500
FW/SE/Nesté				2009	12	40	2012	4 PJ	400	2015-	8	500
Choren	1998	1	NA	2008	45	100				2015-	8	800
FZK/Lurgi	2005	0.1	NA	2008	5	4	2011	5 MW	70	2015-	8	900

Source: Hellsmark and Jacobsson (2012). The table indicates when the various alliances predict that their projects will pass through the different phases. The year refers to completed construction, not to plant in operation. The pilot, demonstration and some of the pre-commercial plants will not operate in a continuous mode. It is, therefore, not meaningful to convert a physical size (MW) into a production volume (PJ/year) for these plants. In the case of Värnamo, a demonstration plant was taken into operation for the production of heat and electricity in 1993. Attempts to reconstruct the plant for demonstrating the production of synthesis gas have been made since early 2000, but these have not been successful.

government sponsored risk absorption schemes may also be applied, reducing the risks of the lending bank.

Given the costs involved, any government programme has to be very large. In the Swedish case, for instance, a funding scheme for demonstration of synthetic fuels from gasified biomass and other energy technologies instituted in 2008 involves about 875 MSEK (87 MEUR) over a period of 3-4 years. [11] This scheme represents a major increase in the availability of such funding. Through this scheme, the company Chemrec has been granted 500 MSEK (about 50 MEUR) and Gothenburg Energy 222 MSEK (about 20 MEUR) to complete the pre-commercial demonstration phase, see Table 9.1. [12]

Continuing with the case of Sweden, assuming that one plant from each of the three trajectories will be constructed in the next phase, an additional 1,000 MEUR will have to be raised. To cover, say, 20 per cent of the total investment, a funding scheme of an additional 200 MEUR would, therefore, be required. An obvious policy challenge is, thus, to devise large enough programmes that can induce investors to face the technical uncertainties in moving to the first commercial plants. Such programmes must have a long-term commitment from policy makers in order to be effective.

It is a complex process to produce synthetic fuels from biomass gasification and significant delays are common. Given all uncertainties it is reasonable to assume that it will take at least three years[13], probably more, from when a first (and smaller) demonstration plant has been constructed until an investor is willing to commit to a (larger) pre-commercial demonstration plant.

Investors would, thus, be able to decide whether to start constructing the first pre-commercial demonstration plants no earlier than 2014. It may

11 Swedish Energy Agency, 2008. Utlysning: Intresseanmälan för demonstration och kommersialisering av andra generationens drivmedel och annan energiteknik. Dnr: 410-2008-003385. Eskilstuna.

12 The Gothenburg Energy plant is a variant of the TU-Vienna/Repotec technology and represents the pre-commercial plant on the first row in Table 9.1.

13 The figure is a very rough estimate based on previous and similar gasification projects, see Hellsmark, H., (2010). Unfolding the formative phase of gasified biomass in the European Union – The role of system builders in realising the potential of second-generation transportation fuels from biomass. Doctoral thesis, Department of Energy and Environment, Chalmers University of Technology, Göteborg. for a longer discussion.

then take three to four years to construct and demonstrate these larger plants which mean that an investment decision for the first commercial-sized plant cannot be taken until 2017-18. The first commercial fuels from biomass gasification cannot, therefore, be expected to be available earlier than about 2020.

In sum, the high risks, large capital expenditures and long time scale involved in developing the complex and large-scale technology for producing fuels from biomass gasification dictates that, from an investor's perspective, it is vital that policy intervention has a long term perspective and involve substantial sums.[14] The expected time scale involved in shifting from the current demonstration phase to a situation where synthetic fuels from biomass may begin to have an impact on the market may also have to be adjusted.

MARKET UNCERTAINTIES

The EU Directive 2009/28/EC mandates a ten per cent share of renewable transportation fuels (by energy content) by 2020, which translates into approximately 1,300 PJ per year (30 Mtoe per year) based on the road transport fuel consumption in 2005-2010. [15] On the basis on the analysis in the previous section we expect only a small share in the form of fuels from gasified biomass. [16]

Assuming, however, that the supply of synthetic fuels from biomass gasification takes off after 2020 and captures a market of, say, 1,300 PJ per year by 2030 it would involve building some 150 plants, each supplying 8 PJ per year (0.2 Mtoe per year) of fuel. The total value of the fuel supplied would be about 15-30 billion EUR per year, and the total investment 60-120 billion EUR. Hence, a subsequent large scale transformation of the fuel market would entail huge market opportunities for both fuel and capital goods suppliers.

Yet, there are very substantial uncertainties facing investors with respect to market formation that must be addressed if the potential of gasified biomass is to be realised. The main market uncertainty is threats from substitutes in that investments that may eventually deliver synthetic fuels from biomass gasification have to compete not only with the lower cost sugar and starch based biofuels but also with fossil based alternatives, conventional fuels and maybe also with hydrogen and electricity.[17]

With respect to conventional fossil based fuels, potential investors would, in the absence of a deployment policy, face very substantial market uncertainties for both the initial nine plants and for the subsequent 100 or more plants. These uncertainties are illustrated in Figure 9.3. In the figure, we distinguish between low and high cost levels (10-20 EUR/GJ) for producing synthetic fuels from biomass gasification.[18]

These cost levels can be set against past and predicted prices of oil. The average world oil price from 1970 to 2009 was 36 USD (in 2008 dollars). In the World Energy Outlook, IEA (2009) [19] predicts the real oil price by 2030 in two main scenarios. In the reference scenario, it is set at 115 USD/barrel and in the high price scenario it is increased to 150 USD/barrel.

14 Committee on Climate Change (2010, p. 9)) in the UK explains why public intervention must go beyond addressing negative externalities: "Investment in innovation is characterised by uncertainty – i.e. it is known that investments may fail, but a precise probability cannot be placed on failure. Unable to calculate precise risks, investors will act upon imperfect information and will often be risk averse. Long time scales for investment and deployment of technologies increase the length of time investments are at risk and increase risk aversion. For high capital cost investments, frequent in the energy sector, this may be a particular barrier."

15 Eurostat, 2012. Energy statistics, . European Commission.

16 Even though perhaps unrealistically, we assume that all of the projects in Table 1 are realized and at least one commercial scale plant will be built for each project, the combined production capacity of these commercial scale plants would be approximately 60 PJ per year. This amounts to less than 0.5 per cent of the EU transport fuel market. Hence, synthetic fuels from gasified biomass may be available by 2020, but the volumes cannot be expected to be significant by then.

17 However, other market uncertainties also apply such as the size of the potential market (Chapter 3) and the availability of future biomass resources for energy purposes (Chapter 4).

18 These cost levels were provided by advocates of the different projects in Table 9.1 and Figure 9.2; they are further discussed in Hellsmark (2010).

19 IEA, 2009. World Energy Outlook. International Energy Agency, Paris.

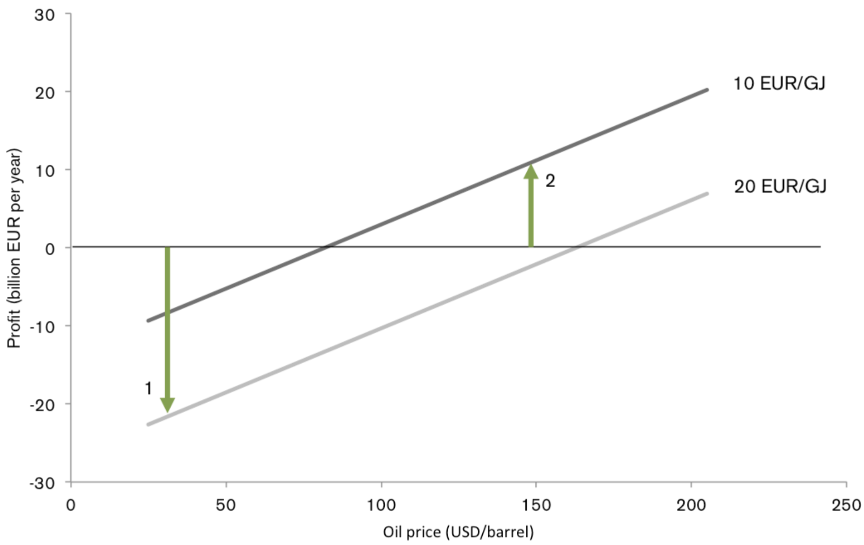

Figure 9.3 A tentative assessment of financial risk for commercially sized plants – annual losses or gains in realizing a 10 per cent market for synthetic fuels from biomass gasification by 2030 (billion EUR). Arrows 1 and 2 are discussed in the text.

Figure 9.3 provides a base for assessing the financial magnitude of the market uncertainties caused by uncertain future oil price. It points to the hypothetic annual losses (or gains) for investors if a 10 per cent market for synthetic fuels from biomass gasification (1,300 PJ per year) is realized in the future. Investors would lose more than 20 billion EUR if that market were to be realised at a production cost of 20 EUR/GJ (corresponding to 163 USD/barrel) and with an oil price at an historic average of 35 USD/barrel (Arrow 1 in Figure 9.3).[20] On the other hand, with production costs of 10 EUR/GJ and with the oil price at 150 USD/barrel, investors would gain more than 10 billion EUR (Arrow 2).

In sum, there are not only substantial technical but also market related uncertainties for all the actors that need to participate to realize the potential. Moreover, these uncertainties are not of a short term character but are expected to stay for many years. Only very powerful and durable[21] incentives may, therefore, be expected to induce the necessary investments to take the industry into a pre-commercial demonstration phase and, eventually, form a significant supply capacity for synthetic fuels based on biomass.

CRITERIA FOR ASSESSING POLICY OPTIONS

Reducing these technical and market uncertainties is the main challenge ahead for policy makers and we will discuss various means of doing so. We will focus on market uncertainties since investment subsidies or risk absorption schemes (managing technical uncertainties) may not be enough to stimulate investments even for the first set of plants (about 4 billion EUR, see Table 1) due to the very large market uncertainties. Before we discuss the usefulness of various policy instruments, we need, however, to specify the assessment criteria, in particular what effectiveness entails.

Effectiveness, efficiency and equity are three commonly used criteria for assessing policy options. [22] The effectiveness of an instrument is assessed by its ability to meet a certain target, e.g. ten per cent renewable transportation fuels by 2020 or hundred per cent by 2050.

20 We here assume an exchange rate or 0.75 EUR/USD.
21 The time scale involved here is not unique. Mobile telephony dates back to the 1950s and a large scale diffusion took place in the second half of the 1990s. The first offshore wind farm was built in 1991 and in 2011, 14 TWh was supplied in Europe and the European Wind Energy Association expects a large scale diffusion to begin after 2020.

22 Jacobsson, S., et al. (2009). EU renewable energy support policy: Faith or facts? Energy Policy 37, 2143-2146.

Efficiency[23], or cost-effectiveness, is assessed by the social costs involved in meeting a given target. There are two challenges in applying this criterion. First, by definition, it makes sense to assess the cost-effectiveness of instruments only if they are expected to lead to the achievement of a certain target, i.e. if the effectiveness criterion is fulfilled (see below). Second, minimising costs, not in the short term, but over several decades means that we need to focus on what policy instruments can be expected to generate the lowest cost solution over the whole period, taking technical change into account. This rests, to a large extent, on the innovative capabilities in the capital goods industry. Hence, applying this criterion requires that we understand the impact of various instruments on the behaviour of the capital goods sector and its ability, in turn, to drive technical change.

The third criterion is equity which is a factor in creating social legitimacy for policies supporting new technology. Excess profits threaten legitimacy and must be avoided.[24]

In order to assess the effectiveness of a policy instrument, we need to specify the goal of intervention. As far as we are aware, a goal has not been set for the diffusion of synthetic fuels, neither in individual countries, nor at the EU level. However, as we move beyond 2020, an aggressive strategy to cut emissions is argued to require a major increase in the supply of biofuels from lignocellulosic feedstock (compare discussion in Chapter 4), including synthetic fuels from biomass gasification. [25]

What goal should then the effectiveness criterion be related to? The effectiveness of any policy instrument must be assessed, as is evident from the sections above, by its ability to influence the strategic decisions of actors to explore and develop alternative technical solutions, fill the whole value chain and coordinate actions.

Arguably, for the period from now until 2020, a first goal would be to move from smaller demonstration plants to having fully commercially sized plants from the different trajectories up and running. Hence, a first goal is to 'put the various technologies on the shelf'. [26] This is likely to be achieved no earlier than 2020. In the next stage, a second goal for 2030 could be set at 20 per cent renewable transportation fuels, of which half could be synthetic fuels from biomass gasification. This would amount to about 1,300 PJ (30 Mtoe) or about 150 plants.[27]

This means that policies must be assessed with respect to their ability to meet these two goals within the specified time frame. To be effective, we will argue that several alternative technologies need to be developed. This is, of course, inherent in the first goal but also, arguably, a necessity if the second goal is to be reached.

The different technological trajectories do not represent conventional 'competing designs', i.e. design configurations that can fully substitute for each other. [28] The applications of the technologies in the three trajectories to specific contexts are more or less constrained in their potential. For instance, feedstocks vary in their availability, e.g. the use of EF with black liquor as feedstock is constrained by the number of pulp mills with chemical process technology (in contrast to mechanical). Moreover, there are joint production opportunities in the pulp and paper (Chapters 2 and 5), petro-chemical (Chapter 2) and district heating industries (Chapter 8) but, of course, these are limited by the size of these industries and by existing technical infrastructure.

The lowest cost level for producing synthetic fuels from biomass gasification in Europe, based on domestic biomass resources, can be expected to be found in Sweden and Finland due to large heat sinks and a paper and pulp industry in which

23 We here refer to economic efficiency. See e.g. Chapter 6 for a discussion of different measures of energy efficiency.
24 Verbruggen, A., (2008). Windfalls and other profits. Energy Policy 36, 3249-3251.
25 Page 473, IEA, (2008). World Energy Outlook. International Energy Agency, Paris.

26 This is broadly in line with the 450 Policy Scenario in IEA (2008) if EU maintains its share of the global biofuel market.
27 This is broadly in line with the 450 Policy Scenario in IEA (2008) if EU maintains its share of the global biofuel market.
28 Utterback, J.M., (1994). Mastering the dynamics of innovation: how companies can seize opportunities in the face of technological change. Harvard Business School Press, Boston.

the technologies (all three trajectories) can be integrated. The potential in a European market perspective is, however, quite limited. Ekbom et al. [29] (Table 7.1) show that the potential for FT-diesel production using black liquor is about 80 PJ for Sweden and Finland together. This would substitute for about 20 per cent of the petrol and diesel consumption in these two countries. Even if production were to be doubled by the inclusion of fuel production in mechanical paper mills and district heating systems, meeting a goal of 1300 PJ by 2030, and going beyond it, would certainly require that the higher cost applications of the technologies would also need to be developed and exploited.

With the long time taken to go from small demonstrations to fully commercial plants, i.e. 'putting the technologies on the shelf' and the extension of that time axis in their subsequent diffusion, effectiveness involves creating markets for all the three trajectories applied to different contexts, which then will develop in parallel rather than sequentially, jointly gaining market shares from fossil alternatives and not from each other.

POLICY OPTIONS FOR REDUCING MARKET UNCERTAINTIES

Having established a key criterion for assessing the effectiveness of various policy instruments, we will now proceed to discuss a number of options where we assume that the policy instruments operate at the EU level. The main instruments of interest are a general quota for all types of biofuels, separate quotas for conventional biofuels from crops, and for biofuels from ligno-cellulosic material and waste (sometimes referred to as 'first' and 'second generation' of biofuels, respectively), and finally separate feed-in tariffs for many different conversion pathways. Before we turn to these, we will comment on another option, namely the inclusion of the transport sector in the ETS. This is sometimes advocated as a solution but it is plain that the volatility of the price for emission permits and the highly uncertain future of the size of the cap create very large uncertainties for investors who have to estimate income streams over two or more decades. Hence, in terms of Figure 9.3, the market uncertainty is very high indeed, which strongly discourages investments.

A quota for biofuels is currently operating in e.g. Germany. A general quota induces, however, an expansion of the least cost options first, i.e. first generation biofuels.[30] Whereas the desirability of conventional biofuels from crops is questioned (in terms of both its ability to reduce emissions and its use of arable land), the potential is large, especially if we consider import opportunities from Latin America and Africa (see also discussion in Chapter 4). A general quota would, therefore, not be a strong inducement mechanism for firms to invest in up-scaling and further developing biomass gasification for the production of synthetic transportation fuels.

To stimulate such development, the European Commission has decided that the "... contribution made by biofuels produced from municipal waste, residues, non food cellulosic material, and ligno-cellulosic material shall be considered twice that made by other biofuels". [31] Such a double counting would, of course, mean that a 10 per cent goal for synthetic fuels (see above) can be reached by supplying 650 PJ per year only. Yet, our conclusion of the need for a parallel development of the three trajectories in many countries holds; as shown above the supply capacity from lower cost options in the Nordic countries is still

29 Ekbom, T. et al. (2003). Technical and Commercial Feasibility Study of Black Liquor Gasification with Methanol/DME Production as Motor Fuels for Automotive Uses - BLGMF. Nykomb Synergetics AB, Stockholm.

30 Tradable green certificates (TGC) is a more advanced form of quota system that has been favoured by the EU Commission as a deployment policy in the field of renewable electricity (Jacobsson et al., 2009). The core of this policy is, as for quota systems in general, to select the currently most cost-effective technology and only in a step-wise manner introduce more costly technologies. Hence, the aim is to avoid a parallel development of technical alternatives with different cost levels. It cannot be expected to fulfil the effectiveness criterion as this requires creating markets for all the three trajectories in parallel.

31 In addition, the EC proposes that when Member States design their support systems they may give " ... additional benefits to ... biofuels made from waste, residues, non-food cellulosic material, ligno-cellulosic material and algae, as well as non-irrigated plants grown in arid areas to fight desertification ... " (EC, 2009, p.26).

quite limited in comparison.[32]

A double counting of fuels from lignocellulosic materials and waste would provide an added incentive to investors in fuels from gasified biomass that better reflect their performance in terms of CO_2 emissions. Market uncertainty remains high, however, and is magnified by the interdependency with the price of conventional fuel. Assuming that both first and second generation biofuels are blended into conventional fuels, the competitiveness of the latter vis-à-vis the former will depend on the price of conventional fuels. If that price increases, first generation biofuels gains a competitive edge simply since it, in terms of volume, replaces about twice as much conventional fuels as the synthetic alternatives.[33] Potential investors, thus, have to consider the future prices (over decades) of not only different kinds of biofuels but also of conventional fuels. This adds uncertainty to any investment analysis.

A separate blending quota for synthetic fuels from lignocellulosic materials and waste would alleviate the problem of interdependency with the price of conventional fuel and take away the market uncertainty with respect to competition with more mature biofuels. As and when the first larger plants have been taken into operation, a predetermined quota could be applied. In order to stimulate a supply capacity in the Nordic countries, a unified EU blending quota for second generation biofuels may have to be coupled to trading opportunities, i.e. an export from Sweden and Finland to other countries (as is specified in Directive 2009/28/EC). Integrating the Nordic and German markets may, however, lead to equity problems. As discussed above, the estimated cost levels of synthetic fuels from biomass gasification differ a great deal, to the advantage of Swedish and Finnish suppliers. With an integration of the markets, price levels would be expected to be equalised, with potential huge excess profits gained by the Nordic suppliers.

32 Double counting would, of course, easily lead us to set a higher goal in terms of percentage of fuel consumption, maintaining the goal of 1300 PJ per year.

33 Choren, 2007. Suggestion presented on slideshow: CHOREN Stellungnahme Förderpolitik Biokraftstoffe_2007 12 engl 01, provided by Mattias Rudloff at Choren, Freiberg.

An additional problem with a quota is the very substantial information requirements for a central planner in setting the quota, both its initial level and its escalation. Basically, today nobody can with certainty say when the first commercial plant will be operational. It is even more difficult to judge how quickly the supply capacity in the capital goods industry can grow – it depends not only on the strategic choice of a number of capital goods firms but also on the access to specialised skills in a range of areas, including gasification and catalysis.[34]

Feed-in with cost covering payment that differs between technologies (and contexts of application) is a well proven regulatory framework to stimulate the diffusion and further development of a range of technologies in parallel, i.e. a feed-in tariff is expected to score high on the effectiveness criterion. Just as double counting in a quota system, a feed-in tariff may stimulate more expensive, but higher performing, alternatives through setting higher prices. In principle, excess profits may be avoided by a careful price setting routine. Such prices, which are normally set for a period of 15-20 years, would need to be adjusted for fluctuating feedstock prices.

However, there are two major problems with this instrument, at least at this stage. First, effectiveness necessitates that one tariff is set for each technological trajectory (and specific context). It is not, however, possible to calculate costs with the required precision without experience with full size commercial plants. Second, there is not, as yet, competition in the capital goods sector within each trajectory which means that setting a feed-in price would involve negotiations between government and monopolistic suppliers with access to superior information. This opens up for problems with respect to the equity criterion.

A dedicated quota for synthetic fuels from lignocellulosic materials and waste appears to be a more attractive option as prices do not need to be set for 15-20 years but may evolve as

34 A recurrent theme in interviews with capital goods suppliers and other firms was the lack of specialised competences in the field.

experience is gained. Yet, as explained above, there are very considerable information problems for a central authority to set a quota over a longer period of time. Moreover, it remains doubtful if a promise by current politicians of a future quota would be enough to convince firms that a market will materialise with prices that will cover costs.

In sum, none of the currently discussed policy options come out as a strong candidate, at least not at this stage of development of the industry. An option would be to implement a 'bridging policy' that reduces the information needs among policy makers while taking away the market uncertainties for the first set of plants. One alternative would be to implement plant-specific tax exemptions (increasing the price competitiveness of synthetic fuels from biomass gasification) coupled to guaranteed market and off-take price from public sector customer or, possibly, traders or petrochemical firms. Such a price would, in effect, be a miniaturised plant specific feed-in tariff. The possible drawback in terms of information asymmetries would remain but be limited to a few specific investments.

With a bridging policy, the market uncertainty (in terms of relative price level vis-à-vis conventional fuels) is absorbed by the customer but the tax exemption would reduce the size of the potential losses. At the same time, as argued above, some of the technical risks would need to be absorbed by society at large. This limited and temporary construction would take the capital goods industry through to the stage where the first commercially sized plants are built, reducing technical uncertainties and completing the respective value chains. It would also give the added benefit of generating a pool of experience and competences on which a longer term policy can be based, be it a dedicated quota for lignocellulosic fuels or a targeted feed-in tariff. Of course, a possible outcome of this policy would be that a learning process reveals that gasification of biomass, or a particular trajectory, is not viable.

CONCLUDING REMARKS

The purpose of this chapter was to identify policy challenges and discuss options for moving from the current small scale pilot and demonstration plants in the European Union to a larger scale diffusion of gasified biomass.

In the EU, three main technological trajectories are being explored to gasify biomass. Nine alliances of firms, institutes and universities centre on their own demonstration plant in which one of these trajectories is applied to a specific context. These plants use different production processes and different feed stocks for producing different types of synthetic fuels. For these alliances, the challenge is to complete the demonstrations and then scale them to supply synthetic fuels from the first commercial-sized plants by about 2020.

From an investor's perspective, a commitment to synthetic fuels from biomass gasification involves facing a number of technical uncertainties that can only be reduced through building demonstration plants. Demonstration programmes that absorb technical uncertainties need to be supplemented by policies that ensure that markets are formed. There is an abundance of different public policy instruments to form markets and assessing the usefulness of each of them requires that clear criteria are developed. The effectiveness of an instrument is assessed by its ability to meet a certain target whereas efficiency, or cost-effectiveness, refers to meeting this target at lowest cost. Equity is a third credible criterion.

Discussing the effectiveness of an instrument requires that a goal is specified. We suggested, as an example, that an EU goal for 2030 could be set at 20 per cent renewable transportation fuels, out of which half could be synthetic fuels from biomass gasification. This would amount to about 1,300 PJ per year (30 Mtoe per year), involving some 150 plants. Reaching this goal necessitates the coexistence of a range of technologies applied to different contexts and with quite different cost levels. With the inherently long time axis in moving towards the first commercial scale plants, and the subsequent multiplication of these, effectiveness therefore involves creating markets for all three trajectories applied to a range of contexts which then will develop in parallel, rather than in sequence.

Most of the currently discussed policy instruments fail on this criterion of effectiveness. Equity issues would also arise. A way forward is a 'bridging policy' that takes away market uncertainties for the first plants whilst reducing the information needs among policy makers. Such a bridge could be built by implementing a small number of plant-specific tax exemptions coupled to guaranteed market and off-take price. The market uncertainty is absorbed by the customer but the tax exemption would reduce the size of the potential losses. This bridge would a) ensure a market; b) demonstrate a strong commitment to the technology; c) take the capital goods industry through to the stage where the first commercially sized plants are built, reducing the technical uncertainties and populating the respective value chains; d) generate a pool of experience and competences on which a longer term policy can be based. A final advantage with this temporary and limited policy is to learn more about the viability of gasified biomass.