BIO-ENERGY'S ROLE IN THE EU ENERGY MARKET: A 2010-2020 PERSPECTIVE

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ABSTRACT: The paper reports on a study commissioned by DG-TREN of the EC, that wishes to further develop its policies regarding the increased use of bio-energy. Three fundamental economic factors and their interaction were investigated, i.e. the demand function for renewable energy in general and biomass in particular, the supply function of biomass and biomass derived fuels, and the technology development function. There are several scenario models in use for this type of studies. One well-known model is SAFIRE, developed by ESD, and used in the TERES II study which formed the basis for the EC's 1997 White Paper on renewable energy 'Energy for the Future'. Other models were used in e.g. the EC supported Shared Analysis Project (1998). One characteristic feature of these models is the assumption of a perfectly elastic supply curve. Supply elasticity is an unrealistic assumption though. In the study reported here, more realistic inelastic supply curves are derived and used. The model used for projecting demand curves is SAFIRE. Innovative modelling elements are the emerging trade in biomass fuels, and the incorporation of new technologies (such as pyrolysis for electricity production). The paper reviews the biomass fuel supply function, in terms of quantities and costs, today, and in the future (2010, 2020) and also reviews the technology development function, in terms of capacities and costs, conversion efficiency, penetration and learning. The paper analyses the influence of policy alternatives (RES targets vs. GHG emission trade, European energy crops vs. biomass imports), and investigates the relevance of technologies for further R&TD.
Keywords: biomass resources, energy market, bioenergy policy

1 OBJECTIVE

In this paper, a recent study carried out for DG-TREN of the EC is reviewed ([11]). The study was carried out by three partners: BTG, CRES, and ESD. The first author of this paper (at the time working for BTG) was coordinator, editor and responsible for the methodology. ESD concentrated on adapting and running a computer model, simulating economic developments over the time frame considered, and CRES on biomass availability and supply. The objective of this study is to provide reliable and realistic data on bioenergy's contribution to the EU energy market by 2010 and 2020, while taking into consideration the various policy instruments such the Directive on RES-Electricity, the Directive for renewable fuels (including biofuels) for transport as well as bioenergy's contribution to achieving the EU's Kyoto commitments.

2 ANALYSIS APPROACH

The current and future role of bioenergy fundamentally depends on a number of economic factors, particularly:

- Demand function: The demand for renewable energy in general and biomass in particular.
- Supply function: The supply of biomass and biomass derived fuels.
- Technology development function: The characteristics of biomass fuelled energy conversion technologies.

The equilibrium of these functions determines the role of biomass as a source of renewable energy, and for scenario studies to be realistic, scenario models should properly reflect these functions.

The demand function for biomass

Several factors were distinguished to analyse the demand function. We differentiate between sector covenants and large-scale market approaches. In the approach of covenants, individual industries or economic sectors are being obliged to produce or use a specified quantity of renewable energy. An example of this approach is the recent EC directive on the promotion of renewable fuels for road transportation (2003/30/EC) (And further the 1997 White Paper on 'Energy for the future' ([4]), and the EU's directive on the promotion of electricity produced from renewable energy sources in the internal electricity market (2001/77/EC) ([6])). In large-scale market approaches a new value component of renewable energy is introduced: i.e. a component of sustainability in addition to the pure energy value, and the manner of implementation is left to market forces. Examples of such sustainability components are tax exemptions associated with renewable energy, traded avoided greenhouse gas (GHG) emissions connected with electricity, and traded GHG emission allowances between electricity generators.

The reasons why these policies are pursued vary, but they can all be grasped with the term 'sustainability'. They are explained in the various official documents describing the policies of the EC. The most commonly recognised reasons for promoting renewable energies (taken from the EC's White Paper on 'Energy for the future') are:

- Environmental protection.
- Reducing dependency on energy imports and increasing security of supply (Renewable energy sources are indigenous)
- Job creation, predominantly among the small and medium sized enterprises which are so central to the Community economic fabric.
- Regional development with the aim of achieving greater social and economic cohesion within the Community.

- Creation of business opportunities for European Union industries (in many third countries, in Asia, Latin America and Africa).

Since, in financial terms (that is, in the immediate view of economic actors, disregarding so-called externalities) renewable energy is generally more expensive than conventional energy, one can analyse the value of 'sustainability' in terms of monetary units per unit of energy (€/GJ or /kWh).

A large market, currently in development, is the result of the Kyoto Protocol (KP) which obliges the so-called Annex I countries to reduce their GHG emissions by a certain quantity. The KP allows its Annex I countries to realise this on an aggregate level (covering all their economic sectors), either by emission caps or trade in emission reductions, within their country, but also outside their country by means of trade (Joint Implementation - JI, the Clean Development Mechanism - CDM). JI and CDM make GHG emission neutrality into a tradable good. The actual development of this new market can be illustrated with the activities of the World Bank managed Prototype Carbon Fund, the emerging CDM programmes, and the existing JI programmes, executed by the USA, and several European countries, and also by the European Emission Trade Scheme (ETS) planned for take-off by 2005 (directive 2003/87/EC). A new value component of renewable energy has thus been introduced: a component of emission neutrality in addition to the pure energy value. Although originally expressed in monetary terms per tonne of GHG emission reduction (€/t CO2-eq.), emission neutrality can also be analysed in terms of monetary units per energy unit (€/kWh or /GJ).

In a sense, therefore, the two approaches (sector covenants and pure markets) have much in common. And in practice one observes the implementation of mixtures of the two. A consequence of the sectoral covenant approach is the existence of discerned markets of different sizes within which (without interchange) optimisations for sustainability values are sought. If 'sustainability' were allowed to be traded freely between the various economic sectors of the EU (e.g. electricity sector, heat distribution sector, transportation sector, industrial sector), market equilibria in terms of e.g. biomass consumption are likely to emerge at other levels than if single sectors are given specific emission caps or if single sectors are being obliged to implement specific quantities of renewable energy. To a large extent (but not completely), these differentiations could be reflected in the economic model that was used to carry out this study. Specifically for bio-transport fuels, the existing policy of promoting the use of these fuels to a pre-determined level was taken as a starting position, and the costs of this policy, additional to the continued use of fossil energy resources, were calculated. For the heat and electricity market, on the other hand, a 'sustainability premium' was defined, to be taken as an add-up relative to pure energy prices. Ignorant of future price developments, various price levels were assumed for this sustainability premium and elaborated in scenarios. Recognising that there is more to sustainability than GHG emissions alone, analyses of the market for avoided GHG emissions were taken as mere indicators for suitable price levels of a sustainability premium.

The supply function of biomass and biomass derived fuels

Just as sustainability, bio-energy is not supplied on a single market. There are a number of regulations that effectively create a division in the supply of biofuels. This is because part of the biofuels consist of contaminated waste, whereas waste disposal and processing are strictly regulated in such a way that the biofuels which belong to that category cannot be offered on the more general fuel market. Various regulations on a country level, and also on a European level, keep the supply and use of contaminated biomass in check. The relevant European regulations are the Directive on the incineration of waste (2000/76/EC), the Directive on the limitation of emissions of certain pollutants into the air from large combustion plants (2001/80/EC), and the Directive on the landfill of waste (1999/31/EC). This is of significant influence on the biomass fuel supply side, particularly on biofuels like: manure, slaughter house waste, waste from pulp and paper production, and biodegradable municipal waste and sewage sludge. However, those bio-fuels play an important role today in the gamut of bioenergy, and this study shows that they are likely to play an important role in the future. To stress the strong regulative role of waste management policies in view of the use of these bio-fuels, this study refers to them as 'non-tradeables'. The opposite bio-fuel category, predictably, are the 'tradeables', and these are the clean types of bio-fuels. The impact of policies on the market of these bio-fuels is less direct, as a result of the more distant effects of the relevant policies, i.e. the Directive on RES-Electricity (2001/77/EC), the Directive on biofuels or other renewable fuels for transport (2003/30/EC), the Directive on the GHG emission trade scheme (2003/87/EC), and the Kyoto Protocol's flexible instruments (CDM, JI). The distinction of bio-fuels into tradeables and non-tradeables enables an allocation of the various bio-fuels to specific applications, in such a manner that the use of non-tradeables is restricted, whereas tradeables can be used anywhere. Additionally, non-tradeables concern biomass types that bear a negative value to the owner, in contrast to tradeables.

In this study, the notion of trade goes further than that. Whereas in previous studies for the EC, notably TERES II ([3]) and the Shared Analysis Project ([2]), biomass was regarded as a local fuel (used close to the place of its production), we assumed the possibility of international trade in biomass fuels, both intra the EU, and into the EU. Intra EU biomass trade was already studied under the EC ALTENER programme ([1]). In addition, we specifically included the option of imports from third countries, which was already investigated in studies carried out for the FAO ([12]), the Dutch Government and the Dutch electricity sector ([8], [9]). Incorporation of this option considerably shifts the level of the biomass supply function, and is particularly relevant in view of a major conclusion of the Shared Analysis Project, i.e. that the growth in biomass energy is constrained by the European biomass resource base. If international trade is a realistic option, biomass fuels would become relevant for the EC policy to reduce the dependence of the EU economies from oil imports (as proposed by the EC in its Green Paper 'Towards a European strategy for the security of energy supply', [5], and thus also in this way contribute to increased sustainability.

The technology development function of biomass fuelled energy conversion technologies

Whereas, today, one is able to produce final energy products from biomass (the final energy product being either electricity, heat (or a combination: CHP) or fuel for transportation), biomass energy conversion technologies are strongly in development. Technology is the intermediary between biomass fuels and the final energy product. It is characterised by a conversion efficiency and a capital cost component. Particularly for biomass-fuelled electricity generation technologies, large R&TD programmes are being carried out, aimed at achieving higher energy conversion efficiencies at effective cost levels. To a much lesser extent this is the case with biomass-fuelled CHP and heat generation. The developments in those areas are not so much aimed at the improvement of conversion efficiencies, but rather at emission level control and user convenience. Both types of R&TD issues are relevant for this study. The first is more geared towards the improvement of the economic feasibility, and the latter towards technical feasibility and user acceptance. Specifically the economic objectives in the area of biomass-fuelled electricity generation technologies are investigated in this report, and modeling rules derived for the scenario elaborations with SAFIRE.

With regard to renewable transportation fuels, the EC is explicit about its ambitious objectives, but in most European countries a decisive start with the implementation of this policy still has to be made. At the same time, the technical options to address these EC objectives are numerous. Bio-transportation fuels are among the most attractive ones, but even within this category there exist many technology options, both in terms of bio-fuels and vehicle propulsion techniques. For this study it was attempted to make a realistic estimate of costs and conversion efficiencies of bio-transportation fuels for the time window considered.

Seeking equilibria of supply and demand

The future role of biomass fuels was estimated by means of the SAFIRE model that simulates economic investment behaviour. The model was fed with a number of alternative scenarios to test the impact of different hypotheses. These hypotheses concern the capital costs of applications, the costs of biomass fuels and the value of sustainability premiums.

For the use of non-tradeable biomass types, as defined above, in electricity and heat generation, several investment levels for conversion technologies were assumed. The acquisition costs of these fuels was taken as zero. The principal background to this approach is that these types of biomass are waste in the first place, the owners of which need to dispose of. Any negative value attached to these fuels was considered to balance the operating and capital costs associated with waste removal, e.g. incineration plants. The costs of processing non-tradeables further, i.e. beyond pure incineration, into electricity or useful heat was considered additional.

For tradeable biomass fuels in electricity and heat applications, biomass fuel prices are being established on a much larger market (as discussed above). Here, the equilibrium prices of biomass fuels were estimated by analysing the supply and demand functions of biomass. The general principle is illustrated in Figure 1, showing projected supply and demand curves of bio-fuels for electricity and heat generation for the year 2010 (the data shown are purely illustrative). For other target years, different supply and demand curves may apply. In an ideally competitive market, all transactions take place at the single price level (P2010) where supply meets demand (Q2010). All scenario studies on the economic role of biomass energy need price data on bio-fuels, however, it is a special characteristic of this study that biomass fuel prices are assessed in a dynamic model and that the assessment is made explicit.

For bio-transport fuels a different approach was chosen, since it appears that this sector is directly affected by European policies. Here the production costs of bio-transport fuels were taken as an input, and the sustainability premium required to meet the agreed sectoral objectives were determined.

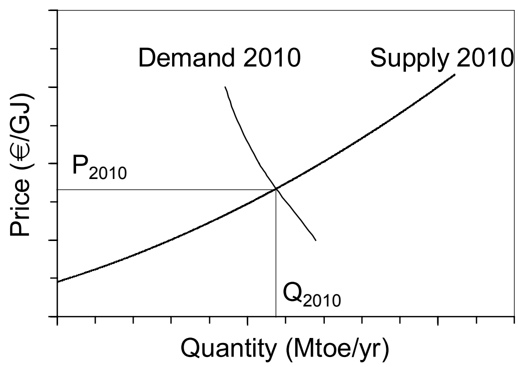

Figure 1: Price determination in a perfectly competitive market for biomass fuels and heat and electricity.

3 MAIN FINDINGS

Biomass availability

The study found a total availability of biomass fuels in the EU15 of 130 Mtoe/yr for the year 2000, growing to 170 Mtoe/yr in 2020 (Table 1). These overall figures should be regarded as indicative. In the first place, they are inaccurate. An inaccuracy in the range of ±10% in these figures is the result of an assumption on land use for energy crops, i.e. that the current set-aside area (about 10% of the arable land) is available for energy cropping (This assumption on land availability is not arbitrary. It presumes that a low value product like fuels cannot compete with the usual agricultural products), and that 50% of that area is available for the raw materials of bio-diesel and bio-ethanol. If, instead, solid energy crops would be produced here, the figures presented would increase by 10 Mtoe/yr. If, on the other hand, liquid bio-fuels would represent the preferential energy crops, the ailability would drop by 10 Mtoe/yr. In the second place, these data disregard import possibilities, which, as substantiated in the sources investigated, give rise to unlimited supplies. At a high cost though, however not always more expensive than locally produced energy crops. Within the context sketched here, the availability of tradeable bio-fuels in the EU15 amounts to 86 Mtoe/yr in 2000 (100 Mtoe/yr in 2020), of non-tradeable bio-fuels to 40 Mtoe/yr in 2000 (66 Mtoe/yr in 2020).

The growth in the availability of organic wastes is most striking. This is the result of the EU wide implementation of the EC directive on the landfill of waste (1999/31/EC), discouraging the landfilling of biodegradable waste and a prescribing a time schedule to reduce this manner of waste disposal to a specific level.

On average, supply costs (delivered to end-user) of tradeable biomass fuels in the EU15 vary from 1.6 €/GJ (solid industrial residues) to 5.4 €/GJ (solid energy crops) (Table 2). Specifically for estimating the supply costs of solid energy crops, a new generic methodology had to be prepared and applied. This was because of the multitude of methods employed by the various authors on that subject. The method adopted here, closely resembles the ones commonly used in the EU's analyses of agricultural policies. Estimates were prepared for every single country. On average, the supply costs of solid energy crops are close to those of imported biomass, which was taken at a standard level of 6 €/GJ. Single average supply costs

Table 1: Availability of bio-energy in Europe in 2000,2010 and 2020 (Mtoe/yr).

	EU15			Accession States, + BG & RO		
	2000	2010	2020	2000	2010	2020
Tradables:	**86**	**93**	**101**	**21**	**22**	**24**
Forestry byproducts & (refined) wood fuels	34	38	42	7.9	8.7	9.6
Solid agricultural residues	25	28	31	7.3	8.1	8.9
Solid industrial residues	11	12	13	2.1	2.4	2.6
Solid energy crops /a	16	16	16	3.2	3.2	3.2
Non-tradeables:	**40**	**53**	**66**	**7.1**	**9.4**	**13**
Wet manure	11	12	13	3.4	3.8	4.2
Organic waste						
- Biodegradable municipal waste	6.7	17	28	0.5	2.5	5.7
- Demolition wood	5.3	5.8	6.4	0.6	0.6	0.7
- Dry manure	1.9	2	2.3	0.4	0.4	0.5
- Black liquor	9.9	11	12	0.7	0.8	0.9
Sewage gas	1.7	1.9	2.1	0.4	0.4	0.5
Landfill gas	4.0	3.8	2.1	1.1	0.9	0.4
Transport fuels	**4.9**	**4.9**	**4.9**	**0.8**	**0.8**	**0.8**
Bio-ethanol /a	3.7	3.7	3.7	0.5	0.5	0.5
Bio-diesel /a	1.2	1.2	1.2	0.3	0.3	0.3
Total bio-energy	**131**	**151**	**172**	**28**	**32**	**38**

a/ It is assumed that 50% of the set-aside area is available for solid energy crops and 25% each for bio-ethanol and biodiesel.

of 23-29 €/GJ were determined for the refined bio-transport fuels bio-ethanol (from sugar beet and wheat) and biodiesel (from rape and sunflower seed).

Note that these supply costs are not necessarily equal to the prices occurring at market equilibrium. With the information collected, supply curves (costs vs. quantities) were constructed that could serve to analyse the market equilibrium for tradeable bio-fuels.

Equilibrium of supply and demand

Demand curves for bio-fuels were generated by the SAFIRE model, by running the model at a variety of biomass fuel prices. Intersection points of supply and demand were determined to assess equilibrium prices and quantities. In terms of primary energy usage, the results for the EU15 are shown in Figure 2. Of the data shown, those for the low sustainability-premium scenario are the most realistic, as that scenario is closest to the economic reality of today.

Among the most outstanding results are:

- The large growth of bioenergy from 41 to 67 and 123 Mtoe/yr (2000-2010-2020). This is much less though than foreseen in 'Energy for the future' (135 Mtoe in 2010), but substantially higher than reported by the 'Shared Analysis Project' (up to a maximum of 72 Mtoe/yr in 2020).
- Most growth is in tradeable biofuels (68 out of 82 Mtoe/yr over 2000-2020).
- The price of tradeables is high, at levels of 3.7-4.9 €/GJ.
- In these scenarios, bio-transport fuels take a small proportion in 2020 (6 Mtoe/yr), and the targets of the bio-transport fuel directive are not met. (The targets imply a quantity of 17 Mtoe of bio-transportfuels per year in 2010). Below, the question is addressed what policies would be needed to achieve those targets.
- There is a large growth in the use of solid agricultural residues.
- There is considerable growth in forestry by-products and refined wood fuels.
- Biofuel imports into the EU takes off.
- Only a small role of solid energy crops, and of energy crops for bio-transport fuels is found.

The transports directive's (2003/30/EC) objective, to replace 5.75% of the energy of all petrol and diesel transport fuels by renewable fuels, is not met in any one of the scenarios shown in Figure 2. This conclusion, obviously, builds on the assumption that bio-fuels are the only

Table 2: Average supply costs of tradable biomass and crops for transport fuels (EUR/GJ).

	EU15	Accession States, + BG & RO
Tradeables:		
Forestry byproducts	2.4	2.1
Wood fuels	4.3	2.7
Dry agricultural residues	3.0	2.1
Solid industrial residues	1.6	2.5
Solid energy crops	5.4	4.4
Imported biofuels	6	6
Transport fuels:		
Biodiesel	23	23
Bio-ethanol	29	29

means to achieve that objective, and disregards other technology options that could serve the purpose (e.g. renewably produced, but non-biomass based, hydrogen for fuel cells).

An intriguing question, then, is how the objectives of the transport directive can be met? To analyse this matter, the sustainability premium was varied (in the base case scenario of existing technologies) to a level where the targets are achieved. Whereas the preceding scenario runs showed that sustainability premiums of 50 - 100 €/tonne CO2-eq. were not enough to finance the targets set, it was found that the premium had to be increased to an average level of nearly 220 €/tonne CO2-eq. If that premium applies, the major biofuel producing countries become Germany, France, Spain and the UK. It was also found that the present set aside area is not sufficient to produce sufficient bio-transport fuels within the EU15. If the EU15 wishes to meet the targets of the bio-transport fuels directive with European grown energy crops, 9% of arable land should be dedicated to the production of these non-food crops. A target such as determined in the transport directive does not apply to the accession states, but if there would, about 6% of the total arable land of the EU15 plus the accession states will be required to meet the same target as defined for the EU15 in 2010. Although the modelling results do not show a high penetration of biofuel production in the accession states, there is - given the substantial area of arable land in those countries - a large potential for producing biofuels and exporting them to the other countries. In SAFIRE the production of biofuels is primarily driven by the national demand for biofuels. Trade of biofuels within Europe was postulated as an assumption to define how the overall target should be met in terms of physical quantities, but is not an integral part of the model, and there may be efficiencies involved if SAFIRE would allow such trade. This implies that these results are somewhat pessimistic in terms of the level of the sustainability premium.

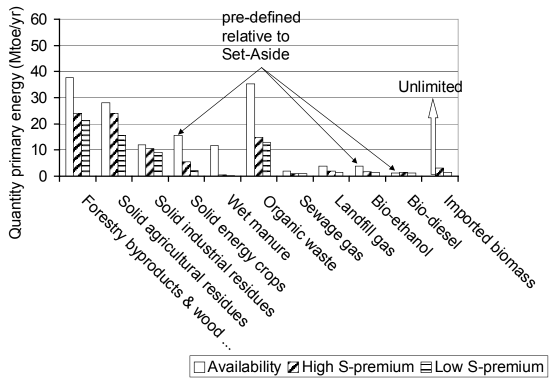

Figure 2, Availability and use of biomass in the EU15 in the Technology Base Case, in 2010. Two scenarios are shown: Low Sustainability Premium (Low S-premium) and High Sustainability Premium (High S-premium).

Meeting RES targets

There are two EC documents that actually set targets for the role of bioenergy in the sectors of electricity and heat (transport was discussed above). The first, and most general one, is the White Paper on 'Energy for the future'. A plausible interpretation of this document shows that biomass is expected to contribute in the following manner to the 2020 sustainable energy targets of the EU:
31 Mtoe for non-CHP electricity
65 Mtoe for non-CHP heat
32 Mtoe for CHP electricity and heat
18 Mtoe for bio-transportation fuels
The second document is Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market. Actually the directive is broader than biomass alone, setting indicative national targets for electricity produced from renewable resources by 2010. By that year, a total of 22% of the electricity consumed in the EU15 should be made from renewable sources. For the Technology Base Case/Low-Sustainability Premium Scenario, the role of biomass in achieving these targets is presented in Table 3.

In this scenario, the role of bio-electricity is limited to 2.6% of total electricity production by 2010, and bio-energy contributes by 12% to meeting the targets of the RES electricity directive. This is rather limited. At present, the generation of renewable electricity is often heavily subsidised. Subsidies of 50 €/tonne CO2 as shown in the high sustainability premium scenario, correspond with 0.06 €/kWh of electricity. This level is currently not uncommon in many EU15 countries, such as Germany and the Netherlands. The study shows that these incentives remain necessary if the targets in Directive 2001/77/EC are to be achieved.

Table 3: The role of bio-electricity in achieving the targets for RES electricity by 2010 (Technology Base Case, Low Sustainability Premium).

	TWh/yr	share of target	share of total electricity
Bio-electricity (excl. co-combustion)	43	7%	1.4%
Bio-electricity (co-combustion)	35	5%	1.1%
Total bio-electricity	78	12%	2.6%

Rather than the available quantities of biomass, it is the economy of bio-energy technologies that limits the employment of biomass as a sustainable energy resource. The size of the sustainability premium is therefore essential for biomass to play a significant role in electricity generation. If the European GHG emission trade scheme develops favourably, at the low levels as anticipated, and if ETS develops as an alternative for currently existing incentive schemes, then the role of biomass electricity seems not to be able to become as predominant as anticipated in the past. The same applies to the role of biomass in the transport sector, where extremely high sustainability premiums are needed to finance the achievement of the politically agreed targets. This should not necessarily be an adverse development, if one concludes that the prevailing incentive schemes for biomass energy are less economically efficient. Before doing so, one should remember that the sustainability premium as defined in this study concerns more than carbon emissions alone, but includes issues like supply diversification and independence as well. If those issues are worth our while, the we are willing to afford more than the value of carbon credits alone. How this willingness to pay should be translated in financial terms is an important question, still unanswered, for carrying out this type of studies.

Further research

Externality costing should be made into an operational tool. A major finding is that, in order to achieve the 2010 targets politically agreed for bio-energy, and in order to enable the industry to go ahead with the developments begun, relatively high sustainability premiums are required. Would this be a reason to reduce the support to European bio-energy? No, not if the price of those premiums balances the value of all sustainability issues, listed before. These sustainability issues concern reduced dependence on imported fossil fuels, environmental values, job creation, etc. A difficulty for policy makers is that they do not have a yardstick at their disposal to judge the matter. We do observe a large difference between the required sustainability premiums and today's price expectations for carbon credits under the various trade schemes of the Kyoto Protocol and the European Emission Trading Scheme. But we do not really know whether the price for sustainability is high or not. An answer to that question seems all the more urgent in view of the well-defined EC decisions concerning the desired role of renewables in the various economic sectors (e.g. refer to the RES Electricity Directive 2001/77/EC and the RES Transport Directive 2003/30/EC). Comparing the latter two sectors, we found that the sustainability premiums required to implement these policies are clearly of different orders of magnitude. This may be justifiable, but is it?

The EXTERNE project ([7]) carried out during the 1990s by the EC and the US Department of Energy was a major attempt to provide a common basis for comparing energy technologies while including the so-called external effects. One would wish the results of that activity to be translated into a tool by means of which the evaluations such as carried out for this study can be made more objective. And those results need not only be translated into such a tool, but they need also to be updated and extended to include all issues that belong to a sustainable development, but that are not yet internalised in the European economy. This would improve the quality of political decision making.

Continued learning from experience is also needed, and the European R&TD and demonstration programmes are important means to make this possible. A major topic that deserves more attention from industry are technologies that facilitate international trade in bio-fuels. The international trade in bio-fuels was found to become more and more important. At the same time it contributes to specific sustainability objectives of the EC's bio-energy policy, particularly a reduced dependence on energy imports and increased security of supply, and, if European technologies are involved, the creation of business opportunities for European Union industries (in Asia, Latin America and Africa). Associated technologies concern production and use of biomass-based energy carriers that can be traded and used cost-effectively. Examples of such energy carriers are bio-ethanol, biodiesel, and pyrolysis oil (bio-oil). Utilisation techniques could involve application in gas turbines for electricity production, and road transport. Innovative intermediate upgrading techniques, such as hydrogenation, could be needed to further adapt imported bio-fuels to end-uses. A review of existing technology developments of industries and governments is therefore suggested.

We conclude by speculating that to achieve the targets for biomass's role in the energy European system, the existing energy market is perhaps too resilient. So, could a true change be achieved by entering new fuel provision and utilisation chains? May be through the versatile route of pyrolysis that enables the use of inexpensive resources, trade and standardised applications ([10])? And maybe through opening a new market offered by the interconnected European gas distribution system. Note that whereas the electricity market is equivalent to 10,000 PJ of electricity annually, the European gas grid serves a demand of 15,000 PJ per year of gas on a net calorific basis. That market has not been addressed yet at all.

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