BIOMASS AVAILABILITY IN THE EU

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ABSTRACT: Biomass availability is understood as an economic viewpoint, i.e. as a supply function relating prices to quantities. The technical potential of biomass fuel supplies is discussed and related to long-term policy targets of biomass fuel consumption. Supply costs are reviewed for residues, wastes and energy crops, both for internal EU resources and imports into the EU from developing countries. Particularly for energy crops, costing methods are reviewed, and the influence of farm size and land costs investigated.
Keywords: biomass resources, energy crops, economic aspects.

1 WHAT IS BIOMASS AVAILABILITY? [1]

Over the past years several notions about biomass fuel supply have come into existence, e.g.:

- Contractibility of a biomass resource, implying that a resource is for sale, and not yet purchased by anybody else for a non-energy application.
- Availability of a biomass resource, implying that a resource is present in such a form as to be usable.
- Actually, such notions are often not precisely defined by those who use them in the biomass literature.

It is perhaps recommendable to go back to the concepts of economic science, in this case to the supply function. Like demand, supply is not a static number, but rather a function of price and quantity. Everywhere along the supply function, biomass fuels are physically available, and for sale. Only then can we start investigating questions yet unreflected in the above definitions, such as:

- Under which price conditions could a particular biomass resource be purchased, even if that resource is already being used for another purpose?
- Will there be a producer surplus (e.g. available to European farmers)?

So much about the title of this paper.

In this paper, the arena of potential biomass resources capable of providing substantial quantities in view of the expected demand is investigated. In future biomass fuel markets, biomass fuels will either be by-products of other economic activities, ranging from agriculture and forestry, and industries (food, construction, paper, etc.) to households (municipal waste), or they will be direct products of agriculture (including short-rotation forestry). Subject to forces in the energy market, by-products could be withdrawn from current uses and destined for fuel applications. For example, straw, in the Netherlands currently often used for animal bedding, may become a recognised fuel in the Dutch energy sector. The same has already happened in Denmark. The matter is further complicated by potential changes in biomass recycling flows. Due to increased residence time, any type of recycling reduces the availability of residues for fuel applications.

In view of supplying a desired quantity of biomass based energy, therefore, one cannot simply assume that currently unused biomass by-products are first and foremost available for energy applications, and that their availability should be supplemented by energy crops to make up the total demand for biomass fuels. The pricing mechanism is insufficiently known to justify such a presumption. Instead, it must be concluded that the future market for biomass fuels will be the dynamic result of competition between:

- Alternative applications of biomass by-products,
- Alternative types of land use.

And supplies can originate from within the EU, but also from elsewhere. So these dynamics are not necessarily restricted to the EU. It is for this reason that the concept of 'biomass fuel availability' appears to be inappropriate when describing the investigated market. Biomass fuels do not simply lie around somewhere, waiting to be found. Instead of the static concept of resource availability, the dynamic concept of resource mobilisation seems to be more appropriate here.

2 THE TECHNICAL POTENTIAL OF BIOMASS FUELS

A first legitimate question is, whether it is at all possible to sustainably produce enough biomass fuels to meet the ambitions, without conflicting with other essential land uses in general, or of biomass utilisation in particular. With regard to self-sufficiency on the EU level, the TERES II study ([6]) and 'Energy for the future' ([8]) are positive, whereas the Shared Analysis Project ([3]) is negative (for a detailed analysis of these studies, see also [15], p. 130). Considering the Netherlands, and in view of the specific renewable energy targets set by the Dutch government, Siemons and Kolk, [16], showed that self-sufficiency is only possible with the development of revolutionary, and unlikely, social and economic scenarios in the Dutch agricultural sector. At least intra-EU trade and perhaps even global trade in biomass fuels would be a necessity. This makes one wonder whether sustainable biomass fuel supplies, at the required level, are possible on a worldwide scale. Since about 1990, numerous scenario studies on this subject have been published. 17 of them were reviewed by Hoogwijk, Berndes, Van den Broek et al., [11]. Today's worldwide biomass fuel utilisation is estimated at 936-1310 Mtoe/yr ([15] pp. 124). The most relevant studies reviewed by Hoogwijk, Berndes, Van den Broek et al. arrive at resource potentials ranging between 3000 and 10700 Mtoe/yr. Based on this review, the integrated assessment reported by UCE, UU-NW&S, RIVM et al., [18], arrives at a biomass fuel supply potential of 26300 Mtoe/yr. This value is much higher than the estimates in the individual studies reviewed by Hoogwijk, Berndes, Van den Broek et al., because it aggregates the various potential resource types which are not fully covered in the particular

[1] This paper largely draws on the author's PhD thesis, [15], and on [17].

assessments. The quantities reported are in the order of 30%-110% (Hoogwijk, et al.) and 270% (UCE, et al.) of current worldwide primary energy supplies, both renewable and non-renewable. Time horizons for these assessments, however, range between 2025 and 2100; and by then, total primary energy supplies can be expected to have risen. In their review, Hoogwijk, Berndes, Van den Broek et al. rightly point out various weaknesses in the model interactions and the assumed parameter values. However, their plea for improved studies, for example by incorporating economics of biomass energy systems, seems to lack justification as long as one is only interested in the question as to whether long-term sustainable supplies of biomass fuels are possible without prohibitive conflicts with other interests.

It must be concluded that, in principal, a sustainable supply possibility exists for biomass fuel quantities even above the long-term politically agreed targets. With or without biomass fuel imports into the EU. The sustainability of biomass supply, however, is not something which emerges on its own, and is a particular responsibility for those countries which choose, or feel forced, to import these resources from countries with weaker democratic government traditions or stronger internal economic contrasts. To this effect, the authors of the review study discussed above make some specially relevant suggestions which boil down to the development of measurable social, economic and environmental criteria, combined with certification.

3 SUPPLY COSTS OF BIOMASS FUELS

An essential question for the current study is, at what cost can sustainably produced biomass fuels be acquired. It is sometimes assumed that biomass residues can be less expensive than purposely grown energy crops. This is a mistake. Prices of individual biomass fuels do not depend on the fuel's origin, but on their value for the user. The further development of this issue requires a principal market consideration. Renewable energy is a combined product of energy and sustainability. Its value is therefore higher than that of simple energy. This fact is not always observed immediately by consumers, but in such cases the effects of taxes and subsidies obscure their view on the market. One possible expression for the value of sustainability is €/t avoided GHG emissions, but by employing the specific emission rate of the fossil fuel-derived energy replaced, it can also be expressed per unit of energy (€/kWh). The value of sustainability, thus expressed as a marginal component of the value of sustainable energy, is, in the case of biomass-based production, used to finance two items:

- Incremental costs of biomass fuels in comparison with fossil fuels, including an element to ensure sustainability, and
- Incremental costs of biomass conversion technology in comparison with fossil fuel conversion technology.

How the marginal added value of sustainability is divided between the two will differ from case to case. This division does not depend on case-specific fuel provision costs as experienced by the fuel supplier, or the technology costs experienced by the energy producer (electricity, liquid transportation fuels). After all, there are many types of biomass fuels and many biomass suppliers, and there are many different producers of sustainable energy employing different technologies and operating on different scales. But the truly constant parameter, that is to say constant for each player in the arena of fuel provision and technology use, is the marginal value of sustainability. As a result, once a market has been established, the prices of biomass fuels delivered at the plant gate will solely depend on the inherent fuel qualities, and thus some biomass fuel providers will obtain higher profit margins than others, the differences depending on their production costs rather than on the sales prices of their product. It would be a mistake to assume in a market for clean biomass fuels that there will be differences in fuel gate prices solely on the basis of the origin of a fuel. In this context, 'origin' refers not only to the remoteness of a production site relative to the place of use, but also to the issue as to whether the biomass is a waste for its owner or a primary product. In the absence of monopolies, any differences in gate prices may be expected to depend only on variations in additional processing costs observed by the buyer (such as grinding and drying operations). The argument runs entirely parallel with Ricardo's explanation, [14], for the amount of land rent being a result of wheat prices.

3.1 Production costs of biomass fuels

Residues and wastes

Production costs of residues and wastes are confined to upgrading (such as separating, drying, chipping, pelletizing, etc.). Only occasionally will collection costs have to be included as well. These apply for example to residues which in the absence of an energy application, would have remained in agricultural fields (such as straw, on occasions) or in forests (branches). They do not apply if a material is a waste and requires proper handling in any case (e.g. discarded railway sleepers).

The category of dry (ligno-)cellulosic residues and wastes includes the following materials:

- Straw,
- Sawdust and shavings (timber milling residues),
- Forestry thinnings.

The list can be extended almost endlessly, but relevance diminishes as available quantities decrease. Straw is often excluded without thorough reflection, and the Danish practice suggests that it might be worth having a closer look. Quantities of straw cannot be found in the accessible statistics of the FAO and the EU, however, production data for cereals are available and using an approximate straw/cereal ratio, straw production can be estimated. Assuming a ratio of 0.54 t/t, a total straw production of 87 Million t/yr for the EU15 is found. This amount relates to barley, oats, rice, rye, and wheat production data for the year 1999. This estimated quantity is equivalent to 31 Mtoe/yr (compare this to the EU's ambitions with regard to the use of biomass for energy: appr. 150 Mtoe/yr in 2010, [8]). Prices for straw used for animal bedding fluctuate between 10-100 €/t, delivered, [2].

Today, the lowest quality residues from wood processing industries (sawdust, shavings) are often incinerated (with partial energy recovery), and only limited quantities are processed into products such as fuel briquettes. The occasionally traded amounts are delivered at values around 20 €/t, [1]. The lion share of this amount covers transportation costs. There are no statistics available about the production of such residues. Forestry residues are sometimes suggested as being a biomass type suitable for the energy market. However, with the state-of-the-art tree harvesting techniques of today, the lowest quality wood is chipped into an assortment suitable for various types of panels (fibreboard, hardboard, insulating board, mdf, and particle board). There are virtually no residues of a suitable fuel quality from forests which are under commercial management. A majority of the thinnings are used for paper manufacture. Where this is not so, they also end up in the panel industry. The trade in wood chips and particles gives a fair indication of prices and quantities of the lowest quality by-products generated by both wood processing industries and forestry. During 1998-2000, production of this material in the EU15 increased from 21 to 35 Million solid m3, [10]. The equivalent primary energy value is about 6.5 Mtoe/yr (30 Million m3). Delivered costs including transportation, vary between 25-40 €/t, [12]. Transportation costs (road transport) amount to about 50% of the total.

An illustrative case of residues that have found a market is provided by the trade in raw materials for animal fodder. Intercontinentally-traded products include soya scraps, soya hulls, sunflower scraps - all shipped from Argentina and Brazil to Europe - and coco and palm kernel scraps, mainly shipped from Indonesia and the Philippines. At an f.o.b. price of about 50-60 $/t, soya hulls are about the cheapest of these materials. F.o.b. prices of sunflower scraps fluctuate between 50-100 $/t, [20]. During 1997-1999, the imports into the EU15 of coconut cake, palm kernel cake, soya bean cake, and sunflower seed cake, all materials for the animal fodder industry, rose from 18 to 25 Million t/yr, [10]. The energy equivalent (if one assumes an NCVw of 20 GJ/t) is 9-12 Mtoe/yr.

Energy crops

Energy crops that can provide dry ligno-cellulosic fuels are miscanthus and switch grass (both grass types), willow and poplar (both as short rotation coppice (SRC)). Various studies into the production costs of these crops exist, and the costs reported vary widely. The reasons for these differences are mainly due to differences in analysis methods, and can only partly be explained by the parameter values used. In view of the investment character of both costs and yields in energy cropping, annual production and cash flows would be determined for the year of their occurrence and then they would be discounted at the applicable rate. Unit specific production costs would result from dividing the discounted costs by the discounted production. If sufficient parameter values could be established, the method could be employed both for existing farms switching to the cultivation of energy crops, and for newly established companies dedicated to such production. The method is recommended by the FAO for long-term farming activities, [22]. In practice, this is barely possible for existing farms, due to difficulties in assessing parameter values for the costs of self-provided labour and land use in agriculture. With regard to self-provided labour, there are no accounts on which its value can be determined. As for land use, land is either owned or rented, and only in the latter case are the costs explicit. It appears that land rents are way below the interest rates prevailing on the capital market (1.75% vs. 6.5% is not uncommon).

A method proposed by the Dutch Agricultural Economics Research Institute (LEI-DLO), [13], and employed by Dinkelbach, L., J.v. Doorn, et al., [5] calculates a standardized net hourly labour income for a typical arable farmer (equivalent to 7.95 €/h) as well as the physical labour input required for the production of energy crops. Labour costs for energy crop production are subsequently found by multiplying the two. Since, in comparison with traditional agriculture, considerably less labour is needed for growing energy crops (at least this applies to the multi-annual crops, miscanthus, SRC-willow, and SRC-poplar), farmer incomes would decrease sharply if energy crops were sold for a price reflecting the costs thus determined, unless additional types of income could be generated. As a result of this approach, energy crops cannot be considered a serious option by the agricultural sector. CPV, IMAG-DLO and ECN, [4], employed a similar evaluation methodology, albeit by assuming a twice as high cost for unpaid labour by the farmer. Additionally they applied a margin of 5% over the turnover. Costs calculated in this manner are more favourable for the farmer. However, the cost calculations in both studies bear no relationship with the real cash flows required in farming, and the resulting values cannot be considered to reflect production cost indicators.

Evaluations by Venturi, Huisman and Molenaar, [19], and Bullard, [2], start from the standard gross margin (SGM), as defined in the EU's agricultural accountancy data network. On an enterprise level, the gross margin is defined as the value of production minus certain costs. Standardization is achieved by taking an average, based on region and farm type. Making use of regionally averaged farm sizes, the SGM is expressed on an area basis (€/(ha.yr)), SGM_a. The cost items subtracted are defined in Commission Decision 85/377/EEC concerning a common typology for agricultural holdings in the EU, [7]. They concern costs which can be directly allocated to the crop produced, and include supplementary contracted services. Agricultural subsidies are included in the SGM as positive proceeds. Unit specific production costs (€/t crop) result by dividing the sum of SGM_a and directly allocated costs, by area specific yield:

$$\text{Unit Production Cost} = (SGM_a + \text{area specific direct cost}) / \text{area specific yield}$$

In the calculation of the SGM, capital costs, the fuels to operate machinery, and self-provided labour are not deducted. As a result, the gross margin is available to finance precisely these non-deducted costs, including the farmer's income. Therefore, in contrast with the analysis method of LEI-DLO, the production costs calculated in this manner do reflect accepted incomes in agriculture since the accepted farmer income is a result of the aggregate area-specific gross margin of established holdings. The prevailing variations in holding size and farmer's income are taken as a given fact. If, however, in the longer term, the average holding size substantially increases ceteris paribus farmer's income, then such an estimate of production costs of energy crops, based on currently prevailing SGMs, would be too high. A further drawback is that an SGM-based cost analysis leaves implicit any distinction between farmer's income and capital costs (land, buildings and machinery). Hence, the method does not enable production cost calculations for enterprises specifically established for the growing of energy crops. Understandably, the SGM method is recommended by the FAO for short-term production decisions ([22]) On the other hand, the methodolgy is widely accepted throughout Europe in agricultural accounting.

A third cost calculation method, presented by Meeusen-Van Onna, [13], claims to yield a 'long-term partial cost of production'. Whereas the pure SGM-based method, employed by Venturi, Huisman and Bullard, takes production costs as the sum of directly allocated costs and SGM, this new method also adds the incremental unpaid self-provided labour required for the energy crop (i.e. incremental in comparison with the substituted crop). Physical differences in unpaid self-provided labour can be determined relatively easily (and they can be positive or negative), but their valuation is more complicated. Meeusen-Van Onna proposes the following:

- If the unpaid labour increment is negative, its value would equal the income gained from alternative activities carried out by the farmer during the hours freed. This additional income would thus result in decreased production costs for an energy crop.
- If the unpaid labour increment is positive, its value would be somewhere between zero and market values for labour. Production costs of energy crops would increase by this amount.

A third option contemplated by Meeusen-Van Onna does not exist: that the labour increment is positive, and the farmer cannot provide it. By definition, he can, since only self-provided labour inputs are considered here. Labour which a farmer cannot provide himself is covered by hired additional services, accounted for under the heading of direct costs and therefore already accounted for in the calculation of production costs. Against the proposed valuation method for freed hours resulting from growing energy crops (the negative increment), the objection can be raised that it stands in the way of properly valuing the additional activities. After all, the resulting income is allocated to the production of the energy crop and effectively deducted from its costs. Against the proposed valuation method for positive additional self-provided labour, the objection can be raised that a farmer operating under such circumstances has evidently plenty of unvalued time. Otherwise he would not have been physically able to grow energy crops without hiring additional labour. In view of the fact that the pure SGM method already assumes generally accepted farmer's incomes, a zero value for the positive unpaid labour increment would therefore be reasonable. Although it cannot be denied that there are changes in self-provided labour when switching over from traditional agriculture to growing energy crops, the calculation method proposed by Meeusen-Van Onna does not appear to be improved in comparison with the pure SGM method.

The agricultural subsidies applicable to certain crops in the EU15 complicate the matter. There is one agricultural subsidy that may also be paid out to the producer of energy crops, i.e. the existing subsidy for fallow (Commission Regulation (EC) No 2461/1999). This implies that part of the production costs is paid by the government and that, as long as the subsidy is granted, the relevant value should be deducted from the production costs (as perceived by the farmer) of energy crops. The system of agricultural subsidies is under political debate almost continually, and it may change. If it changes, it will do so as a result of its own social, political and economic dynamics which do not depend on the relatively small events in the field of biomass energy. It is therefore reasonable to accept the current subsidies for energy crops as a true factor leading to reduced production costs. Since the subsidy applicable to energy crops differs in size from the subsidies paid for food crops, a correction should be made in the method applied by Venturi and Huisman, and by Bullard. While taking the necessary discounting operations into account, an improved cost estimate for existing farmers would proceed as follows:

$$\text{Unit Production Cost} = (SGM_a - \text{average standard subsidy} + \text{fallow subsidy} + \text{area specific direct cost}) / \text{area specific yield}$$

In this calculation, the average standard subsidy consists of all agricultural subsidies including the one for fallow, since the average of all subsidies is included in the SGM_a. The thus estimated unit cost is an indicator for a fair price payable by the client at the farm gate. The cost estimates for miscanthus cultivation produced by Bullard are quoted below (Table 1). Note that these estimates do not take account of the suggested correction for agricultural subsidies. The highest costs are expected in the Netherlands, the lowest in Spain. Table 1 shows estimated production costs for a range of yields. The

Table 1. Unit production costs for miscanthus on cereal farms in different member states of the EU, according to yield and SGM.

Predicted annual yield (ECU/t_0)	12 t_0/ha	15 t_0/ha	18 t_0/ha	21 t_0/ha	24 t_0/ha
Belgium	125	102	86	74	65
Denmark	90	73	62	53	47
Germany	134	109	92	80	70
Greece	90	73	61	53	47
Spain	39	32	27	23	20
France	87	71	59	51	45
Ireland	73	59	50	43	38
Italy	91	74	62	54	47
The Netherlands	188	153	129	111	98
Portugal	54	44	37	32	28
United Kingdom	80	65	55	47	42
Mean	105	85	72	62	55

Source: Bullard (2001). The subscript of the amount (t) denotes the moisture content on a wet basis.

reason for doing so is the uncertainty still persisting among agricultural researchers. In view of the yields achieved with beetroot and silage maize in the Netherlands, 15 t_0/ha appears to be a quite reasonable long-term expectation for miscanthus cultivation in Dutch circumstances. In terms of yields and costs, miscanthus is a representative example of an energy crop for dry ligno-cellulosic fuels. The major differences between miscanthus, switch grass, SRC-poplar and SRC-willow are of an agricultural character (suitability for different soil types, the possibility for integration into a crop rotation schedule, etc.). The unavoidable conclusion is that biomass fuel costs, as assumed in a number of feasibility studies and technology evaluations regarding energy production from specially cultivated biomass fuels, were far too low (e.g. for example: [9] and [5].).

Siemons and Kolk, [16] showed that production costs of energy crops are very sensitive to average holding size and cost of land use (ceteris paribus farmer income) (see Figures 1 and 2). Either or both of these parameters may be the reason for the large national differences found by Bullard. The, as yet unspecified, parameter of farmer income, may also vary strongly across the various EU15 member states. Further study into the economy of energy crops, and effective policies for their promotion, should pay attention to this issue.

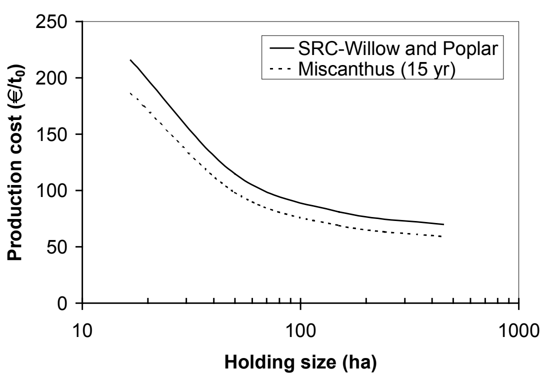

Figure 1. Production costs of miscanthus and SRC as a function of holding size (Source: Siemons and Kolk (1999)

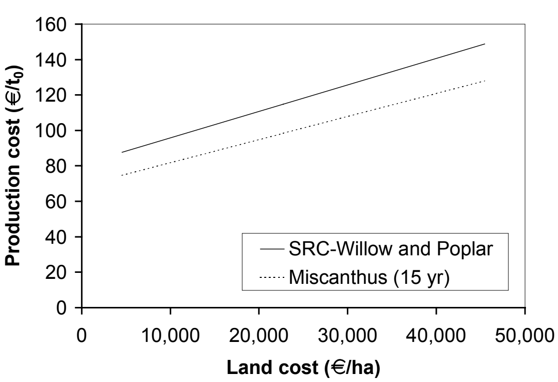

Figure 2. Production costs of miscanthus and SRC as a function of land costs (Source: Siemons and Kolk (1999)).

According to 'Energy for the future' ([8], p. 38), the maximum available land area in the EU15 for energy crops is 10 Million ha. This is 7% of the utilised agricultural area and 13% of the arable land. If, on average, an annual yield of 15 t_0/ha was achievable, the equivalent energy production would amount to 65 Mtoe/yr. The figure is substantially higher than the target in 'Energy for the future' (45 Mtoe/yr from energy crops, [8], p. 39), and this is due to the fact that the policy document, aside from ligno-cellulosic crop types, also assumes crops which are much less productive (oil seeds). Whereas ligno-cellulosic crops yield an energy equivalent of about 270 GJ/(ha.yr) (at 15 t_0/(ha.yr) and 18 GJ/t), a crop such as rapeseed yields only about 43 GJ/(ha.yr).

Note, that there is no a priori reason to restrict the cultivation of energy crops for use inthe EU15, to the EU15's agricultural lands. In a study on the import of sustainably grown plantation wood,Wasser and Brown, [21], report 21 \$/t_{25} and 24 \$/t_{25} for Eucalyptus logs and chips respectively, loaded f.o.b. in Montevideo (Uruguay). A condition for cultivation elsewhere is that transportation costs are sufficiently low. Imports of both the dried products as well as certain preparations, e.g. carbonised or liquefied materials, can be considered. Carbonisation and liquefaction result in increased energy densities (per mass or per volume), and thus may make long-distance transportation cost efficient.

Of the prices reviewed above, only those for energy crops are true unit production costs, the others are mere indicators of such costs. The most important costs are listed in Table 2. It is not self-evident that a crop such as miscanthus (and likewise SRC-willow or SRC-poplar), if grown, should be cultivated for the energy market. It is conceivable that energy applications will replace the existing uses of chips and particles for board and panels, the producers of which could then convert to more expensive alternatives provided by this type of non-food crops.

Table 2. Main indicators of supplier based unit production cost of biomass fuels.

Product		Source
Straw EU (delivered)	10-100 €/t	Bullard (2000)
Chips delivered particle board industries	23-38 €/t	Kuiper (2001)
Cake of soya f.o.b. Argentina, Brazil	129-272 \$/t	Visser (2001)
Soya hulls f.o.b. Argentina, Brazil	56-57 \$/t	Visser (2001)
Cake of sunflower f.o.b. Argentina	48-98 \$/t	Visser (2001)
Miscanthus f.o.b. farm gate /a	32-153 €/t_0	Bullard (2000)
Eucalyptus f.o.b. Montevideo	21-24 \$/t_{25}	Wasser (1995)

a/ At a yield of 15 t_0/ha.

4 FURTHER ANALYSES

These and more considerations are part of a study on the long-term role of biomass energy in the EU, carried out for the European Commission by BTG (NL), ESD (UK), CRES (GR) and IFZ (AU), [17]. In that study the supply function of biomass fuels is being investigated in relation to the demand function of these fuels and the function of technology development. Publication is expected in the end of 2003, and its finalisation will be accompanied by a workshop to which all those interested will be invited.

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