Annex B

Scenario Analysis of Consequence of Renewable Energy Policies for Land Area Requirements for Biomass Production

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Abstract:

This paper contains a short analysis of three targets of the Commission on use of renewable sources of energy. The conclusion is that it is possible to meet the targets, but that relatively large areas of land must be dedicated to the task. Because of some of the inherent uncertainties in a quick analysis it should be considered to develop scenarios for this field of a greater level of detail.

Introduction

Over the past years several targets have been set aiming at increasing the share of renewable sources being employed for energy production. There are multiple sources of renewables and there are therefore many ways to meet the targets. The aim of this paper is to develop scenarios for the consequences for land-use of meeting these targets via different combinations of renewable sources.

The following directives dealing with renewable energy are relevant in this context:

- ✓ *Draft Directive 2001/0265 (COD) of the European Parliament and of the Council on the promotion of the use of biofuels for transport, included in COM(2001) 547.*
  This draft directive includes a target of 5.75% (2010, measured on energy content basis) of all transport fuel (gasoline and diesel) sold in EU to be biofuel. Thus in reality the proposed directive deals with road transport, as both rail, inland waterways, maritime and aviation use other fuels.

- ✓ *Directive 2001/77/EC of the European Parliament and the Council on the promotion of the electricity produced from renewable energy sources in the international electricity market*
  This directive sets indicative targets (2010) for renewable share of electricity production on a member state basis. The combined target is 22.1% of electricity production.
  If the 10 Newly Associated Countries are included the combined EU25 target drops to 21% as a result of the negotiated targets being lower than the EU15 average.

- ✓ *Communication from the Commission. Energy for the Future: Renewable Sources of Energy. White Paper for a Community Strategy and Action Plan. COM(97)599*
  The White Paper includes an indicative objective of 12% of gross inland consumption to come from renewables by 2010.

As the different legal/policy documents do not refer to the same base there are some room for interpretation. The first two documents refer to final energy consumption in two sectors. The last refer to the gross inland consumption.

There are a number of sources of renewable energy of relevance:
- ✓ *Hydropower,* where some expansion of the small-scale hydropower capacity is expected.
- ✓ *Geothermal power,* where only modest expansion is expected.
- ✓ *Wind power,* where significant developments are expected
- ✓ *Photo voltaic,* which is only expected to generate a marginal contribution in 2010 perspective.
- ✓ *Biomass,* where significant developments are expected

Thus the two main sources of development to meet the targets set out in the directives are wind and biomass.

- ✓ Wind is well suited for electricity production, whereas it does not have much potential for the transport sector, apart from the part supplied to electric trains.
- ✓ Biomass is well suited for heat/power production as co-firing fuel in power plants or CHP installation. Additionally it can be used as raw material for production of liquid or gaseous fuels for transport.

Methodology

From a theoretical point of view (but not an economical) it is always possible to build more wind power generating capacity, e.g. offshore. Thus in the following the availability of land for production of biomass is seen as the limiting factor, as this is a limitation which cannot be circumvented by investment.

On the other hand biomass could be imported, e.g. from Russia, and as such increase the share of renewable sources employed. Such import would contribute to security of supply, reduction of CO2 emission and generate employment both in Russia and EU (as biomass production, conversion and consumption is more labour intensive than fossil energy use). This possibility is not covered by this analysis, but forms a "third option" to the focus on wind and to the focus on biomass.

As biomass is the only way to meet the biofuel directive this will be the point of departure. Based on available studies covering biofuel production in EU28 (to be published within 1Q-2003) the potential to meet the target will be assessed, and the consequences in terms of land use will be calculated. Depending on how the biofuel is produced a larger or smaller share of waste products may be available for heat production.

Meeting the renewable electricity directive will require a combination of wind and biomass. The analysis will as baseline take the standard projection for energy production and consumption in 2010 included in the POLES model. The consequences in terms of installed wind turbine capacity and land use for biomass production will be added to the figures found above.

Finally the result will be compared to the renewable energy directives target and needs for additional renewable shares calculated. Here residual biomass for heating purposes will play a role.

Baseline data

The baseline data set for energy production and consumption is primarily based on the Enerdata data set and the POLES energy market model.

2000		EU-15	NAC	Bg, Ro, Tr	EU-28
Gross Inland Consumption (Mtoe)		**1348.88**	**198.91**	**131.69**	**1679.48**
	Fossil fuel	1079.11	198.65	149.17	1426.93
	Nuclear	217.18	14.97	6.17	238.32
	Renewables	52.61	8.86	14.59	76.06
Electricity Generation (TWh)		**2384.77**	**378.97**	**249.30**	**3013.04**
	Fossil fuel	1185.05	191.08	124.76	1500.89
	Nuclear	858.61	173.84	71.76	1104.21
	Hydropower + geothermal	311.71	13.74	52.75	378.20
	Windpower	15.29	0.01	0.00	15.30
	Biomass	14.10	8.90	2.21	25.21
	Other renewables	0.01	0.00	0.00	0.01
Final Energy Demand (Mtoe)		**283.38**	**23.50**	**17.01**	**323.89**
	Road transport	246.20	20.96	14.56	281.72

The baseline projection for 2010 is based on the POLES energy market model. As the model has at present aggregated countries in a different manner than the one used here some approximations have been made. Therefore some figures may not correspond fully to other projections.

2010		EU-15	NAC	Bg, Ro, Tr	EU-28
Gross Inland Consumption (Mtoe)		**1385.64**	**219.91**	**165.30**	**1770.85**
Electricity Generation (TWh)		**2565.49**	**471.45**	**353.13**	**3390.07**
Final Energy Demand (Mtoe)		**309.70**	**28.36**	**21.26**	**359.32**
	Road transport	269.20	25.30	18.19	312.69

Biomass Production Potential

Biomass production include the following categories:

- ✓ Production of oilseeds with the aim of making plant oil, which can be converted to biodiesel. This process generates significant amounts of straw, which can be used as a co-firing fuel in heat and power production.
- ✓ Production of starch crops for conversion to ethanol or ETBE. This production will also generate significant amounts of straws and other waste, Which can be used for co-firing or converted into ethanol via other processes.
- ✓ Production of ligno-cellulose crops (fast growing trees, forest residues, etc.) for use as feed stock for ethanol production, F-T diesel production or as co-firing fuel in CHP installations.
- ✓ The use of waste such as household waste, animal manure, etc. for the production of biogas.

Each type of production has its advantages and drawbacks, which make certain types of production better suited for some areas than others.

The following table includes the most common crops and the average energy yields per hectare in terms of biofuel and additional biomass, which can typically be used for power and heat production.

	Transport fuel	Other energy products
Oilseeds for biodiesel		
Rape	45-50 GJ/ha [1]	40 GJ/ha [1]
Sun flower	27-30 GJ/ha [1]	quantity unknown
Starch crops for ethanol and bioETBE		
Sugar beet	133-157 GJ/ha [2]	limited [2]
Potato	96 GJ/ha [2]	limited [2]
Wheat	25-62 GJ/ha [2]	50-100 GJ/ha [2]
Ligno-cellulose crops		
Agricultural waste	1 GJ/t [2]	9-16 GJ/t [3]
Woody biomass[1]	55-77 GJ/ha [2][3][4]	110-165 GJ/ha [2][3][4]

In addition to the energy content each crop has other assets. Many plants yield different types of protein meal to be used as animal feed. Additionally some crops may yield better habitats for wild animals, may fit into crop rotation schemes, etc. It is therefore not possible simply to select the highest yielding crop as a mono crop. In stead there is a need to fit crops into a larger framework of agricultural economy and environmental concerns.

Available land

Production of energy crops will compete with other types of production for land, wherefore it makes sense to look at the land as the limiting factor. In theory all utilized agricultural land can be used for energy production, though competition with other uses including other crops of course sets a limit much lower.

All figures in mio. ha	EU-15	NAC	Bg, Ro, Tr	EU-28
Utilized agricultural area	130	38	59	227
Forest covered areas	87 (130)[2]	16 (24)	20 (31)	123
Total	217	54	79	350

[1] According to [2] the typical ethanol production from woody biomass is 5-7 GJ/t. According to [4] the average yield of wooded areas, including fast growing trees in Europe is 3-30 t/ha per year with an average of 11 t/ha per year. Finally according to [3] the total energy content of woody biomass is in the range of 15-22 GJ/t. Given the wide range of variation this issues warrant further analysis before solid conclusions can be drawn. The production of bio ethanol from woody biomass is still at an experimental stage, wherefore an immediate scaling up of production is not possible.

[2] According to [5] the total EU-15 forest area is around 130 Mha of which 87 Mha are exploitable on a commercial basis. For NAC such data does not exist, wherefore a similar fraction has been assumed.

Meeting the "Biofuel Directive" voluntary targets

The biofuel directive indicates a target of 5.75% of transport fuel by 2010 as the target for biomass based fuels in the road transport sector. This lead to the following targets:

	EU-15	EU-25	EU-28
2010 Consumption (Mtoe)	269.20	294.50	312.69
Biofuel target (Mtoe)	15.48	16.93	17.98
Biofuel target (PJ)	648	709	753

Meeting the targets can be done in many ways. In the following the consequence in terms of land area of a number of scenarios are calculated. Figures are in percentage of utilized agricultural area. Woody biomass may also be produced as forest residues. In this case, however, the yields would be much lower as a significant share of the biomass would be used for other purposes such as timber, chipboards, paper, etc.

	EU-15	EU-25	EU-28
100% rape seed	10.0 - 11.1	8.4 - 9.4	6.6 - 7.4
50% rape sees, 50% wheat	9.0 - 15.5	7.6 - 13.1	6.0 - 10.3
50% sugar beet, 50% wheat	5.6 - 11.8	4.7 - 10.0	3.7 - 7.9
50% sugar beet, 50% woody biomass	4.8 - 6.4	4.1 - 5.4	3.2 - 4.3
100% woody biomass	6.5 - 9.1	5.5 - 7.7	4.3 - 6.0

Thus meeting the targets in the directive will require between 4.8 and 15.5 % of all agricultural land in EU-15 dropping to between 4.1 and 13.1 % in EU-25. Each scenario will, however, generate a number of additional energy benefits to be taken into account. Figures are in PJ:

	EU-15	EU-25	EU-28
100% rape seed	547	599	636
50% rape sees, 50% wheat	729-1183	796-1294	846-1375
50% sugar beet, 50% wheat	455-909	497-995	528-1057
50% sugar beet, 50% woody biomass	555-833	608-912	695-968
100% woody biomass	1111-1666	1215-1823	1291-1936

Thus all the scenarios goes some way in meeting other objectives. Generally a combination of woody biomass and sugar beet would look favorable. However, it should be borne in mind that woody biomass as a fuel feedstock is still in the experimental stage. Additionally the lack of byproducts of sugar beets may cause the overall economy of the solution to be less favorable than it looks on a pure energy basis.

An ongoing study on potential for biofuel production in candidate countries (as they were when the study started) gives a slightly less optimistic picture, due to the fact that data shows that the average land quality in candidate countries is lower, wherefore average yields will be lower. According to this study it will take an area equal to or greater that the average set-aside land (10%) to meet the objective.

Meeting the "Renewable Electricity Directive" indicative targets

The renewable electricity directive sets an indicative target of 22.1% for renewable electricity. With the targets for NAC the overall target has dropped a bit. However, in the following the 22.1% will be used as the target.

	EU-15	EU-25	EU-28
Electricity generation 2010 (TWh)	2565.49	3036.86	3390.07
Renewable target of 22.1% (TWh)	566.97	671.15	749.21
Expected hydro+geo energy 2010[3] (TWh)	338.13	353.03	410.26
Rest renewable target to be covered (TWh)	228.84	318.12	338.95
Rest renewable target to be covered (PJ)	823	1145	1220
Transport biomass byproducts[4] (PJ)	182-666	199-729	211-774
To be covered by additional actions (PJ)	157-641	416-946	446-1009

The amount of electricity not covered by waste biomass from the transport sector may thus be covered either by wind or by additional biomass:

	EU-15	EU-25	EU-28
To be covered by additional actions (PJ)	157-641	416-946	446-1009
Wind baseline (PJ)[5]	200	200	200
Rest (PJ)	-43 - 441	216-746	246-809

Thus in the most optimistic scenario EU-15 has already met the target. In the pessimistic scenario another 441 PJ electricity is needed.

	EU-15	EU-25	EU-28
Rest (PJ)	-43 - 441	216-746	246-809
100% wind[6] (GW)	0 - 80	39-136	45-147
100% biomass[7] (Mha)	0-1.2	0.4-2.1	0.5-2.2

Thus meeting the objective of the directive would require up to around 1% additional land in EU-15. For EU-25 the figure could be up to around 1.5% additional land. Meeting the objective for EU-15 via extra wind power would require 20-30.000 of the largest generators on the market today (in addition to the strong growth predicted). For EU-25 the number would be significantly higher due to the lower expected production per generator in NAC.

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[3] Based on POLES model with adaptations for the candidate countries not covered on a country by country basis in the model.

[4] Assuming an efficiency of 40% in conversion of biomass energy to electricity.

[5] The POLES model assumes a growth of around 300% for wind over the decade in EU-15. As wind power is practically non-existent in most NAC the baseline for these countries have been set to 0.

[6] Assuming the same average production as in Denmark (5.5 PJ/GW) is probably an error towards the optimistic side as more landlocked countries has lower wind potential. Therefore the estimates are on the low side.

[7] Assuming woody biomass.

Meeting the "Renewable Energy White Paper" indicative objectives

Finally meeting the target of 12% of gross inland consumption coming from renewable resources gives the following:

	EU-15	EU-25	EU-28
Gross inland consumption 2010 (Mtoe)	1385.64	1605.55	1770.85
12 % target (Mtoe)	166.28	192.67	212.50
Existing (2000) renewables (Mtoe)	52.61	61.47	76.06
Planned wind power (Mtoe)[8]	3.50	3.50	3.50
Energy "from biofuels directive" (Mtoe)	26.34 -55.27	28.80 -60.48	30.60 -64.22
Energy range bio/wind electricity[9] (Mtoe)	0 - 26.32	5.16 - 44.54	12.32 - 48.31
Needs to reach target (Mtoe)	**28.58 -83.83**	**22.68 -93.74**	**20.41 - 90.02**

If wind and hydro electricity are counted based on their substitution of fossil fuel for power production the calculation is somewhat more optimistic. In this case the target will be met for optimistic scenarios but not for the pessimistic ones.

The needs in the pessimistic scenario can be met either by installation of another 175GW of wind power capacity or application of around 7-13% of agricultural land in addition to what has already been used.

Conclusion

The conclusion is that it is possible to meet the requirements of all three directives within somewhat reasonable limits. The biofuels directive can be met within an area comparable to the present set aside land or smaller depending of crop composition. The renewable electricity directive is mostly covered by the additional biomass and planned wind power capacity. Finally the renewable energy targets can be met with application of more land.

In this analysis the use of woody waste from forests have not been included. It is assumed that this source of biomass may form either feedstock for ethanol production, when commercial methods become available or as fuel for CHP plants. This may significantly reduce the need for land. On the other hand is it to be expected that the energy density will be lower as part of the biomass is diverted for other purposes.

Further development of small hydropower, geothermal power and heat, photo voltaic, wave, etc. are to be expected. These are not covered by this analysis, which in this context will err on the pessimistic side.

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[8] The expansion from 15.29 TWh to 55.95 TWh included in POLES for EU-15. Included on a 1 to 1 energy content basis.

[9] Wind electricity is included on a 1 to 1 energy content basis. Biomass energy included on an energy content basis.

References

[1] Techno-economic analysis of Bio-diesel production in the EU: a short summary for decision-makers. IPTS, 2002. EUR 20279.

[2] Techno-economic analysis of Bio-ethanol production in the EU: a short summary for decision-makers. IPTS, 2002. EUR 20280.

[3] Oak Ridge National Laboratory homepage on biofuels. http://bioenergy.ornl.gov/papers/misc/energy_conv.html

[4] Renewable Fuels for Cross Border Transportation. Draft report for DG ENV by a consortium led by German Aerospace Centre. 2003.

[5] COM(1998) 649. Communication from the Commission to the Council and the European Parliament on a Forestry Strategy for the European Union.