Potential biomass mobilization for biofuel production worldwide, in Europe and in France

One key factor in ensuring the success of biofuel technologies, which are expected to see high growth, is the availability of biomass resources. Although the targets set in Europe and France for the replacement of petroleum products in the transport sector by 2010 can be met by converting farm surpluses into biofuels, in order to proceed further, it will be necessary to mobilize a resource that is more abundant and potentially less costly: lignocellulosic materials, i.e. wood or straw. The future of biofuels depends on establishing the much-awaited "second generation" biofuel pathways able to convert lignocellulosic materials to ethanol, biodiesel and biokerosene.

The fourth-ranked source of primary energy consumed in the world after oil, coal and gas, biomass is the leading renewable energy today. Available reserves are even larger still, a non-negligible percentage of which could be converted to energy and more specifically to motor fuels.

Recapitulation of the biomass resources used to produce biofuels

Today, the bulk of raw materials converted to biofuels comes from products and residues derived from farming and forestry.

One must distinguish the vegetable materials used to produce the "first generation" biofuels now available on the market (i.e. biodiesel or vegetable oil methyl esters, used to replace diesel fuel; and ethanol, used to replace gasoline) from the vegetable materials used for "second generation" technologies, now under development.

The former include all products from which it is possible to extract vegetable oil to produce biodiesel (e.g. rape, sunflower, soybean and palm) as well as those whose sugars can be fermented to produce ethanol, such as the sugar beet, sugar cane and starch-rich cereals like wheat and corn.

Table 1
Resources and conversion products

Types of biomass	Input products	Finished products
Farm products	Rapeseed, sunflower seed, soybean, palm, jatropha	Biodiesel
	Sugar beet, sugar cane, wheat, corn	Ethanol
Lignocellulosic materials	Straw or cereals (entire plant), wood, slash, scrap	Ethanol and BTL*

*** BTL : Biomass-to-Liquid**

Source: IFP

The latter, known as lignocellulosic materials (wood, straw), correspond to all products composed of cellulose, hemicellulose and lignin that can be converted to a fuel that can replace diesel fuel and kerosene (biomass-to-liquid fuels) or gasoline (ethanol).

Today, most of the biodiesel available is produced from rapeseed oil in France and Europe, from soybean oil in America and from palm oil in Asia.

Ethanol is produced from sugar beets and wheat in Europe and primarily from corn in the United States. Sugar cane is preferred in favorable tropical climates like those of Brazil or India.

Sometime in the next decade, lignocellulose conversion processes will become not only technically feasible but also economically competitive. It will become possible to boost biofuel output by converting straw and wood by-products that are not yet exploited today.

New fast-growth crops (e.g. *Miscanthus* or the short-rotation coppice) could provide another source of available lignocellulosic raw materials.

As we can see, there is a broad range of plant-based feedstocks that will lend themselves to conversion into biofuels, with high production potential.

But there is a key prerequisite: the availability of cultivable land, which will be the object of competition between the food industry and other biomass applications (energy and non-energy alike).

The potential of biomass for energy worldwide

It is currently estimated that 5%[1] of the total output of biomass could be mobilized to produce energy, i.e. a total of 13.5 billion tons of available raw materials. This represents an energy equivalent of nearly 6 billion tons oil equivalent of primary energy, or 26% of world energy consumption. Only one-third of this potential is currently being tapped, mostly in

(1) Source: World Energy Council

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the form of wood-based energy (80%); in 2005, the transport sector accounted for a marginal 1%.

Table 2
Biomass for energy, worldwide

	Quantities of biomass (billions of tons)
Forestry products	2.36
Non-food farm products	5.33
Crop residues	3.5
Wood industry residues	2.1
Other residues (animal fats, etc.)	0.19
Total	**13.5**

Source: IFP based on data from the World Energy Council

By placing additional arable land into cultivation, exploiting residues and seeing the developing countries post higher yields, as expected, this potential could grow to about 18 billion tons of biomass by 2050[2].

It will not be possible to convert all of this biomass to biofuels. Extrapolating from Europe's 30% biofuel content target for 2050[3], one finds a world biofuel production of about one billion tons oil equivalent, i.e. 23% of the potential for energy biomass in 2050. While this estimate seems ambitious in growth terms, it remains consistent with mobilizable biomass resources. In recent estimates, the IEA[4] forecast that biomass-based fuels will only replace 3 and 6% ("reference scenario" and "alternative scenario") of petroleum products by 2030. In other words, the mobilization of biomass to produce biofuels still represents a challenge.

Resources for biofuel production in Europe and France

Current land areas and production figures

• *In Europe*

In the Europe of Twenty-Five, arable land covers 115 million hectares of which 8.3 million hectares is left fallow. The rest of the cultivated farmland corresponds to permanent meadows/pastures and perennial crops, i.e. land areas entirely devoted to growing food for animal and human consumption.

Woodland represents 148 million hectares of which 103 million are commercially viable.

As things now stand, raw materials derived from farming and forestry are produced on a total of 218 million hectares (115 + 103 Mha). Of course, not all of these land areas in their entirety will be used for energy purposes.

In 2005, 61 million of the 115 million hectares of arable land were planted with cereals, oilseed-bearing plants and sugar beets, which are crops that can be converted to first-generation biofuels. Only 4% of these land areas were used for this purpose.

Table 3
European farm products used to produce biofuel in 2005

Type of biomasse	Land area ($x10^6$ ha)	Output ($x10^6$ t)	Percentage used to produce biofuels
Cereals	52	260.5	0.2 %
Oilseeds	7.2	19.9	37 %
Sugar beets	2.2	126.3	4.3 %
Total	**61.4**	**406.7**	**4 %**

Source: FAOSTAT/FAPRI 2005

In 2005, 2.6 million hectares were farmed to produce biofuels, representing 15% of the total area of cultivable fallow land.

In addition, approximately 100,000 tons of palm oil and 50,000 tons of soybean oil were imported in 2005 to produce biodiesel (vegetable oil methyl esters) as well as 160,000 tons of rape from Australia and 1,000 tons from Canada.

• *In France*

There are 18.4 million hectares of arable farmland in France, including 1.6 million set aside to lie fallow. Woodland represents a total of 15 million hectares (27% of the country) of which 14 million are producing forests. This makes a total of 33.4 million hectares with energy potential (18.4 million hectares + 15 million).

Table 4
French crops used to produce biofuels in 2005

Type of biomasse	Land area ($x10^6$ ha)	Output ($x10^6$ t)	Percentage used to produce biofuels
Cereals	8,87	62,3	0,2 %
Oilseeds	1,99	5,9	22 %
Sugar beets	0,37	29,3	1,4 %
Total	**11,23**	**97,5**	**2 %**

Source: FAOSTAT/ONIC 2005

In 2005, only 2% of the crops that convert to biofuels (cereals, oilseed-bearing plants, sugar beets) were harvested for that purpose.

(2) José Goldenberg: World Energy Assessment
(3) IFP, based on data from EEA, Biofrac
(4) World Energy Outlook 2006, the outlook for biofuels

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These crops mobilized 410,000 hectares of land. Of these, 275,000 were left fallow (i.e. 17% of total fallow land). The other 135,000 hectares were occupied by "energy crops", i.e. benefiting from the new aid for energy crops raised on non-fallow land implemented by the latest reform of the Common Agricultural Policy in 2003 and effective in France as of 2004.

Quantities of biomass required to meet the 2010 targets

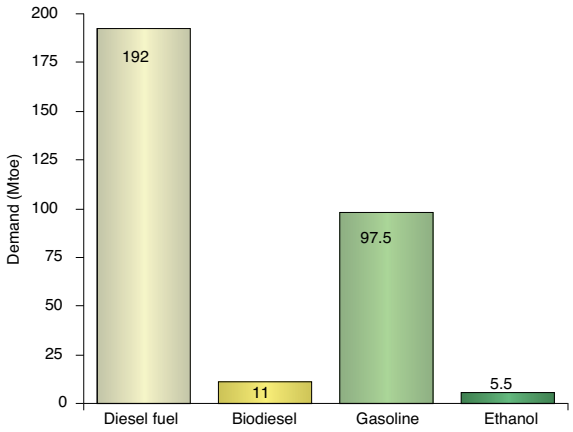
• *In Europe*

The European directive 2003/30/EC set targets for motor fuels in the transport sector: a 2% biofuel content by 2005 and 5.75% by 2010 (in energy equivalents). Presently, these targets are merely indicative and not mandatory in character. The directive provides no indication as to how the production effort should be distributed between gasoline and diesel replacement pathways. In other words, higher biofuel production on one of these market segments can compensate for underproduction on the other.

In 2005, about 4.5 million hectares should have been reserved to produce 5.76 million toe of biofuels. Actual production was lower and Europe posted an initial shortfall of 2.4 million toe in striving to reach these targets.

It will take nearly 14 million hectares to meet the 2010 target, which is to replace (in energy equivalents) 5.75% of diesel fuel and gasoline with biodiesel and ethanol, respectively.

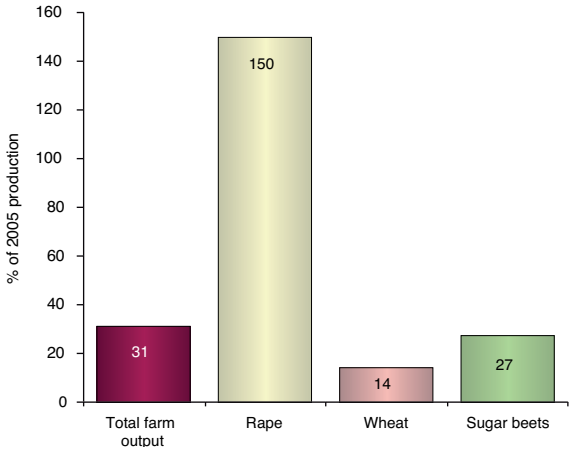
Graph 1 Forecast for motor fuel demand in 2010 (in Mtoe)



Source: IFP

Graph 2 shows that the size of the land area needed to grow rape, which by itself appears to cover a greater area than all of the fallow land in Europe (10 million hectares versus 8.2 million). Furthermore, according to an estimate by INRA (the French national agronomic research institute), 70% of all fallow land in France is cultivable. If we apply

Graph 2 Percentage of current farm production to be mobilized to reach the 2010 target



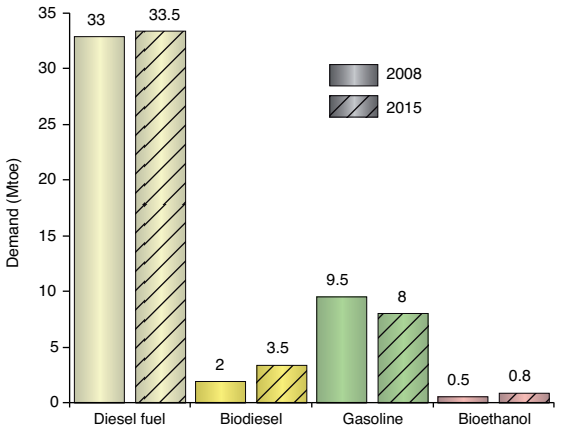
Source: IFP based on data from the FAO

this percentage to Europe, only 5.7 million hectares would be available. Clearly, other types of farmland or resources will have to be mobilized to reach the 2010 target. The European Commission has anticipated this additional demand for land to produce biofuels by creating an incentive (45 euros per hectare) to raise energy crops on non-fallow land. The ceiling of 1.5 million hectares set for this incentive should soon be raised to 2 million hectares.

• *In France*

The French government has set ambitious targets: a 5.75% biofuel content in motor fuels by 2008, 7% by 2010 and 10% by 2015. The corresponding demand for motor fuels and biofuels are given in Graphs 3 and 4, assuming that these percentages break down equally for gasoline and diesel fuel.

Graph 3 Motor fuel demand for 2008 and 2015 (in Mtoe)



Source: IFP

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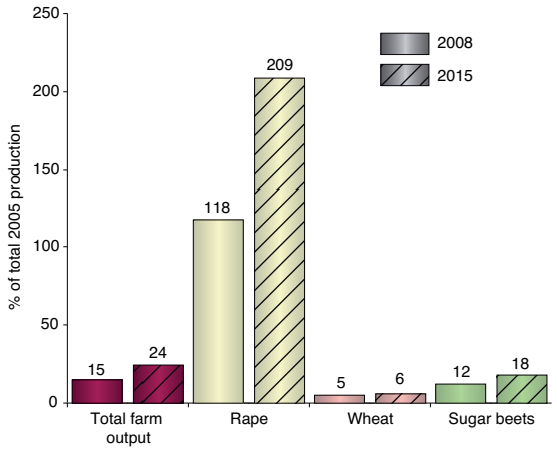
Graph 4 Percentage of current farm production to be mobilized to reach the 2008 and 2015 targets



Source: IFP

Like Europe, France would see its 1.05 million hectares of cultivable fallow land (70% of the total land area, according to INRA) fall short of demand starting in 2008. Non-fallow land is already being used by French farmers, who are converting certain pieces of non-fallow land to energy crops, benefiting from the European incentives resulting from the 2003 reform of the CAP.

Other types of biomass resources

A number of solutions can be envisaged to generate sufficient quantities of biomass, including:

- *Use the farm surplus*

It represents the percentage of products not contributing to European food self-sufficiency, and includes non-food farm products as well as products for export outside the European Union.

In Europe, this surplus represents 3.5 million hectares of non-fallow land used for non-food production (flax fiber for textiles, products to make cosmetics, flavorings, etc.) and 4.7 million hectares used to grow products for export outside the EU. Thus, in addition to the existing areas of fallow land, it would theoretically be possible to mobilize a total of 14 million hectares. If crop rotation for this land were organized to meet the preponderant demand for diesel fuel, hence for oilseed-bearing crops, the result would be a maximum output of 16 Mtoe (12.2 million tons) of first-generation biofuels (7 Mtoe of biodiesel and 9 Mtoe of ethanol).

In France, this surplus could be used to produce, on 3.4 million hectares, up to 6 Mtoe of biofuels (ethanol and VOME, produced in proportion to demand for the replacement of diesel fuel and gasoline).

This potential will not be fully exploitable, however, in light of the large scale of European exports on the international market for farm products. In the years to come, there will be a shortage in the world cereals supply in connection with biofuel development in the United States, which will use a large percentage of corn output for this purpose (20% of the corn grown in the U.S. is already "burned" in ethanol).

- *Import vegetable oil*

In 2005, Europe imported 150,000 tons of palm and soybean oil to make biodiesel. Their price differential with rapeseed oil makes them particularly attractive. This being said, they have different technical characteristics and one cannot add more than an estimated 10% to the volumes of esterified oil for technical reasons relative to compliance with European VOME standards.

In Europe, assuming that there is no change in the land area dedicated to the intra-European food supply and considering the shortage of farmland mobilizable for growing rape, at least 4 million tons of oil will have to be imported to produce enough biodiesel to reach the 2010 target.

In France, the rape resources seem barely adequate to meet the 2008 requirements. Starting in 2010, to limit the imports of vegetable oils to produce biodiesel[5], rape for biofuels will have to be grown on land now being used to grow rape for food purposes and/or products for export. To meet the 2015 biodiesel content target set by the government, 44% of the oil required, or 1.7 million tons, may have to be imported.

- *Use lignocellulosic materials*

It is thought that, by 2010, processes to convert lignocellulose into bioethanol or biodiesel (BTL) will be operating at industrial scale. This would allow Europe and France alike to mobilize large quantities of straw and wood that are not currently exploited for energy. This would nearly double the tonnage of first-generation biomass generated by the farming sector.

In Europe, 41.3 million tons of cereal straw and oilseed straw as well as 164 million tons of wood could be used to produce an additional 33 Mtoe of biofuels a year.

Using BTL technology, **France** could produce 7.5 Mtoe of bioethanol and biodiesel from the 13 million tons of straw

(5) Agreste Primeur n°185, November 2006, "Quelles surfaces pour les carburants verts ?" ("What land areas should be set aside for green motor fuels?")

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and 34 million tons of wood not being converted to energy today.

If we include the cereal straw and oilseed straw used to improve the soil, as well as cereal straw used in raising livestock, 30% of all cereal straw and 83% of all oilseed straw would be available to produce energy.

As for wood, mobilizable resources include slash, thinnings and non-commercialized twigs (about 31 million tons) as well as wood waste such as crates, pallets, and even certain woods treated according to need (about 3 million tons).

Short rotation crops (*Miscanthus*, short-rotation coppices, etc.) also offer good potential in terms of productivity and only require small amounts of fertilizers and pest control products. On the other hand, they require more land, whose mobilization remains difficult to estimate.

Biofuel contents in motor fuels that could be feasible

It is possible to estimate the volumes of first- and second-generation biofuels that could be produced from these various biomass resources. One should note that, like a farm surplus, lignocellulosic biomass only represents a potential that can be realized in part. This theoretical potential is likely to drop as a result of competition with existing sectors of production (timber, woodpulp, etc.) and with other types of activities generating energy (heat and electricity) from waste or biomass, not to mention the problematical logistics involved (straw and wood sources are dispersed all over France).

Table 5
Recapitulation of mobilizable resources

	Europe	France
Potential farmland areas	5.74 Mha fallow 8.2 Mha surplus **14 Mha**	1.05 Mha fallow 2.3 Mha surplus **3.35 Mha**
Quantity of biomass	50 Mt fallow 132 Mt surplus 214.5 Mt lignocellulosic **396 Mt/yr**	11.2 Mha fallow 46 Mha surplus 47 Mt lignocellulosic **104 Mt/yr**
Maximum quantity of biofuels	**49 Mtoe/yr**	**13 Mtoe/yr**
Quantity with logistical constraints	**32 Mtoe/yr**	**9 Mtoe/yr**

In 2005, **Europe** produced 3.4 Mtoe (2.86 Mtoe of biodiesel and 0.47 Mtoe of bioethanol). Between now and 2010, if Europe were able to produce the hypothetical maximum output mentioned previously—16 Mtoe of first-generation biofuels—then the 2010 target of a 5.75% biofuel content in motor fuels would be feasible. But attaining this output figure remains difficult, for it would require mobilizing all extra-European exports of rape and wheat. Furthermore, as a result of crop rotation constraints, the farm surplus mostly consists of products that convert to ethanol. Europe would fall short of the quantity needed to reach the targeted 11 Mtoe of biodiesel by slightly more than 10 million tons of rape (or 4 Mtoe of biodiesel).

Achieving an even distribution of the 5.75% across both production sectors (so that diesel and gasoline have exactly the same biofuel content) will be difficult for the first-generation technologies if biomass is only produced from farmland areas in Europe. To reach a global biofuel content of 5.75%, Europe can opt to import (oil or biodiesel) or prefer a higher percentage for the production of ethanol. **If it opts for the latter solution, Europe will have to maximize the output of biodiesel, for which there is real demand. One should recall that Europe is a net importer of diesel, but not of gasoline. If Europe were able to attain a biodiesel content of 3 to 4%, then its 5.75% target would translate into an addition of 10% ethanol to the gasoline pool.** This would mean that all gasoline vehicles would have to run on E10 and/or fuel-flexible vehicles would have to be developed.

Once second-generation processes have been developed, it will be possible to produce between 29 and 46 Mtoe of biofuels suitable for replacing either diesel or gasoline. It might then be possible to increase the biofuel content in motor fuels from 5 to 15% by approximately 2015.

France produced 0.4 Mtoe (i.e. 0.34 Mtoe of biodiesel and 0.06 Mtoe of bioethanol) in 2005. If all extra-EU exports were to be mobilized, which is highly unlikely, it would be possible to replace a maximum of 5.3% of diesel and 45% of gasoline, only using first-generation products. But this would imply eliminating wheat and sugar exports while making a massive replacement for gasoline, a motor fuel whose consumption is only 10 million tons and falling.

Unlike Europe, France aims to apply the same biofuel content to both gasoline and diesel production streams (General Tax on Polluting Activities, or TGAP[6]). Even if the 2008 target is easily attained (with a global biofuel content of 11%), the production potential of ethanol is still much greater than that

(6) TGAP: general tax on polluting activities

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of biodiesel. After reaching the 2008 target, it will be a problem to develop biodiesel from rape.

Subsequently, biofuel production could reach between 8 and 12 Mtoe, thanks to lignocellulose. The biofuel content might then eventually rise from 11 to 30%.

This assessment of the potential of the biomass materials that could be mobilized to produce vegetable-based motor fuels shows that, although biofuels will probably never fully replace petroleum products in the transport sector, they constitute an alternative that should not be disregarded. They could replace up to nearly 30% of the motor fuel consumed in the transport sector. Nevertheless, these optimistic scenarios will not materialize without public support for these alternative fuels, currently more expensive than petroleum products. Further R&D is needed to optimize first-generation technologies and develop the second generation, which are vital to the future of biofuels and to which IFP has a strong commitment.

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