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Biomass, an energy source of the future?

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The current energy system is not sustainable. Therefore a consistent energy scheme should be worked out and rapidly implemented. In that perspective all technological options must be considered. It becomes more and more obvious that energy savings must be the top priority all the more so because they are already a major contributor to the increase of fuel supply security, to cost saving and to environment protection. Among the current renewable energies which are part of the transition program, biomass is not given the importance it deserves. Jean-Pierre Schaeken Willemaers, active in the energy business, as a board member of different industrial companies and a member of the advisory board of the Thomas More Institute, is addressing in this paper some key issues relating to this source of energy such as biomass availability and supply, its impact on employment, on agriculture prices and on environment, to what extent it can be a substitute for conventional energy and at what cost as well as which types of biomass are more suited to the European economical and geophysical environment. This tribune is part of a larger research program on European energy issues initiated by the Institute over two years ago under the supervision of the author of this paper.

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Introduction

The directive 2009/28/EC of the European Parliament and Council gives under article 2 the following definitions:

- energy from "renewable sources" means energy from renewable non-fossil sources, namely solar, wind, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogas.

In particular:

- biomass means the biodegradable fraction of products, waste and residues from biological origins from agriculture (including vegetal and animal substances), forestry and related industries, fisheries and aquaculture as well as the biodegradable fraction of industrial and municipal waste;
- bio-fuel means liquid or gaseous fuel for transport produced from biomass.

Under recital 8, the directive indicates a 20% target for the overall share of energy from renewable sources and a 10% target for energy from renewable sources in transport. Under article 17 "Sustainability criteria for bio-fuels and bio-liquids", it also states that both types of fuels shall " not be made from raw material obtained from land with high biodiversity value, namely land that has one of the following statuses in or after January 2008:

- Primary forest and other wooded land where there is no clearly visible indication of human activity and the ecological processes are not significantly disturbed;
- Highly bio-diverse grassland that is:
  - natural, namely grassland that would remain so in the absence of human intervention and which maintains the natural species composition and ecological characteristics and processes; or
  - non-natural, namely grassland that would cease to remain so in the absence of human intervention and which is species-rich and not degraded, unless evidence is provided that the harvesting of the raw material is necessary to preserve its grassland status.

According to IEA[1]'s Reference Scenario[2], world primary energy demand is projected to increase by 1.5% per year between 2007 and 2030, an overall increase of 40%. Developing Asian countries are the main drivers of this growth, followed by the Middle-East. Always according to the same scenario, fossil fuels remain the dominant sources of primary energy world wide, accounting for more than three quarters of the overall increase in energy use between 2007 and 2030. The main driver for coal and gas is the inexorable growth in energy needs for power generation. World electricity is projected to grow at an annual rate of 2.5% to 2030. Over 80% of the growth takes place in non OECD countries. Coal remains the backbone fuel of the power sector, its share of the global generation mix rising by 3% point to 44% in 2030. The use of non-hydro modern renewable energy technologies has the fastest rate of increase in the reference scenario. Most of the increase is in the power generation[3]: the share of non-hydro "renewables" in total power output rises from 2.5% in 2007 to 8.6% in 2030. In late 2008 and early 2009, according to IEA, investments in "renewables" fell proportionally more than in other types of power generations; for 2009 as a whole, it could drop by close to one fifth. Without the stimulus provided by government fiscal packages, "renewable" investments would have fallen by almost 30%. Weaker fossil fuel prices are also undermining the attractiveness of investments in clean energy technology.

The economic crisis and resulting lower fuel energy demand growth account for three quarters of the foreseen lower global emissions by 2020 while government stimulus spending to promote low carbon investments and other new energy and climate policies account for the remainder. Non OECD countries account for all of the projected growth in energy related CO_2 emissions to 2030. Hence the necessity of having those countries contributing to the reduction of greenhouse gases emissions.

In the more ambitious 450 scenario[4], primary energy demand grows by 20% between 2007 and 2030. This corresponds to an average annual growth rate of 0.8% compared to 1.5% in the Reference scenario. End use efficiency is the largest contributor to CO_2 emission abatement in 2030 accounting for more than half of the total savings in the 450 scenario,

[1] International Energy Agency, World Energy Outlook 2009.
[2] The Reference Scenario provides a baseline of how global energy markets would evolve if governments make no changes to their existing policies and measures.
[3] IEA estimates that 1.5 billion people still lack access to electricity, well over 1/5 of the world's population. Some 85% of the people live in rural areas. Expanding access to modern energy is a necessary condition for human development.
[4] To limit to 50% the probability of a global average temperature increase in excess of 2°C, the concentration of greenhouse gases in the atmosphere would need to be stabilized at a level around 450 ppm CO_2 equivalent.

compared with the Reference scenario. In this scenario, coal based generation is reduced by half compared to the Reference scenario in 2030 while nuclear power and "renewables" make much bigger contributions.

Carbon capture and storage (CCS) in the power sector and in industry represents 10% of total emissions savings in 2030. The 450 scenario entails USD 10.5 trillion more investment in infrastructure and energy related capital stock globally than in the Reference scenario through the end of the projected period. Around 45% of incremental investment needs or USD 4.7 trillion, are in transport. In the short term, the maintenance of the government stimulus effort is crucial to this investment. Natural gas will play a key role whatever the policy landscape; in the 450 scenario world primary gas demand grows by 17% between 2007 and 2030.

This paper concentrates on biomass and addresses some key issues relating to this source of energy, in particular: biomass availability and supply, its impact on employment, on agriculture prices and on environment, to what extent it can be a substitute for conventional energy and at what cost, which types of biomass are more suited to the European economical and geophysical environment.

Biomass

Energy from biomass reduces European dependency on energy imports and thus increases the security of supply. It also provides new markets for farmers and creates jobs in rural communities, one way to boost the agricultural economy. Biomass is a natural fit for the power industry whether used as the only fuel or blended with fossil coal for instance. It shares with coal and gas the advantage of being available on demand. Biomass is renewable and is good for the environment[5]. It makes a productive use of crop residues, wood, some carbon wastes which otherwise would be burned or disposed off in a landfill.

1. Bio-power

Power can be generated from biomass through different processes.

Co-firing

The feedstock is a mix of coal and biomass. Co-firing efficiency in large scale coal fired plants is higher than the one of biomass-dedicated plants. In the case of co-combustion of up to 10% of biomass (in kcal terms), only minor changes in the equipment are needed. Above that percentage, the equipment (mills, burners, dryers and so on) must be adapted. With low-cost local biomass, the payback of the incremental investment is very short.

Cogeneration dedicated power plants

Such plants are usually much smaller (up to 100 MW) than modern cogeneration coal-fired plants because of limited availability of local feedstock and high transportation costs. The usual feedstock consists of wood, residues and wastes. The efficiency depends obviously on plant size and is normally around 30%. However the efficiency can be higher with high quality wood chips in modern CHP plants[6]. Fossil energy necessary to produce this feedstock is a few percents of the final energy.

Gasification

Biogas can be produced from thermal-chemical processes (pyrolysis) or from anaerobic fermentation. The biogas can be used in combustion engines with efficiency up to 35%. Its production can also be integrated in a combined cycle power plant (IGCC) running on 100% biomass. Abundant resources and favourable policies are enabling bio-power to expand in Northern Europe (mostly cogeneration from wood residues), in the USA and in countries producing sugar cane (e.g. Brazil). Global biomass electricity capacity is in the range of 47 GW[7]. IEA projections suggest that the biomass share in

[5] Biomass combustion is a carbon free process because the resulting CO_2 was previously captured by the plants being burned.
[6] Combined heat and power.
[7] IEA, Energy technology essentials.

electricity production may increase from the current 1.3% to some 3.5% by 2050. Biomass for heat production is the most efficient form of biomass use (conversion efficiency of over 90%). US bio-power plants have a combined capacity of 7000 MW. These plants use 60 MMtons of biomass fuels (primarily wood and agricultural wastes) to generate 37 TWh of electricity each year. As with conventional power from fossil fuels, bio-power is available 24 hours a day, seven days a week. Small modular bio-power systems with rated capacity of 5 MW or less can supply power in regions without grid connections.

The 2010 energy goal for biomass in Europe according to the Biomass Action Plan (COM-2005-528) is broken down into:

- 19 MMtoe liquid bio-fuels;
- 75 MMtoe biomass for heat;
- 55 MMtoe biomass for electricity.

The supply of biomass for energy in 2020, in Europe, will be in MMtoe[8] (millions of tons oil equivalent):

Forest based biomass	75
Agricultural based industry	97
Waste	23
Imports	25

The total arable land available in the EU27 is around 109 MMha. In 2006, 2.5 MMha are used for energy crops. This figure will increase significantly[8]. Around 60% of all renewable energy in the EU comes from biomass: energy derived from wood or plant matter that is used in heating and power generation. In Germany, energy from biomass has taken the second largest overall share of the renewable mix (22% against 4% for solar; wind remains by far the largest player). According to a recently released eurobarometer for biogas, Germany is Europe's largest producer generating approximately 40% of all biogas produced in the EU in 2006. The total energy potential for biogas has been subject of several projections and the most optimistic one leads to a total replacement of all European natural gas import from Russia by 2020! The Finnish biomass resources are stupendous. Finnish forests cover 26.5 MMha which corresponds to 78% of the country's surface. The wood residues for power production are estimated at about 30 MMm^3/year or 72 TWh. For several years, cogeneration from biomass is securing 76% of district heating. The Finnish figures are however an exception. Indeed in average, to cover the power needs of a country from biomass, two to three times the arable land would be necessary.

Costs and prices

Co-firing in coal power plants requires limited incremental investments (USD 50-250/kW) and the electricity cost may be competitive (USD 20/MWh) if local feedstock is available at low cost. Due to their small size, dedicated biomass power plants are more expensive (USD 1500-3000/kW) than coal plants and so is the price of electricity produced. Electricity costs in cogeneration mode range from USD 40-50/MWh. It appears that for the coming years, biomass cogeneration and onshore wind power remain the best choice in the renewable energy sector on the basis of quality/price criteria. On the other hand biomass prices are not expected to burst following a sustained growth. Reference is made to the price/ton of wood pellets in Austria, the European leader in that market, which shows a downward trend.

What is the impact of energy from biomass on food prices?

It is a matter of fact and this is a recent trend in economic history that the take-off of energy and food prices is simultaneous in the period 2006-2008. Speculation played a key role in this price surge. In 2006-2008 interrelations between agriculture and energy markets materialized more than in the past because of 1st generation bio-fuels, anticipation of long term import demand of food and energy from emerging countries as well as speculation as recalled above. In 2008, physical operations sold only 31% of the positions, traditional speculations 28% and index traders 41%[9]. In particular, the Indian and Chinese demand for plant oils considerably increased since 2000. For instance China is currently importing 45% of rape grains traded world wide instead of 10%, 10 years ago.

As the most natural and environment friendly renewable feedstock for power generation and as the only renewable energy (with the exception of hydropower) enabling continuous power production, bio-energy represents today the most effective choice in "alternative" options to address global warming. There are however disadvantages. Indeed today's bio-power plants have generation costs higher than fossil fuel power. Biomass feedstock contains less concentrated

[8] AEBIOM estimates (European Biomass Association).
[9] Tancrede Voituriez, IFRI, June 2009.

energy, are less economic to transport over long distances and require more preparation and handling than fossil fuels. Moreover one of the main challenges of the increasing use of bio-power is competition with natural gas.

2. Bio-fuels

"Until recently bio-fuels were great green hope. They were praised by politicians on both sides of the Atlantic as the answer to climate change and oil dependency with the bonus of boosting farmers' incomes. The first set of concerns around bio-fuels relates to their direct effects: damage to water, soil and biodiversity along with a rebound effect in the form of higher food prices…This led the EU to develop green standards to guard against promoting bio-fuels that do more environmental harm than good… The EU has drawn up rules to guard against the worst effects of direct land use change, inserted into the EU's 2008 renewable directive, but the indirect effects have not been taken into account[10]."

On the other side of the Atlantic, the Environmental Protection Agency (EPA) proposed to regulate bio-fuels to their direct and indirect emissions. Let us take as an example the American corn based ethanol which offers a greenhouse gas saving of 61% compared to fossil fuels, according to EPA. But when EPA counted the carbon cost of indirect land change caused by corn based ethanol the saving fell to 16%.

To better ensure that production, transport and use of bio-fuels and bio-liquids added up to a significant saving of carbon emissions when compared to fossil fuels, the directive 2009/28/EC of April 2009 provides that:

- The greenhouse gas emission saving from the use of bio-fuels and bio-liquids shall be at least 35%;
- Whit effect from 1 January 2017, the greenhouse gas emission saving from the use of bio-fuels and bio-liquids shall be at least 50%;
- From 1 January 2018 that greenhouse gas emission saving shall be at least 60% for bio-fuels and bio-liquids produced in installations in which production started after 1 January 2017.

The question is why bio-fuels have been so successful in spite of their well known drawbacks?

One reason is the profits generated by investments in that sector thanks to public (too?) generous subsidies and favourable legislation which has been adopted without consideration to direct *and* indirect consequences. Under such support scheme bio-fuels are an unexpected opportunity for (short term) investors and are boosting farmers' business which is welcome in a period of crisis. It is interesting to note that green lobbies are so prompt to call for the precautionary principle when it deals with GMO and are much more tolerant in the case of bio-fuels. Green and farmers' lobbying in spite of more and more controversies is obviously a success.

A new survey published by the "Friends of the Earth" and prepared by the consultancy firm Scott Wilson Group, reports that bio-fuels used in the UK could have doubled the GHG[11] emissions of fossil fuels they replace. This survey concludes that in the UK, instead of saving on GHG emissions, bio-fuels increased these emissions by 1.3 MMtons since the implementation of the obligation to incorporate them in the fuel. This results, inter alia, from the change in land use. In the UK, bio-fuels are produced from soya grown in Brazil, Argentina and the USA. In those countries the huge development of bio-fuels, of which from soya, needs new land taken from existing agricultural area or from natural ecosystems like tropical forests, dry forests and so on. "Friends of the Earth" also points out that some bio-fuels like ethanol from mais grains are not as natural as proclaimed. Indeed if its CO_2 emission is calculated on the entire production chain (cultivation, harvest, conversion, transport and distribution) the CO_2 saving for a car running on 10% ethanol in the gasoline is about 4%. This calculation is based on a "light" production of corn.The saving should be reduced when it deals with intensive farming.

A study from the Cornell university even concludes that one litre of ethanol requires 1.3 litre of oil, thus a negative balance. Their conclusions are clear: this type of ethanol contributes more than gasoline to global warming. A Stanford university survey comes to the same conclusion. "Friends of the Earth" stresses the other environmental impacts besides greenhouse effects. Mais growing is producing nitrogen which is one of the worst pollutants of rivers and water tables. It also needs a lot of water, weed killers and insecticides. On top of that if part of the mais for ethanol was grown on fallow lands, the increased cultivated surfaces would boost CO_2 emissions because it is proved that such lands absorb less CO_2 than grass pasture. Current concerns for many 1^{st} generation bio-fuels are that they:

- could contribute to higher food prices due to competition with food crops. It was the case in the USA with mais;
- are an expensive option to energy security;

[10] *European Voice,* March 26,2009.
[11] GreenHouse Gas.

- provide only limited GHG reduction benefits (with the exception of sugar cane ethanol);
- do not meet their claimed environmental benefits because the biomass feedstock may not always be produced sustainably;
- could accelerate deforestation;
- have potentially a negative impact on biodiversity.

The cumulative impacts of these concerns have increased the interest of developing bio-fuels which can be produced sustainably by using biomass consisting of the residual non-food parts of current crops that are left behind once the food crop has been harvested as well as other crops that are not used for food purposes such as straw, stems, miscanthus, jatropha, algae woodchips, pulp from fruit pressing and so on, the so called second generation bio-fuel. That bio-mass contains cellulose and lignin. The production of bio-fuels from ligno-cellulosic feedstocks can be achieved through two very different processing routes both currently under demonstration phase:

- bio-chemical;
- thermo-chemical.

The first fully commercial scale operations are not expected before 2012 and most probably after that date. The commercial scale production cost of second generation bio-fuels have been estimated by IEA to be in the range of 0.8-1.00 USD per litre of gasoline equivalent for ethanol and at least 1 USD per litre of diesel equivalent for synthetic diesel when crude oil price is comprised between USD 100-130/bbl. If commercialization succeeds and rapid deployment occurs world wide beyond 2020, the costs could decline to between USD 0.55-0.6/l for both ethanol and synthetic diesel by 2030.

As "Renewable Energy World.com" reports: " the relatively high cost of support currently offered for many first generation bio-fuels is an impediment to the development of the second generation bio-fuels as the goals of some current policies that support the industry (with grants and subsidies) are not always in alignment with policies that foster innovation." Taking into account the above considerations, it would be a better approach to:

- Concentrate on the most adequate bio-fuels such as wood and plant residues and the other bio-materials mentioned under this chapter and progressively drop the other ones;
- further promote pragmatic measures like increased use of railroad, higher efficiency car motors, better organised public transportation and so on.

It is worth reminding that bio-fuels are far from being a total substitute for conventional fuels. For example, in France, to secure 10% of the oil consumption for transport, from bio-fuels, about 5 million hectares would be needed which is about 30% of France's arable land.

Impact of EU bio-fuel policy on employment

What about the impact on employment resulting from the bio-fuel directive 2003/30/EC having the objective of achieving a bio-fuel substitution share of 5.75% in 2010.

According to a study by ZEW[12],policies that effectively promote the use of bio-fuels in the EU up to a substitution share of some 15% would not cause adverse employment effects, assuming that sufficiently mature bio-fuel production technology is at disposal as briefly explained hereafter. In any case the overall calculated employment effects, resulting from the balance of positive and negative contributions, are modest. The losses of jobs mainly occur in the refinery sector as well as in the energy and the transportation sectors.

A study carried out by Reilly and Paltsev (2007) points out that a bio-fuel industry that supplies a substantial share of the liquid fuels demand would have a very pronounced effect on land use and price and on the agricultural markets. For example " the USA would lose USD 100 billion of net exports of agricultural crops turning from a net exporter to a large importer" and the Authors conclude by disputing the idea that bio-mass energy could be a significant domestic energy source.

The situation is however very different in Brazil. The analysis conducted by Scaramucci and Cunha (2007) concludes that replacing 5% of the world gasoline demand with ethanol from sugar cane produced in Brazil by the year 2025 would increase Brazilian GDP by more than 11% and generate 5 million jobs.

[12] Zentrum für Europaische Wirtschafsforschung GmbH-Center for European Economic Research.

3. Chemicals derived from biological raw materials

"Chemicals from biological raw materials like wood and straw are being touted as the next big thing for the chemical industry and its customers…Industrial biotechnology using sectors like food and drink, pulp and paper, textiles, automotive, aerospace and packaging would be impacted… IB[13] advocates boast about lower net carbon emissions and reduced waste volumes (as many of the bio-derived products would be biodegradable) compared to those of normal petrochemicals. On the political- economic side, a bio-economy would rely less on oil imports from parts of the world deemed relatively unstable."[14]

However "the applications of biotechnology to the chemical industry is a relatively new endeavour, considerable uncertainty remains concerning the direction and extent of future development, an issue critical for raw material providers, manufacturers and users alike."[14] ADL also emphasizes that "it is risky in this endeavour to depend on government interventions for the business to succeed, since politics are fickle and more broad based measures such as carbon pricing would only have minor impact on the final cost of most chemicals."

Conclusions

As society does not have the financial resources to hedge against all possible negative outcomes, investments in bio-energy should principally focused on the more efficient use and production of energy and in areas providing widely agreed societal benefits including economic, social and current and future environment concerns. As the most natural, efficient and environment friendly renewable energy for power generation, especially in co-firing and cogeneration modes, and as the only renewable (except hydropower) enabling continuous power production, biomass represents the most effective choice to address global warming, security of supply and economic concerns although a number of problems have still to be solved. Already today around 60% of all renewable energy in the EU comes from biomass energy derived from wood or plant matters that is used in heating and power generation.

As far as transport is concerned, the first priority should be given to improving energy saving[15] (further the use of railroad, more efficient and smaller cars and the like) and to dedicating financial resources to the most suitable bio-fuels (requiring the lowest subsidies or possibly no subsidies at all) from an economical, efficiency, social and environmental perspective as explained in this paper with a progressive drop of the other bio-fuels which by the way are more and more contested. A new survey published by the "Friends of the Earth" reports that bio-fuels in the UK could have doubled the GHG emissions of fossil fuels they replace. This results, inter alia, from the change in land use. Subsidies and too generous support schemes are another concern. According to Renewable Energy World.com, "the relatively high cost of support currently offered by many first generation bio-fuels is an impediment to the development of second generation bio-fuels as the goals of some current policies that support the industry with grants and subsidies are not always in alignment with policies that further innovation".

There is a paradox in the bio-fuel policy. Indeed the cheaper the fossil fuels are, the less attractive renewable energies. This is the case when global energy demand decreases because prices decrease makes fossil fuels more attractive. The outcome would be the same if the share of renewable energy grows. Where is the balance between higher costs of renewable energy and competitiveness of European industry which is aiming at being the leader in the renewable business?

In any case conventional energy for power generation and for transport can, as a rule, only be replaced partially by biomass in the coming decades. For example, an area equivalent to about 30% of the current agricultural land in Europe should be dedicated to bio-fuel to reach a production equivalent to 10% of the European fuel consumption which is not acceptable. On the other hand to cover the power needs of a country like France, from biomass, two to three times the arable land would be necessary. As far as the impact of bio-fuels on employment is concerned, a study conducted by ZEW, a German centre for economic research reports that the use of bio-fuels in the EU up to a substitution share of some 15% would not cause adverse employment effects, assuming that sufficiently mature bio-fuel production technology is at disposal and on the other hand that the overall calculated employment effects resulting from the balance of positive and negative contributions, are modest. Other studies come to the same conclusions. This significantly differs from political statements claiming important net job creations.

[13] Industrial Biotechnology.
[14] Arthur D. Little, PRISM/2/2009.
[15] According to IEA, as mentioned in the introduction, the economic crisis and the resulting lower fuel energy demand growth account for three quarters of the foreseen global emissions by 2020 while government stimulus spending to promote low carbon investments and other new energy related climate, policies account for the remainder. End efficiency is the largest contributor to CO_2 emission abatement in 2030 accounting for more than half of the total savings in the 450 scenario.

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