Bioenergy and emerging biomass conversion technologies

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Background

Bioenergy is an important topic to include in a foresight analysis of the world agricultural markets and Europe. In the recent Agricultural Outlook report from OECD-FAO[1], it is concluded that one of the main drivers for agricultural market development in the period 2007-2016 is the growing use of cereals, sugar, oilseeds and vegetable oils to satisfy the needs of a rapidly increasing biofuel industry. This project part focuses on emerging technologies in relation to bioenergy, specifically biofuels for the transportation sector, and the role of bioenergy in sustainable energy production and uses.

What is the problem?

- Present world population increases dramatically and even with low future growth rate, the world population size will at the earliest get to a plateau around year 2040 with a population size of nearly 8 billion[2].
- The world society is increasing its energy consumption dramatically. This demand is mainly based on fossil fuel availability. Today, about 80% of the total primary energy supply consists of fossil fuel[3]. According to a reference scenario based on present development, the largest increase in energy supply until 2030 will be in the fossil fuels coal and gas. However, as concluded in the Agricultural Outlook from OECD-FAO, these predictions may be misleading and biomass may increase more rapidly (Fig 1).

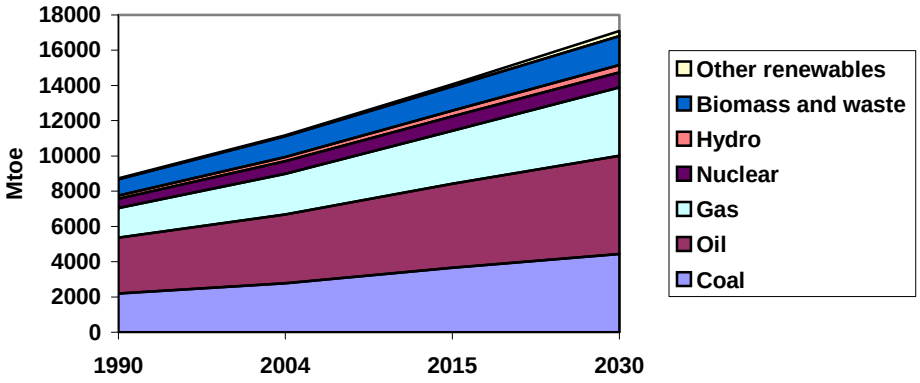

Fig 1 Total primary energy supply[3]

- The transport sector is increasing dramatically and consumes at present about 25% of the world energy supply[3]. Again following a reference scenario based on present development, the main source in 2030 is still expected to be oil.

- There are obvious problems that should be addressed if the development are continuing as illustrated in Fig 1:

- Limited fossil fuel resources. Predictions for the duration of these resources are constantly changing depending on the present consumption and how many new and different accessible sources are included. Reserves-to-production ratios for oil, coal and natural gas are about 40 years, 150 years and 60 years, respectively[4].
- Dependency on a limited number of supplier countries.
- Growing concern about increased CO_2 levels caused by human activities, most likely resulting in global warming[5].
- Alternatives for vehicles based on liquid fuel are not in general commercially available at present, implementation of improved vehicle technologies on the marked are just in its very beginning and renewable liquid transportation fuels are strongly debated.

Future

The targets

The European Union (EU) has set targets for the future in relation to energy policies expressed in the recent Green paper from 2006: A European strategy for sustainable, competitive and secure energy. At the meeting in the European Council in March 2007, an energy Action Plan being part of the European Council Action Plan (2007-2009) was agreed on in which clear strategic targets to be reached by the year 2020 were defined[6]:

- 20% savings of EU energy consumption compared to projections as estimated by the Commission in its Green paper on Energy Efficiency
- 20% renewable energy in overall EU energy consumption
- 10 % share of biofuels in overall EU transport petrol and diesel consumption. The binding character of this target is appropriate subject to production being sustainable and second-generation biofuels becoming commercially available..

Bioenergy as renewable energy

Biomass is constituted of primary products like agricultural crops, wood or aquatic biomass as well as secondary products like crop residues and organic waste e.g. from households and agricultural industries. Primary biomass is a limited resource since the land where it can be grown is limited. Primary biomass is a valuable resource as it has many functions. For agricultural products the basic functions are food and feed, for forestry it is paper, construction materials and solid fuel, whereas energy crops like willow can be seen as a multifunctional resource involving securing water reservoirs, biodiversity, landscape etc. which means that the supply and impact are interconnected with other services that just energy content. Also crop and forest residues are to a certain extend needed for preserving the fertility of the soil which is important to remember when addressing biomass resources for energy.

In the future, biomass will also increasingly be needed as substitutes for other products now made from nonrenewable resources like fossil oil, coal and metals, e.g. as biocomposites for purposes like components in cars, furniture but also building materials etc. The secondary biomass available as organic waste from industry and households is a biomass resource which is expected to increase in importance as a source for bioenergy with a stronger emphasis towards recirculation.

Bioenergy is considered a renewable energy since biomass is derived by means of the sun and natural processes that are replenished constantly. The important biological process is the photosynthesis which has a maximal annual radiation use efficiency of less than 2%, highest in tropical

rainforests[7]. For other renewables like hydro, geotherm, solar, wind, tide and wave energy, human technologic innovations has already provided more energy efficient processes. Globally, renewable energy accounted in 2004 for about 13 % of primary energy supply and combustible renewables and waste (mainly biomass) for about 10%[8].

During photosynthesis, CO_2 is bound but it is again released when the biomass delivers energy. Hence bioenergy is CO_2 neutral as long as the production process of the biomass is CO_2 neutral. This depends on agricultural management involving the use of fertilizers, pesticides and machineries and the characteristics of the crop species/cultivar grown. Especially the production of mineral fertilizer is very energy intensive. Energy and GHG (Green House Gas) balances will be different in different cropping systems e.g. when comparing organic and conventional farming strategies[9].

Biomass yield is depending on region, soil conditions, climate, chemical requirements for output products, characteristics of the crop species/cultivar grown, environmental impacts etc. With increasing demand for biomass for bioenergy and other non-food products it is assumed that current cropping systems and choice of species/cultivars and the cultivars themselves will be improved and/or chanced in order to deliver appropriate biomass characteristics.

Bioenergy and conversion technologies

Biomass is applied in different energy sectors: for heat and electricity production and for transportation fuel (Fig 2).

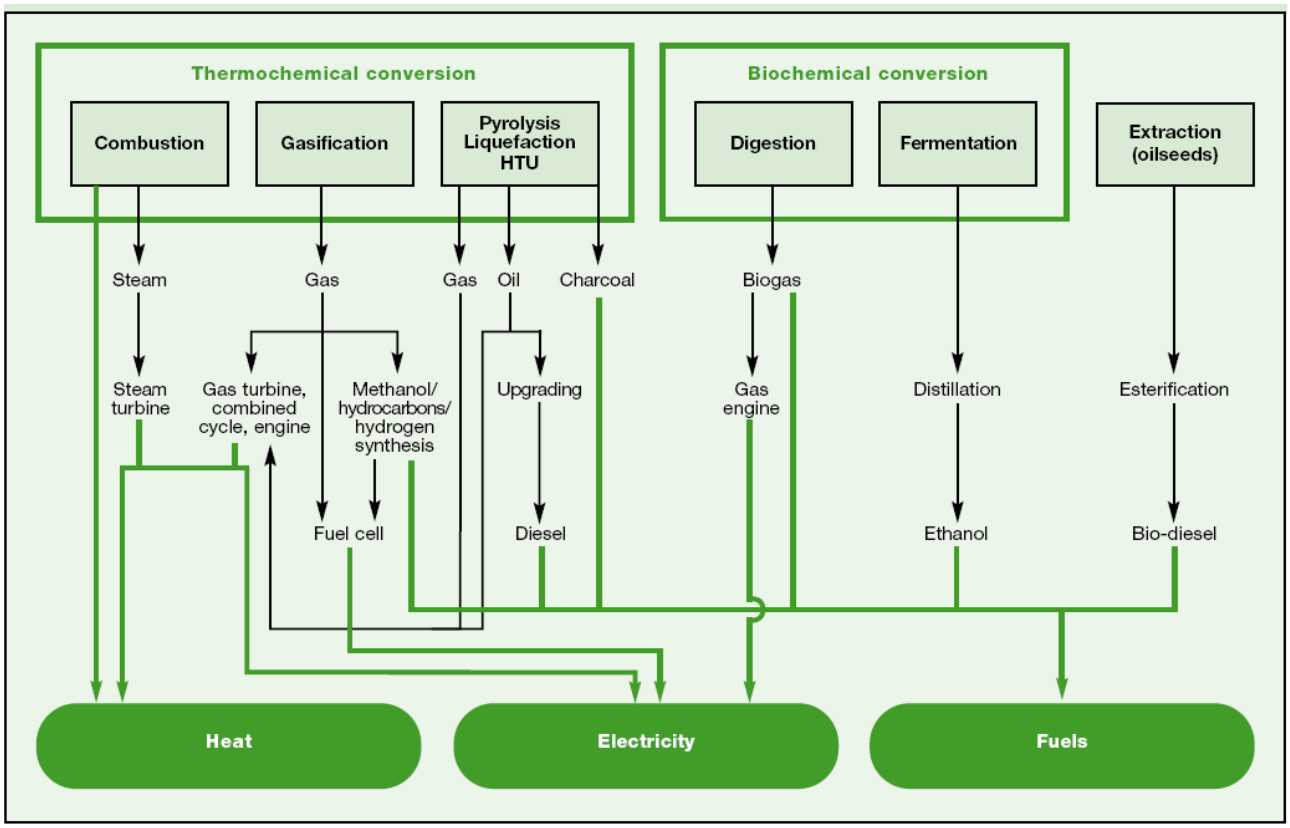

Fig 2 Main Biomass energy conversion routes[10].

In current policies, bioenergy for the transportation sector has much focus primarily due to focus on CO2-emissions. The existing and future technologies for transportation fuels may be described as (cf.[11]):

- First generation biofuels are made using commercial processes that have been widely adopted by the industry. Raw materials come from agriculture and food processing.
    - Biodiesel: extraction with or without esterification of vegetable oils from seeds of plants like soybean, oil palm, oilseed rape and sunflower or residues including animal fats derived from rendering
        - applied as fuel in diesel engines
    - Bioethanol: fermentation of simple sugars from sugar crops like sugarcane or from starch crops like maize and wheat
        - applied as fuel in petrol engines
    - Bio-oil: thermo-chemical conversion of biomass. A process yet not commercially viable.
        - applied as fuel in diesel engines
    - Biogas: anaerobic fermentation or organic waste, animal manures, crop residues and energy crops
        - applied as fuel in engines suitable for compressed natural gas.
- Second-generation biofuels are derived from non-food feedstock including lignocellulosic biomass like crop residues (straw) or wood. Two transformative technologies are under development.
    - Bioconversion: modification of the bioethanol fermentation process including a pretreatment procedure
    - Thermochemical: modification of the bio-oil process to produce syngas and methanol, Fisher-Tropsch diesel or dimenthylether (DME)
- Third-generation biofuels may include production of bio-based hydrogen for use in fuel cell vehicles.

Society has to build their priorities based upon system analyses of ecological, economic and societal sustainability, e.g. from energy balances, GHG balances and other sustainability accounting methods. A recent review of LCA studies on liquid biofuel systems for the transportation sector concludes that conventional grain- and seed-based biofuels can provide only modest GHG mitigation benefits by any measure (per GJ fossil fuel displaced, per vehicle km driven, or per hectare land use)[12]. One of the reasons is that grains and seeds often constitutes less than half of the biomass produced and it is difficult in the LCA to compensate for the co-products. With future technological improvements including conversion of lignocellulosic raw materials the prospects for use of primary biomass may change[12]. Increased focus on integration of several technologies in single industrial units using a biorefinary concept is also expected to improve the overall energy efficiency[13]. As an example is the IBUS concept[14].

A way of estimating the potentials in different part of the world for new and emerging technologies within biomass for heat, power and biofuel is by looking at indicators for innovation based on bibliometric searches (Fig 3)[15]. It can be concluded that Europe has a fair share of both installed capacity and knowledge production for the established but still not mature technologies of biomass for heat and power. On the other hand, Brazil and USA are world leaders in commercial

available biofuel technologies whereas Europe is still among the leading actors in biofuels research. Europe has a strong position within biodiesel production[15].

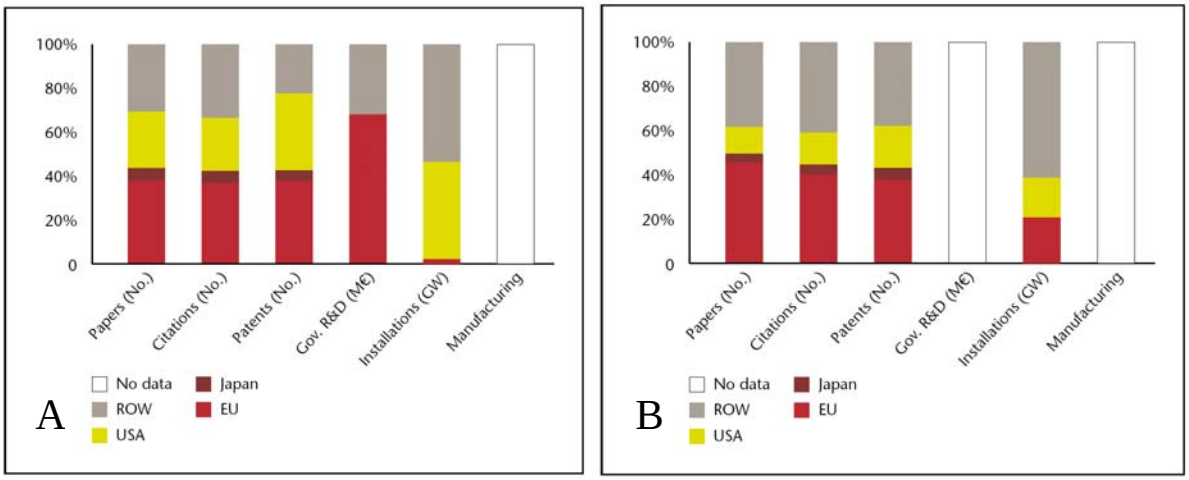

Fig. 3 A: Indicators for biofuel energy technologies. The data for publications and patents cover all biofuels, but bioethanol predominates. Production data is for bioethanol only. B: Indicators for biomass technology for heat and power production. Installed capacity refers to electricity only. ROW = countries outside EU, Japan and USA[15].

Implication of bioenergy production

Since biofuels in general covers two very subsidized areas, energy and agriculture, there are many external factors influencing the development of this sector both directly and indirectly. At the moment, it is argued that biofuel has influenced food prices strongly. That e.g. wheat and maize prices increase all over the world is however a combined result of the increased demand for grains for bioethanol and low wheat yields in countries like Australia[1].

Environmental implications have to be addressed very carefully when evaluating emerging bioenergy marked. Germany is one of the largest producers of biodiesel and biogas, due to political regulations (tax exemption, Renewable Energy Sources Act). Biodiesel and biogas feedstock originate from domestic cultivation of oilseed rape and maize. It is clear from the present development that high crop yield is needed to be able to have an economic efficient process, which implies high input of fertilizers, pesticides and fungicides and may contribute to pollution of waters and some places acidification of the soil.

Also rural development may be influenced by conversion of food and feed producing farms to larger farms producing feedstock for biofuels. An example of this is Brazil, where agricultural area increasingly is used by a few, large farms for production of sugarcane for bioethanol. This may imply scarcity of land and food for smallholders. The environmental sustainability of Brazilian bioethanol production is also frequently questioned[16].

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