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# The role of biomass in the future global energy supply

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## Abstract

Securing the future global energy supply is a far from trivial task. Many studies have exclusively focused on energy technologies that are already developed and have gained market shares. However, large unexploited potentials are hidden in biomass. The present paper seeks to provide an overview of the oftentimes neglected possibilities that are associated with intensive, intelligent, and sustainable utilisation of biomass for integrated production of a wide range of products including environmental-friendly energy.

**Keywords:** biomass, biofuels, biorefining, Process Analytical Technology

## Introduction

The vulnerability of the global energy production and distribution system has been proven at several occasions. In the 1970'ties, the global dependency on fossil oil was made quite clear on two events. The market price for crude oil increased heavily causing dramatically societal changes. Hasty decisions for reductions in the energy consumption had to be made leading to reduced productivity and poor economic growth in many regions around the world. These events and their consequences are referred to as the *oil crises*. [1], [2]

Among the 35 worst polluted sites on the planet, four of them result from reckless energy production arising from specifically coal mining, distribution of oil in pipelines, and accidental release of radioactive material into the surrounding environment. Linfen, the People's Republic of China, Chernobyl, Ukraine, and the Niger Delta, Nigeria, represent a few of the well-documented cases. [3]

The lessons learned from energy production in the past are associated with many negative memories. Future energy production cannot continue via this devastating path. New innovative solutions that respect the diversity of nature and mankind have to be developed, matured, and implemented.

## A change of paradigm is needed

Academic and scientific societies have acknowledged the existence of the environmental impacts caused by consumption of fossil fuels. Extreme weather conditions manifested in e.g. heat waves, wood fires, and massive precipitation are occurring more frequently than ever before. An elevated global average temperature has been observed. It is believed that the increased emission of greenhouse gasses (including carbon dioxide, methane, and nitrous compounds) is responsible for the temperature shift and thus energy production based on fossil fuels can be linked directly to the mentioned natural disasters claiming many casualties and necessitating tremendous reconstruction efforts. [3], [4]

Indeed, energy has become a global issue.

At present, fossil energy resources account for 79 % of the World's energy consumption, 7 % is covered by nuclear power, and renewable energy sources deliver the remaining 14 %. [4]

Diversity in the energy product portfolio is necessary in order to reduce the dependency on any single energy source. Naturally, the energy products of interest must confirm with some basic requirements: they *must* be sustainable, renewable, and clean. [1], [5]

A recent Danish desktop study presented on the $15^{th}$ European Biomass Conference in Germany in May this year estimates that 75 % of the World's energy consumption can be covered by utilisation of renewable energy sources within the year 2030. The study proposes a true *change of paradigm*, which shifts the societies from being dependent on fossil fuels to become economies based on *renewable energy sources*. The optimal energy product mixture depends on the availability in each region of the World, but it is stated that fossil fuels can be out phased in a nearby future. Immediate action from all regions of the World is required to fulfil this sustainable vision. [5], [4]

## Renewable energy sources

A number of pollution-free, sustainable, and renewable energy sources exist. Solar power (both thermal and photovoltaic), hydropower (traditional plants and recent wave-generator-concepts), geothermal energy, wind power, and last but not least biomass derived energy all carry a great potential to reverse the negative effects that fossil energy production has on the environment.
No single renewable energy technology should be preferred on expense of the others. In the long term, the global energy supply can *only* be secured through an intelligent integration of various renewable energy products. [5]

Biomass is by definition a sustainable, renewable resource. Biomass is generated by the ingenious process of the photosynthesis, which captures carbon dioxide from the atmosphere and stores energy chemically in plant biomass. The amount of carbon dioxide that is released upon combustion of the biomass equals the amount that was initially trapped during photosynthesis. Biomass in the context of renewable energy thus becomes *carbon dioxide neutral*, since there is no net emission of carbon dioxide to the atmosphere. [7], [6] Biomass can be used for sustainable, environmental-friendly, clean energy production in several ways. One approach that has gained much attention over the past years is by processing it in the *biotechnological refinery*.

## Biorefining

Analogous to a petrochemical refinery producing a wide variety of products from crude oil, the same principles can be applied to a biomass based refinery. A biotechnological refinery, *biorefinery*, has many advantages over petrochemical refineries. [10], [11]

The term *biorefinery* has been defined as

*"a facility for achieving large-scale integrated production of fuels, power, and chemicals from biomass"*. [4]

One important keyword is *integration*. A biorefinery has the capability of utilising multiple biological raw materials, denoted feedstocks, depending on availability and market price. Furthermore, by-products generated in one part of the biorefinery can serve as substrates in another. This is apparent for instance when integrating production of liquid biofuels with biogas. The digested biogas substrate can be separated into a liquid, high-value organic fertiliser and a solid fibre fraction suitable for enzymatic hydrolysis and subsequent bioethanol fermentation. The term *waste product* is more or less non-existing in the context of biorefining. [6]

The biotechnological approach exerts some fundamental advantages compared to the classical chemical synthesis. Low process temperature, low energy consumption, and high product specificity are the most important ones. [6]

The generalised biorefinery concept is summarised in Figure 1.

| **Feedstocks** | **Processes** | | **Primary products** | **Final products** |
|---|---|---|---|---|
| Wood | Hydrolysis | | Sugars, lignin | Heat |
| Grass | Gasification | | Synthesis gas | Electricity |
| Silages | Digestion | → | Biogas | Biofuels (biodiesel, bioethanol, methane etc.) |
| Whole crops | Pyrolysis | | Bio-oil | Bio-based chemicals (plastics, solvents, acids, pigments, pharmaceutics, enzymes, flavours, colouring agents etc.) |
| Energy crops | Extraction | | Carbon rich materials | |
| Organic residues | Separation | | Plant products | Feedstuff for livestock, protein |
| Organic wastes | Combustion | | Heat | Polymers, building materials |
| | | | | Organic fertiliser |

**Figure 1. The biorefinery concept**

Adapted in modified form from [4], [9], and [10]

From Figure 1, the great diversity in the product portfolio can easily be recognised. The core processes in a biorefinery involve the use of microorganisms; bacteria, yeast, and fungi. Since the conversion of feedstocks into high-value products is performed by living organisms, the processes are normally carried out at relatively low temperatures. Still, the overall energy efficiency of a biorefinery has to be optimised to ensure the economical feasibility. Applied integrated thinking can elegantly solve many practical problems, provided that the solutions are implemented already in the *planning phase* of the biorefinery. Otherwise, re-configuration of the biorefinery infrastructure might not be economically feasible due to too high additional investment costs. [5], [9]

From a strict technological point-of-view, integration of Process Analytical Technology (as defined by the Food and Drug Administration, United States) in the context of biorefining will be of utmost importance in order to be able to obtain feasible process performance. Novel sensor and control technologies for bioconversion processes are becoming increasingly sophisticated. In short time, robust equipment at low-cost will be available on the market. Development of biorefineries at *any* scale in *any* part of the World applying state-of-the-art technology for optimal energy efficiency will therefore soon be possible. [12]

## The first step has been taken

An example of such integrated thinking is evidenced by the IBUS concept (Integrated Biomass Utilisation System), developed by the Danish energy company DONG Energy formerly known as ELSAM. The concept links renewable energy production with fossil energy production from coal. Excess steam from a coal plant is used in the physico-chemical pre-treatment of feedstocks in the biorefinery, and the surplus fibre fraction from the biorefinery is burned in the kettles at the coal plant. The input feedstock in the testing facility is residual straw collected from agriculture. The straw is pre-treated in order to open the complex structure and facilitate microbial conversion of the sugars. A subsequent fermentation yields bioethanol; a *biofuel* in great demand, since it can substitute fossil transportation fuels. [8]

## Conclusions

- A sustainable global energy supply can *only* be accomplished by intelligent integration of various renewable energy products in all regions of the World.
- The global dependency on politically unstable regions possessing vast majorities of the fossil fuel reserves can be omitted by transforming the global society from being dependent on fossil fuels to become economies based on *renewable* energy sources.
- Integrated thinking using biomass for production of a wide range of high-value products – including energy – can solve many environmental and societal problems and at the same time create new market opportunities for developing countries.
- By adapting the principles of biorefining in developing countries and investing strategically in biomass based economies the developing regions can establish a high degree of self-sufficiency in relation to a wide range of products including *food*, *feed*, *fuel*, and *fibres*. In other words: complete high-technological societies can emerge based on renewable biomass resources.

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