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Renewable energy from agro biomass

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Abstract. In Finland forest biomass is an important energy source but currently there is also interest to use agro biomass for energy. The free energy potential of agro biomass, i.e. 21TWh, is the same magnitude as the techno-economical potential of unused wood resources in Finland. An implementation of such an energy resource would require that 500,000ha of field should be allocated for the reed canary grass. The straw yield should be also harvested and generated to energy. Biogas production from manure and bio waste would have less importance in the energy production but it would be important for recycling phosphorous.

From the environmental point of view the utilization of straw for energy and biogas production would have clear environmental advantages compared with the fossil energy sources. The environmental impact of a wide-scale reed canary production depends on what crops the reed canary grass will replace. If the reed canary grass is cultivated instead of annual, intensively grown crops such as cereals and grassland for silage its environmental impact is positive. If it replaces fallows covered with perennial grasses its impact can be negative. In both cases it is supposed that the field area is allocated from one crop to another and the Finnish field area remains constant.

Keywords: bio energy, biomass, agro biomass.

INTRODUCTION

Finland is strongly dependent on the imported energy (Statistics Finland, a). On the other hand, 500,000 ha of the field area (Ministry of Agriculture and Forestry in Finland 2005) could be allocated for bio energy crops. The reed canary grass (*Phalaris arundinacea* L.) (RCG) is so far the only energy crop which has economic meaning. Its cultivation area increased fast in the beginning of 2000's but it has declined later on (TIKE 2007, TIKE 2010). This decline was a consequence of the rapid increase of grain prices in 2008. Energy and food compete from the same limited area of field. This example shows how the prices of food and energy are connected with each other.

There are sources of agro biomass such as manure, straw, and waste from food industry that could be processed to biogas. The residue from biogas processing, so-called digestate, can be used as an organic fertilizer. Besides the energy generation this route is a realistic choice for recycling plant nutrients, especially phosphorous, which will be a scarce plant production resource in the near future (Cordell 2010).

Wood has been the most important source of renewable energy in Finland. For this reason it is a good reference point for agro biomass in terms of energy potential and environmental impacts. Peat is another good reference point though it is not renewable energy. The Intergovernmental Panel on Climate Change (IPCC 2006) and

The European Union (EU 2006) have defined peat as a fossil fuel. Despite these definitions peat has an established position in the Finnish energy policy and it will be used for energy generation in future, too.

Energy generation from biomass can have positive and negative impacts on environment. Green house gas emissions are not the only issue but emissions to soil and waters, and biodiversity should be considered, too. Energy balance and the environmental impacts of bio energy should be analyzed before their wide scale implementation.

MATERIAL AND METHODS

This study is a literature review about agro biomass resources available for energy in Finland. They are compared with wood and peat. Environmental impacts of agro biomass production are also discussed shortly.

Agro biomass resources in Finland

Agro biomass is a common name for different biomasses originating from the agriculture. Agro biomass consists from plants and their parts but also slaughter waste and by- products from the food industry belong to this group. In Finland, fiber plants and crops for industrial use other than food have only marginal importance. Manure and straw are the biggest available biomass resources measured in mass or volumetric units. There is also spoiled fodder, tops of sugar beet, peeling waste, process waters, whey, distiller's wet grains and corresponding biomass items that contain compounds usable in energy production.

Energy crops are one group of agro biomass. So far, they have not had any outstanding proportion in the Finnish cropping area. A long term climate and energy strategy of Finland states that we have 500,000ha of field that could be used for the other purposes than food and fodder production e.g. for bio energy production (Ministry of Agriculture and Forestry, Finland 2004; A long term climate and energy strategy 2008 in Finland).

Reed canary grass (RCG)

Cultivation of the RCG for energy generation grew fast in the beginning of the 2000's (TIKE 2007). Fig. 1 presents the development of the cultivation area in the period of 2001 – 2009. The fast growth was followed by a decline in 2008–2009. Despite the fast growth the acreage of the reed canary was still minor, less than 1% from the total field area. The background of the increased area was a demand from bio power plants and economical competitiveness with other crops. Economical competitiveness was based mainly on farming subsidies but not on high product prices on the market. When prices of cereals doubled in 2008 farmers were no more interested in increasing the area of the RCG. Production of cereal offered a better profit than energy production. After 2008 the cereal prices have gone down but interest in the RCG has not recovered.

However, the RCG is so far the only energy plant grown on fields and the only energy plant which has an economic meaning. Plans to produce ethanol from barley for traffic fuel have not come true and cultivation of turnip rape for biodiesel flagged after a promising start. Biodiesel is taxe liked fossil sulfur containing diesel in traffic use and this does not encourage in producing biodiesel. In off-road use biodiesel is tax-free.

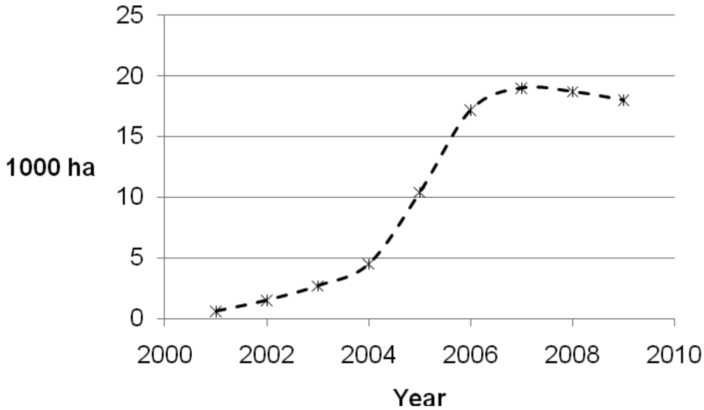

Figure 1. Development of the cultivation area of the reed canary grass 2001–2009. (TIKE 2007, TIKE 2010).

In 2007 the cultivation area of the RCG was 19 000 ha (Tike 2007) and the energy yield was 0.5TWh. The energy yield has been counted by anticipating the dry matter yield to be 5.0Mg ha^{-1} (Lötjönen et al. 2009) and the heating value for the dry matter 17.6MJ kg^{-1} (Alakangas 2000). If all surplus field, totally 500,000ha, were allocated for the RCG the energy yield would equal to 12.2TWh.

Straw

Straw is a mainly unused biomass resource in Finland. As a by-product of the cereal production it is in the most cases chopped and left on the soil surface. Some 20% of straw is used for animal bedding and 6 million kg i.e. 2,400 ha for energy (Ministry of Agriculture and Forestry, 2004). After the first oil crises in the 1970's Ahokas et al. (1983) evaluated the heating value of the straw yield to be 7.6TWh. An expert group of the Ministry of Trade and Industry (2007a) made a new evaluation in 2007. According to this group the energy content of straw was about 10TWh. Because 20% of the straw yield is exploited the unused potential is 8TWh.

Energy from agro waste

Manure is a potential resource for energy generation. Liquid fermentation can be used for slurries with dry matter content below 13% and dry fermentation for manure with 20 – 35% dry matter content. A working group of the Ministry of Trade and Industry considered possibilities to execute a feeding tariff for electricity produced from biogas and this working group estimated that the total amount of manure corresponded to 1.5TWh as energy. This was a theoretical potential and after taking into consideration practical and economical restrictions the working group concluded that the technical potential of manure was 0.4TWh (Ministry of Trade and Industry, 2007b).

Unused wood and peat resources

Laitila et al. (2008) have estimated the techno-economical potential of wood biomass for energy to be 15.9 million. m^3 and equal to 32TWh energy. When the share of forest chips (5.2TWh) and wood in small scale combustion (4TWh) already in use are subtracted the real net increase could be about 23TWh. Kärhä et al. (2009) have also estimated that the techno-economical increase of forest chips in 2020 could be 23–25TWh. The total contribution of wood energy was 82TWh in 2008, 22% from total primary energy consumption, (Statistics Finland, a). According to the previous estimations it could be 105TWh in maximum if stem wood is further used mainly for other purposes than energy.

The annual growth of peat is 37TWh (Selin 1999) and the consumption has varied between 17TWh and 28TWh (Statistics Finland, b) in the 2000's. Thus, the unused potential is 9–22TWh per year.

Environmental impacts of energy production from agro biomass

Liquid bio fuels (bio ethanol and rape methyl ester (RME)) have proved to have equal or even higher negative impact on environment than gasoline and diesel (Mäkinen et al. 2006, Virtanen et al. 2009). The main proportion of the negative environmental impacts originates from plant production activities and inputs to the plant production (especially N-fertilizers). If straw would be used to substitute fossil fuel in ethanol processing the green house emissions would decrease about a quarter and in that case they would be below emissions of gasoline (Mäkinen et al. 2006).

Straw and stems of oilseed plants used for heat and power generation decrease clearly the green house gas emissions compared with peat and other fossil fuels (Virtanen et al. 2009). Their emissions are in all environmental impact categories the same magnitude as the emissions of wood chips. The primary energy consumption per 1MJ generated energy is very low, only 0.02MJ MJ^{-1}. The RCG is a similar fuel as straw but its green house emissions were about half of emissions of peat and its impact on eutrophication was much higher than the impact of straw. In cereal production all nutrient emissions are generally allocated to grains and for this reason straw is free from the nutrient emissions at harvesting.

Berglund & Börjesson (2006) and Börjesson & Berglund (2007) have analyzed different biogas systems in terms of energy efficiency and environmental impacts. They have found that the input energy is 20–40% of the energy content in the biogas produced. The proportion of the input energy depends on transportation distances and properties of raw materials, on the system design, and allocation methods (Berglund & Börjesson 2006). Biogas systems had in general lower emissions than the fossil reference systems. The environmental benefits of biogas plants resulted often indirectly from a changed land use and handling of organic waste. It is typical for biogas production that indirect environmental benefits exceed direct benefits when fossil fuels are substituted.

CONCLUSIONS

The energy potential of agro biomass, i.e. 21TWh, is the same magnitude as the techno-economical potential of the unused wood resources in Finland. Introduction of such an energy resource would require that 500,000ha of field area should be allocated for the RCG. The straw yield which is not yet utilized should be also harvested and generated to energy. Biogas production from manure and bio waste would have less importance in energy production but it would be important for recycling phosphorous.

From the environmental point of view the utilization of straw for energy and biogas production from manure and bio waste would have clear environmental advantages compared with the fossil energy sources. The environmental impact of a wide-scale reed canary production depends on what crops the RCG replaces. If the RCG is cultivated instead of annual, intensively grown crops such as cereals and grassland for silage, its environmental impact is positive. If it replaces fallows covered with perennial grasses its impact can be negative. In both cases it is supposed that the field area is allocated from one crop to another and the Finnish field area remains constant.

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