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Future demand for forest-based biomass for energy purposes in Sweden ☆

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ABSTRACT

This paper assesses the potential changes in the demand for forest-based biomass for various energy purposes in Sweden in 2030 and 2050, respectively. The assessment is based on a review of scenarios and predictions of how the Swedish energy system may develop, taking into account techno-economical conditions. It includes potential changes in district heating, electricity production in combined heat and power plants, industrial process energy, and production of biofuel for road transportation. In addition, the potential demand for forest-based feedstock in the chemical and petrochemical sector, replacing current use of fossil feedstock, is analysed. The assessment suggests that Sweden may see an additional demand for forest fuels at about 30 TW h in 2030 and 35–40 TW h in 2050. This can be compared with the current use of biomass for energy in Sweden at 130 TW h per year, and the estimated potential increase of sustainable harvest of logging residues (slash and stumps) at some additional 20 TW h per year, based on current conditions. If also potential demand for forest-based feedstock in the chemical and petrochemical industry is included, another 10–15 and 25–30 TW h of biomass per year may be needed in 2030 and 2050, respectively. The future demand is sensitive to the pace and magnitude of energy efficiency improvements and electrification in the various sectors. If far-reaching energy efficiency improvements and electrification are realised, the total additional demand for biomass as energy and industry feedstock may be about 20 and 30 TW h per year in 2030 and 2050, respectively, thus roughly corresponding to the sustainable harvests of logging residues. If, however, efficiency improvements and electrification are only marginal, then the additional demand for biomass as industry and energy feedstock may reach 70 TW h and 100 TW h per year in 2030 and 2050, respectively. In these cases, the use of logging residues will not suffice and additional biomass would be needed. A combination of regulations and incentives is recommended to accelerate the fuel and feedstock switch, especially in the transportation and industrial sectors, and incentives promoting a substantial improvement in energy efficiency and electrification in all sectors.

1. Introduction

The European Union (EU), has set a long-term goal to develop a competitive, resource-efficient and low carbon economy by 2050 (European Commission, 2011). The transition to a bio-based economy (bioeconomy) is considered a crucial step and the European Commission has formulated a strategy and action plan for a bioeconomy for Europe (European Commission, 2012a). Several individual EU Member States (e.g., Sweden, Germany, and Finland) have designed national bioeconomy strategies and regional agencies and industrial groups have also formulated strategies (de Besi and McCormick, 2015). Biomass is increasingly used to displace non-renewable resources (especially fossil fuels) in response to policies that are designed to address concerns about climate change and energy security, and to promote innovation and growth of biobased industries that use biomass as feedstock.

The Swedish strategy for a bioeconomy in 2050 (FORMAS, 2012) focuses on efficient resource use and identifies key themes for further research necessary for a shift to a bioeconomy. Biomass-based energy (bioenergy) is expected to play a key role in reaching Swedish goal of climate neutrality, i.e., no net emissions of greenhouse gases (GHG) to the atmosphere by 2045 (SOU, 2016; Government Offices of Sweden, 2008). Predictions indicate a significant increase

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in the use of biomass in the coming decades, for transport, indoor heating, electricity generation and in various industrial processes (Swedish Environmental Protection Agency, 2012).

The use of biomass for energy in Sweden has increased continuously since the mid-1970s and has been critical in the phasing out of oil use for heating and electricity generation. Today, petroleum is almost exclusively used for transport and bioenergy and petroleum both contributes about 130 TW h per year, i.e., almost one-third each of the total energy supply in Sweden (excluding heat losses in nuclear power production) (Swedish Energy Agency, 2015a). This energy system transition has so far contributed to a reduction in domestic Swedish GHG emissions by some 25% since the 1990s (Swedish Environmental Protection Agency, 2016).

Fig. 1 illustrates the supply and final use of biomass-based energy in the Swedish energy system 2014 (Swedish Energy Agency, 2015a). Almost half of the Swedish bioenergy use occurs in the forest industry sector, where by-products and residues are used for generating process heat and for combined heat and power production (CHP) (Swedish Energy Agency, 2015a). The use of forest residues (mainly tops and branches) and organic waste for district heat and CHP production, represents some 30% of the total bioenergy used. The remaining part is used for heat production in single-family houses, etc., and for the production of transportation fuels (Swedish Energy Agency, 2015a). The use of biofuels in the Swedish road transport sector corresponded to about 12% in 2014 (or about 11 TW h per year) (Swedish Energy Agency, 2015b). A minor part of the biomass supply originates from imported biomass, whereas some biomass-based energy carriers, e.g. liquid biofuels, are exported and not included in Fig. 1 (representing a minor part).

Sweden has a long-standing political commitment (since the 1970s) to the development of renewable energy. The carbon dioxide (CO_2) tax on fossil fuels introduced in 1991 and renewable electricity certificates of 2003 represent two important political incentives behind the significant increase of bioenergy. These incentives have effectively supported an increased use of biomass through, for example, fuel-switching in district heating and the building of new biomass-based CHP plants. The existing infrastructure in the forestry and energy sectors, notably the district heating systems, has facilitated this development. Furthermore, professional actors in these sectors have been able to respond constructively to changes in relative fuel prices (Nilsson et al., 2004).

The CO_2 tax (and exemption from it), in combination with other national policies related to the EU Renewable Energy Directive (RED) implemented in 2009 (European Parliament and Council, 2009), has recently also promoted an increased use of biofuels in the transportation sector (Grahn and Hansson, 2015). However, fossil fuels still provide almost 90% (or about 75 TW h per year) of the energy used for road transports in Sweden (about 30 TW h gasoline and 45 TW h diesel per year) (Swedish Energy Agency, 2015b). Petroleum and some natural gas are also used as fuel (30 TW h per year) and feedstock (25 TW h per year) in the Swedish industrial sector (Eurostat, 2015).

This paper complements other papers in this Special Issue, which focus on aspects of biomass production, by presenting an assessment of the potential increase in demand for forest-based biomass for various energy purposes in the coming decades in Sweden. Thus, we investigate whether the historical trend of a continuous increase in bioenergy supply and use, as described above, can be expected to continue also in the future. The paper includes a comprehensive assessment of all various sectors potentially increasing (or decreasing) their use of forest-based bioenergy. This knowledge regarding the total potential increase in future forest fuel demand, where the different sectors are added together, is missing today since existing studies mainly assesses the different sectors separately.

The assessment is based on a literature review and evaluation of existing predictions, forecasts and scenarios of how the Swedish energy system may develop until the years 2030 and 2050, with special focus on changes in the use of biomass for energy. The following biomass uses are included: heating and cooling, electricity production by CHP, industrial process energy, and biofuel production. The potential replacement of petroleum and natural gas as feedstock in the Swedish industrial sector is also discussed. Scenarios and forecasts from the recent five years are included in the literature review and evaluation to obtain a current and relevant overview of the biomass uses in question.

Carbon capture and storage (CCS) represents one option to reduce fossil carbon emissions more rapidly than what is possible unless society accepts high costs associated with early retirement of the infrastructure that has been built up to enable the use of the fossil resources. CCS has not yet been applied at scale to operational commercial fossil fuel power plants, but could enter the market if incentivized by regulation and/or if they become compet-

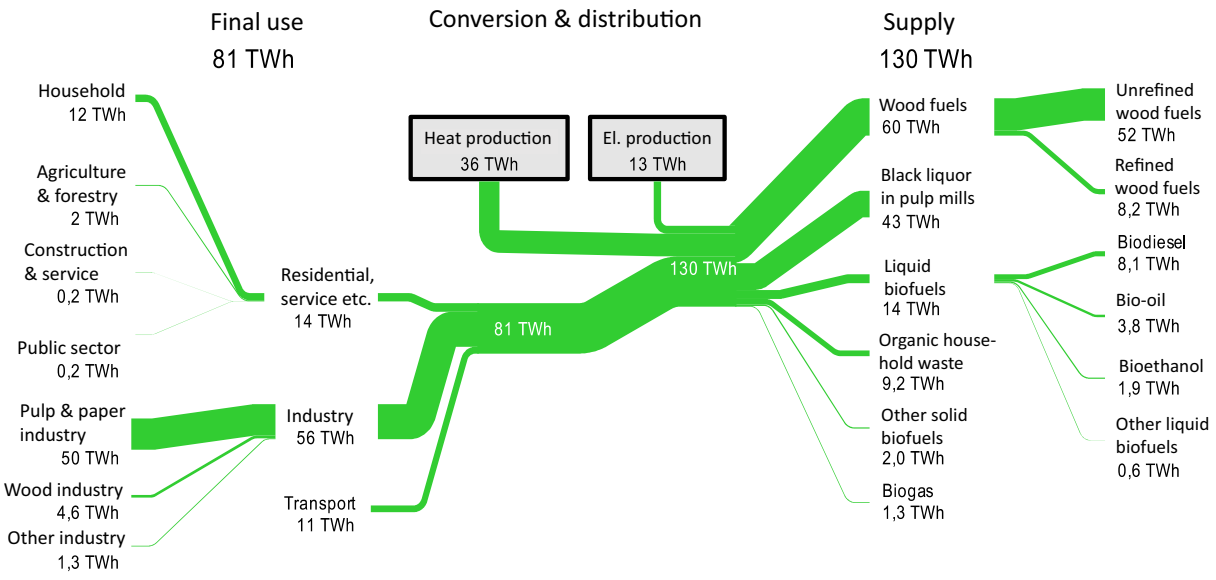

Fig. 1. Biomass-based energy in the Swedish energy system 2014 (Swedish Energy Agency, 2015a).