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Domestic heating from forest logging residues: environmental risks and benefits

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ABSTRACT

The European Union (EU) relies largely on bioenergy to achieve its climate and energy targets for 2020 and beyond. Special focus is placed on utilization of biomass residues, which are considered to cause low environmental impacts.

We used the dataset from the latest European Commission document on the sustainability of solid and gaseous biomass (SWD2014 259), complementing those results by: i) designing three pathways for domestic-heat production using forest logging residues, with different combustion technologies; ii) expanding the analysis to include forest carbon stock development with and without bioenergy; iii) using absolute climate metrics to assess the surface temperature response by the end of the century to a bioenergy and a reference fossil system; iv) including multiple climate forcers (well-mixed GHG, near term climate forcers and surface albedo change); iv) quantifying life cycle impacts on acidification, particulate matter emissions and photochemical ozone formation; v) reviewing potential risks for forest ecosystem degradation due to increased removal of residues.

Supply-chain GHG savings of the three pathways analysed ranged between 80% and 96% compared to a natural gas system, above the 70% threshold suggested by the EU. However, the climate impact of bioenergy should be assessed by considering also the non-bioenergy uses of the biomass and by including all climate forcers.

We calculate the Surface Temperature Response to bioenergy and fossil systems by means of Absolute Global surface Temperature Potential (AGTP) metric. Domestic heating from logging residues is generally beneficial to mitigate the surface temperature increase by 2100 compared to the use of natural gas and other fossil sources. As long as residues with a decay rate in the forest higher than $2.7\%*yr^{-1}$ are considered as feedstock, investing now in the mobilization of residues for heat production can reduce the temperature increase by 2100 compared to all the fossil sources analysed, both in case of bioenergy as a systemic change or in case of bioenergy as a transitory option.

Furthermore, several environmental risks are associated with the removal and use of forest logging residues for bioenergy. These issues concern mostly local air pollution, biodiversity loss and, mainly for stumps removal, physical damage to forest soils.

Forest logging residues are not free of environmental risks. Actions promoting their use should consider: (i) that climate change mitigation depends mainly on the decay rate of biomass under natural decomposition and time and rate of technology deployment, (ii) whether management guidelines aimed at protecting long-term forest productivity are in place and (iii) whether proper actions for the management of adverse effects on local air pollution are in place.

Abbreviations: AGTP, Absolute Global surface Temperature change Potential; AS, Advanced Stove; DH, District Heating; EC, European Commission; EU, European Union; GHG, Greenhouse Gases; GWP, Global Warming Potential; id, idem; (I)LUC, (Indirect) Land Use Change; LCA, Life Cycle Assessment; NMVOC, Non Methanic Volatile Organic Carbon; NG, Natural Gas; NTCF, Near-Term Climate Forcers; PS, Pellet Stove; STR, Surface Temperature Response; SM, Supplementary Material; SOC, Soil Organic Carbon; WMGHG, Well-Mixed Greenhouse Gases; JRC, Joint Research Centre.

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1. Introduction

The European Union (EU) promotes bioenergy as one of the main renewable, low-carbon sources to achieve its ambitious climate and energy targets for 2020 and beyond (EC, 2014a; EU, 2009a). Among bioenergy feedstocks, residues, including logging residues from forestry operations, are strongly supported under European legislation. Biofuels from residues are subject to multiple counting towards the renewable transport targets and are assigned zero greenhouse gas (GHG) emissions up to the point of collection (EU, 2009a). Furthermore, they are considered to cause low environmental impacts and very low Indirect Land Use Change (ILUC) emissions (EC, 2012).

Currently, no mandatory sustainability criteria at European level have been formulated for solid biomass used for power and heat production. However, the European Commission (EC) provided recommendations to Member States to develop criteria similar to the ones designed for liquid biofuels (EC, 2010). A recent document from the EC presented the state of play of bioenergy in the EU (EC, 2014b) and introduced updated typical and default GHG emissions values for a large selection of bioenergy pathways. A companion document (JRC, 2014) detailed the datasets and assumptions used to calculate those values.

The simplified life cycle methodology, applied in (EC, 2014b), accounts for the GHG emissions (CO_2, CH_4 and N_2O) related to the production of power or heat from biomass caused by: the combustion of fossil fuels, the combustion of biomass (only non-CO_2 GHG), cultivated soils, and direct Land Use Change (LUC). We define the system boundaries and the results obtained with this methodology as "supply chains" (Figs. 1 and 2). The EC methodology suggests that bioenergy should deliver GHG savings of at least 70% with respect to a defined fossil fuel system. The scope of such criterion is to compare the supply-chain GHG emissions of various bioenergy pathways on a common basis (GHG savings) to identify and exclude the pathways that perform worst on this relative scale.

Several Life Cycle Assessments (LCA) of wood pellets produced from various biomass feedstocks have generally reported high GHG savings when compared to an arbitrary reference fossil system (Caserini et al., 2010; Giuntoli et al., 2013; Magelli et al., 2009; Tsalidis et al., 2014).

However, many recent studies have demonstrated that the assumption of immediate carbon neutrality for forest biomass is not correct; the timing of carbon release and absorption as well as the inclusion of all the relevant carbon pools is essential to identify the climate performances of bioenergy (Agostini et al., 2013; Cowie et al., 2013; Helin et al., 2012; Matthews et al., 2014; McKechnie et al., 2011).

Other studies went beyond the carbon-only accounting to highlight that other climate forcers such as surface albedo change should be included in the analysis (Cherubini et al., 2012; Holtsmark, 2014). Further, it was pointed out that the quantification of the climate impact of bioenergy is also influenced by the specific climate metrics used (Cherubini et al., 2012). Cherubini et al. (2014) highlighted that biogenic-CO_2 may be assimilated to short-lived GHG and that its impact on peak temperature is determined by rates of emission rather than by cumulative emissions.

However, the way to account for the climate impact of bioenergy in policy is still debated in the scientific and policy community (Schulze et al., 2012; Bright et al., 2012; Haberl et al., 2013).

Finally, concerns over the impact of an increased removal of logging residues on forest ecosystems were raised and guidelines and mitigation measures have been proposed (IEA, 2014; Lamers et al., 2013; Fritsche et al., 2014; Sikkema et al., 2014).

We present a LCA that links together these various aspects of the environmental footprint of bioenergy in a case study related to domestic heating production from forest logging residues. The dataset presented in the JRC report (2014) is the starting point of our LCA but we complement those results by: i) defining three pathways with different end-use technologies; ii) expanding the system boundaries to include forest carbon stock development with and without removal of residues for bioenergy; iii) using instantaneous and cumulative absolute climate metrics (Absolute Global surface Temperature change Potential (AGTP)) to assess the response of the planet surface temperature to the production of heating by bioenergy and by the reference fossil system, evaluated at the year 2100; iv) including not only CO_2, CH_4, N_2O (Well Mixed GHG (WMGHG)) but also Near Term Climate Forcers (NTCF) and surface albedo change; v) quantifying life-cycle impacts on acidification, particulate matter emissions and photochemical ozone formation; vi) reviewing potential risks for forest ecosystems due to increased removal of residues.

We envision that this comprehensive assessment will help policymakers and local authorities to carry out their own assessment of possible risks and trade-offs when using logging residues for bioenergy, so that only the best pathways are promoted and the potential environmental risks are properly monitored and mitigated.

2. Materials and methods

2.1. Goal and scope definition

The LCA used is of the attributional comparative type, it analyses the environmental performance of three systems producing thermal energy for domestic use with forestry logging residues as biomass fuel. The term logging residues refers, in this context, to the crown mass (tops and branches with leaves, also called slash) and stumps (Helmisaari et al., 2014), produced as a result of commercial logging operations for the production of industrial wood (sawlogs and pulpwood). We did not include logs from any thinning operation.

We study three pathways: loose residues burned in a log-stove; a district heating plant utilizing forest chips and a domestic stove fuelled with wood pellets (see Fig. 1). The analysis is divided into two stages. In a first stage we focus on the supply chain impacts of the three bioenergy systems and we compare them to a fossil reference supply chain system using natural gas (NG) (Fig. 2). This approach is the one applied in European legislation for GHG emissions (e.g. typical and default GHG emissions values in EU (2009a)).

In the second stage we go beyond the EU methodology limitations and we expand the system boundaries to include the forest system. This approach reveals additional information on the land-use impacts of bioenergy as compared to the non-bioenergy system. We quantify the implications on the forest carbon balance and we review other possible risks and benefits posed to the ecosystem by an increased removal of logging residues.

The functional unit considered is 1 MJ of useful thermal energy; this includes losses due to start-up and shutdown, partial loads, thermal inertia and losses in the heat distribution system (Obernberger and Thek, 2010).

The environmental impact categories evaluated are: global warming, acidification, particulate matter and photochemical ozone formation. The physico-chemical properties of the wood are summarized in Table S1. We use the characterization models at midpoint recommended by the ILCD (2012) (Table S2). The characterization factors used are detailed in Tables S3–S4. The model used to calculate the response of global surface temperature to the