Journal of Cleaner Production 183 (2018) 772–785

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Methodological accounting tool for Climate and Energy Planning in a Norwegian municipality

Clara Valente [a,] [*], Ellen Soldal [a], Fredrik Moltu Johnsen [a], Felipe Verdú [b], Hanne Lerche Raadal [a], Ingunn Saur Modahl [a], Ole Jørgen Hanssen [a]

[a] *Ostfold Research, Stadion 4, 1671, Kråkerøy, Norway*
[b] *Geodata AS, Schweigaards gate 28, 0191, Oslo, Norway*

ARTICLE INFO

Article history:
Received 30 November 2016
Received in revised form
19 February 2018
Accepted 19 February 2018
Available online 21 February 2018

Keywords:
Local climate actions
GIS
LCA
Energy demand
Forest logging residues

ABSTRACT

The aim of this study was to propose a methodology to support the production of Climate and Energy Plans in Norwegian municipalities by analyzing whether locally available woody biomass, specifically forest logging residues, within the municipality (in this case, Fredrikstad), could cover the demand for heating in municipality buildings over the next 20 years. Three different tools, a geoprocessing tool for forestry (GEOSKOG), a methodology for environmental assessment (Life Cycle Assessment) and a tool for processing geographical data (Geographical Information System), were used in combination with energy data related to municipal buildings. The goal was to quantify the share of energy end-use (heat) that could potentially be replaced by bioenergy from forest logging residues and to calculate the potential GHG benefits from this substitution. The annual heating demand for municipal buildings in Fredrikstad currently heated by electric and oil boilers was 9.3 GWh. The potential annual GHG savings from the bioenergy substitution of fossil fuel (oil) boilers and electric boilers (Norwegian and Nordic electricity mix) equaled 292 tonnes CO_2-eq, 95 tonnes CO_2-eq and 535 tonnes CO_2-eq respectively.

1. Introduction

The world's cumulative energy use in buildings has increased due to population growth, improved building standards and comfort levels, together with an increase in the time spent inside buildings. At the same time, the demand for public services, like health, education, culture and leisure has risen, also affecting the energy use in public buildings (Pérez-Lombard et al., 2008).

In Norway, the stationary energy use per capita (i.e. energy use, including electricity, in the manufacturing, residential and service sectors) is quite high compared to the average for International Energy Agency (IEA) countries in Europe (Unander, 2004) (see research question number 2). Electric heaters are a very common heating source in Norwegian buildings and this separates Norway from the other Nordic countries (75% of the residential and 50% of public buildings use electricity as the main heating source, Scarlat et al., 2011). The building sector is interested in policies for implementing low-carbon energy solutions and increasing the renewable energy share based on bioenergy in general, and forest biomass in particular (Trømborg et al., 2008).

The European Union (EU) 2020 strategy aims to increase the share of renewable energy by 20% and at the same time reduce greenhouse gas (GHG) emissions by 20% compared with 1990 levels (EU, 2009). Non-member states, such as Norway, have also set national targets for 2020 (Pezdevšek Malovrh et al., 2016). Norway aims to increase the annual use of bioenergy by 14 TWh by the year 2020 (Anon., 2007). In order to achieve this target, it will be necessary to invest in district heating infrastructure and to implement measures for converting fossil fuel boilers into bio-boilers (see research question number 4). At the same time, the annual energy demand of the Norwegian service sector is projected to increase from 32 TWh to 49 TWh by 2050 (Rosenberg et al., 2013). Forest biomass is the main potential source for enlarging bioenergy production in Norway, where access to biomass from agricultural production and wet organic waste is relatively limited (Bergseng et al., 2013). Norway has >1.5 ha of forest available for logging per capita, compared with Europe (excluding Russia) which has approximately 0.25 ha per capita (Pöyry, 2014). The standing forest

---

[*] Corresponding author. Ostfold Research, Stadion 4, 1671, Kråkerøy, Norway
E-mail addresses: clara@ostfoldforskning.no (C. Valente), ellen@ostfoldforskning.no (E. Soldal), fredrik@ostfoldforskning.no (F.M. Johnsen), Felipe.Verdu@geodata.no (F. Verdú), hlr@ostfoldforskning.no (H.L. Raadal), ism@ostfoldforskning.no (I.S. Modahl), ojh@ostfoldforskning.no (O.J. Hanssen).

https://doi.org/10.1016/j.jclepro.2018.02.203
0959-6526/

stock in Norway is increasing, as the annual harvest has been lower than the annual increment for years (de Wit et al., 2006; Granhus, 2013). There is potential for increased forest biomass utilization (Trømborg et al., 2008), and forest logging residues in particular may be an interesting raw material for bioenergy production in regions with high levels of forestry activity. However, unlike neighboring Finland and Sweden which are pioneers in the field of using forest residues for energy production (Repo et al., 2011), the level of forest residue extraction is currently very low in Norway (Sjølie et al., 2016). Until 2013, Norwegian forest owners received subsidies for the harvest of forest logging residues. These authors explored the willingness of non-industrial private forest owners in Norway to supply logging residues for wood energy production and found that almost 60% of owners were positive towards this. This positive attitude of owners increased with forest area, education level and was greatest in regions with strong forest traditions. Bergseng et al. (2013) state that "due to market conditions, biomass for energy production is not likely to be a driving force initiating forest activities in Norway, i.e. increased use of bioenergy will mainly be based on "left overs" from conventional activities related to timber production, in particular logging residues". Intensified harvest of forest logging residues should be an important part of Norway's renewable energy strategy and the potential for utilization of forest logging residues for energy production is large (see research question number 1). In Norway, the greatest potential for forest logging residues comes from Norway spruce (Picea abies (L.) Karst) stands, as these constitute 64% of the annual cut volume (Hanssen et al., 2017). Forest logging residues from harvest operations include roots, stump, foliage, branch mass and unmerchantable tops (Dibdiakova et al., 2014), but in this study, we use the term forest logging residues specifically for branches and tree tops, which makes the removal of logging residues after clear-cutting a form of aboveground whole-tree harvesting (WTH). In conventional forestry, total residue removal is not recommended from a biological point of view (Hanssen et al., 2017).

Lately, the sustainability of bioenergy production from residues, including forest logging residues, has received more attention due to restrictions on the production of first generation biofuels in the RED-recast directive (European Commission, 2016), together with the increase in demand for biomass from forest residues that is expected to contribute strongly to power generation in coming years (Giuntoli et al., 2016). In the European Commission directive on solid fuels (European Commission, 2012), forest logging residues are considered to have particularly low environmental impacts, including very low indirect land use change (iLUC) emissions. For liquid biofuels, mandatory sustainability criteria have been developed, but no such criteria have been developed for the use of forest logging residues in solid fuel production.

The use of forest logging residues for heat production is not without environmental risks in relation to local air pollution from combustion, biodiversity loss in the absence of proper forest management and, especially in the case of stump removal, physical damage to forest soils (Giuntoli et al., 2015; Sala et al., 2016). Furthermore, although bioenergy has been named as one of the solutions for less climate-intensive energy systems, the climate neutral assumption of bioenergy has been questioned lately (Bowyer et al., 2012; Cherubini et al., 2012; Guest et al., 2013). Research has revealed that harvest of forest biomass can significantly change the surface reflectivity (albedo) and that emissions of biogenic CO_2 via combustion of biomass may contribute to atmospheric warming (Bonan, 2008; Bright et al., 2011; Cherubini et al., 2012). Zero net growth of the forest has been assumed in this study, and zero net CO_2 emissions related to forest dynamics, changed albedo effect and land use change have been modelled. In general, this means that the climate impact of bioenergy may be underrated (Cherubini et al., 2011). Despite this, the climate neutral principle has been used here because Norway is one of only a few countries in the world with a net growth of forests (Statistics Norway, 2013), and refraining from industrial use might in fact lead to increased GHG-emissions in the longer run. However, to illustrate the potential climate impact of bioenergy, a sensitivity analysis has been performed with a characterization factor for biogenic CO_2.

Geographical information systems (GIS) can be valuable for local authorities in the development of Climate and Energy Plans, because they make it easier to identify the spatial distribution of both supply and demand and so match resource availability (supply of forest logging residues) with energy requirements (heating demand in municipal buildings) (see research question number 3 and 5). Life Cycle Assessment (LCA) is widely used for assessing environmental impacts of products, but it can only represent regional impacts to a limited degree (Loiseau et al., 2013). However, the combination of environmental assessment methods such as LCA with GIS is promising for representing the spatial distribution of supply and demand in material and energy flows (Gasol et al., 2011). In the field of bioenergy, for example, there are several studies showing the potential of these integrated tools to be informative methodologies for defining strategies to reduce energy use and GHG emissions by biomass implementation (see for example Gasol et al., 2011; Jäppinen et al., 2013). Biomass availability, and in this case the availability of forest logging residues, is strictly dependent on geographical location, and consequently the profitability of the bioenergy facility depends on its location (see research question number 6) (Panichelli and Gnansounou, 2008; Pettersson et al., 2015; Mustapha et al., 2017). In addition, a variety of factors can affect the availability of this resource such as the intensity of harvesting, the type of forest management, the variation in biomass quality and the transportation distance from the supply, as well as policy and economic aspects of utilization (Cambero and Sowlati, 2014).

Integrated GIS and forest modelling can help to estimate the regional supply of forest biomass, including forest logging residues. Combined GIS and forest models could improve the supply management of forest biomass, even taking into consideration environmental and economic restrictions as described by Rørstad et al. (2010). Lately, the concepts of "regionalization of impacts", where the LCA methodology is used for environmental assessment of a territory in land use planning (Loiseau et al., 2013), and "regionalized LCA", where regionalized inventories are coupled with Life Cycle Impact Assessment methods, have become popular in the scientific community (Mutel al al. 2012; Rodriguez et al., 2014). More regional and local characterization factors have been developed for environmental impact categories, such as eutrophication and acidification (Potting and Hauschild, 2006), and for areas such as global land use impact assessment methodology (Koellner et al., 2013), where environmental impacts such as GHG, biodiversity and ecosystem services, are balanced.

In Norway, each municipality is obliged, through the Planning and Building Act (Norwegian Government, 2008), to prepare a Climate and Energy Plan as part of their efforts to reduce GHG emissions, increase the use of renewable energy resources, such as bioenergy, and increase energy efficiency (Norwegian Government, 2009; Hanssen and Rønning, 2012). Here, we focus on the Climate and Energy Plan for Fredrikstad municipality, in Østfold, south-east Norway. The south-eastern region of Norway is the most densely populated region in Norway, and the annual energy demand in residential and service buildings is expected to rise from 29 TWh in 2006 to 42 TWh by 2050 (Rosenberg et al., 2013). Østfold County has an ambition to reduce GHG emissions to 20% below the 2005 emissions level by 2020 and to be GHG neutral by 2030. Local