Journal of Cleaner Production xxx (2015) 1–8

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Assessing the energy production and GHG (greenhouse gas) emissions mitigation potential of biomass resources for Alberta

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ARTICLE INFO

Article history:
Received 6 April 2015
Received in revised form
28 August 2015
Accepted 30 August 2015
Available online xxx

Keywords:
Biomass
Energy
Environmental impact
Substitution
Resource potential
Sustainable development

ABSTRACT

The use of biomass for energy production fosters sustainable development by saving fossil-based energy and reducing greenhouse gas (GHG) emissions. Alberta's wealth of biomass resources is estimated at 458 PJ potential. However, biomass-based energy development has been slow, and its contribution for provincial energy supply has so far been low. Recognizing the role of biomass for sustainability, the use of potentially available resources should be supported by provincial policy makers. The energy substitution and emission mitigation potential by biomass for Alberta is not fully understood and accounted. In this paper, energy and emission analysis approach was applied to assess the biomass resources potential; and analyse the GHG mitigation and energy substitution potential of biomass in the context of Alberta's final energy demand on a near term planning range, i.e. 15 years. The results demonstrate that utilization of agricultural and forest biomass resources for energy production can avoid 11–15% of GHG emissions and also substitute 14–17% of final energy demand by 2030. In addition, biomass has the potential to substitute 29% of total electricity consumption or 28% of Alberta total internal load. Agriculture is a major source for biomass feedstock supply in Alberta. Policy makers should give due recognition to the potential of biomass-derived energy in developing energy strategies. Further quantification of the economic removal of biomass feedstocks for energy production is needed to facilitate biomass integration to the provincial energy system.

1. Introduction

Fossil fuels support many facets of Alberta's economy. Over 85% of Alberta's total primary and secondary energy use final demand is supplied by fossil fuels (Statistics Canada, 2013). The combustion of fossil fuels is the major sources of greenhouse gases (GHGs), which are behind the global challenge of climate change. Renewable energy resources such as biomass have the potential to reduce GHG emissions by replacing fossil supply. The combustion of biomass feedstock is considered as carbon neutral since the same amount of carbon dioxide is absorbed from the atmosphere during its growth. This is specifically true in a sustainably managed forest where biomass replenishes itself through re-growth. In this study, biomass resources include forest biomass, agricultural crops, and organic fractions of municipal solid wastes. If biomass is allocated sustainably for the production of energy, it has the potential to replace fossil fuels supply and mitigate GHG emissions (Kralovic and Mutysheva, 2006; Bradley, 2010).

Alberta is the fourth Canadian province with a large resource of biomass next to British Columbia, Quebec, and Ontario provinces (Alberta Innovates Bio-solutions, 2012). Alberta's total installed generating capacity was 14,598 MW of electricity in 2014. Over 80% of Alberta's electricity installed capacity comes from fossil fuels. Coal fired plants made up 43% and natural gas contributed 40% (Alberta Energy, 2014). The remaining 17% was from hydro, wind, biomass and others.

Biomass-based energy development in Alberta is slow and contributes less to the total provincial energy supply. Five plants in Alberta produce biodiesel from canola feedstock, but they are also equipped to process animal tallow into biodiesel. Alberta also has a long history of producing ethanol since 1998 in Red Deer. Four plants produce ethanol mainly from wheat feedstock and some municipal solid wastes. There has been recent development of electricity generation by wood facilities. Over ten facilities from Alberta's forestry sector convert the energy content in wood waste, kraftpulp, forest residue, and wood chips into electricity (Bradley, 2010). A few

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http://dx.doi.org/10.1016/j.jclepro.2015.08.118
0959-6526/© 2015 Published by Elsevier Ltd.

of these facilities are designed with a combined heat and power generation to maximize the energy harvest. Three of these industries generate electricity from different types of organic wastes and manure through anaerobic digestion (S&T Consultants Inc. and Cheminfo Services Inc., 2012; Bradley, 2006; GenSolutions, 2007).

Some studies have explored the substitution potential of biomass for energy supply and also reduction of GHG emissions (Wood and Layzell, 2003; James and Network, 2009; Kralovic and Mutysheva, 2006). Important agricultural feedstocks categories like agricultural lignocellulosic and grains were not considered in their estimations (Wood and Layzell, 2003; Kralovic and Mutysheva, 2006). The useful energy output of a fuel is dependent on the type of energy conversion technology. Comparing the magnitude of energy potential based on only the heat content (Wood and Layzell, 2003) oversimplifies the actual potential. Emission factors for fuel combustion are dependent primarily on fuel properties such as carbon content, density and heating value and on the combustion technology (Environment Canada, 2013). Previous studies estimated the environmental mitigation potential of biomass for Alberta either based on its carbon content (Wood and Layzell, 2003) or fuel combustion emission at plant (Kralovic and Mutysheva, 2006). Such preliminary estimates can be enhanced through conducting of a comprehensive assessment that covers the whole life cycle of energy production and conversion technologies. Although biomass resources potential can be assessed using area of harvest and carbon density methodologies (Wood and Layzell, 2003), it is not the best approach for the case of Alberta. This is because the size of area available for harvest in Alberta is far bigger than the area harvested per annum in actual circumstances. Moreover, there has been recent development in the area of biomass inventories that account for biomass wastes by Statistics Canada which used to be disregarded in the annual inventories (NR Canada, 2008; Statistics Canada, 2014). This improves the quality of data for resource potential analysis.

Alberta's sustainable energy development strategy has been largely focused on energy efficiency improvements, carbon capture and storage (CCS) technology developments, and wind power capacity improvements (Government of Alberta (2009)). As a consequence, renewable biomass resources development for energy applications has been slow. If biomass is to contribute to a larger extent to the province's energy supply, then substitution of primary fossil resources by renewable biomass alternatives has to be assessed in a comprehensive way by accounting all feedstocks categories and conversion technologies. Assessing the potential of biomass resources unlocks the information and environmental barriers for bioenergy development in Alberta.

This paper systemically analyses the significance of biomass resources for energy in Alberta through conducting of resource inventory, energy analysis, and environmental analysis. The main objectives of this study were to (i) assess the forest and agricultural biomass resources potential for Alberta, (ii) quantify the biomass-based energy potential for electricity, heat, and vehicle fuel, and (iii) analyse the GHG mitigation and energy substitution potential of biomass for Alberta's final energy demand in the near term planning range.

2. Materials and methods

This study aims at producing comprehensive information and knowledge about the biomass potential for energy applications and GHG mitigation in Alberta. Basic materials and procedures followed in this study are described as below.

2.1. Feedstock assortment

This study approached the research problem first by categorizing the biomass resources into three main feedstock assortments: forest, agricultural, and municipal solid waste (MSW) biomass feedstocks.

2.2. Data collection and handling

The magnitude of the biomass supply for each feedstock was collected from a wide range of sources including official public sector online sources, reports, and other literature. Thus, all data used in this study is secondary data. To improve the quality of data, the majority of information was collected from official federal and provincial online sources. Data and information about material and energy resource flows were collected online mainly from websites, including Statistics Canada, Natural Resources Canada (NRC), National Energy Board (NEB), Canadian Forestry Database, Alberta Energy, Government of Alberta, and Alberta Electricity System Operator (AESO). Data and information related to emissions and emission conversion factors were mainly from Alberta Environment and Environment Canada. The comparative advantage in this study was that information on some critical biomass resources, which had not been traditionally inventoried, are now publicly available. When data was missing for some aspects of the biomass resources, information was collected from reports or generated based on calculations derived from making reasonable assumptions. An inventory for biomass resources was compiled on a spreadsheet and finally summarized in a table using heating values. See also Supplementary material: A for information about the biomass resource assessment.

2.3. Energy balance

After summing the total amount of each feedstock, either in tonnes or bone dry tonnes (BDt) as appropriate, this mass was converted into energy content in unit of peta joule (PJ) per year using conversion factors (See Appendix A) for HHV values. Thus, the total amount of biomass potential that can be converted for energy purposes was estimated and quantified in energy units.

2.4. Energy analysis

We developed three scenarios for energy analysis, namely Reference scenario, Case 1, and Case 2. The reference energy scenario was formulated based on the business-as- usual *energy use final demand* for Alberta. Case 1 and Case 2 are biomass-based energy scenarios that were formulated to calculate the maximum amounts of heat, electricity, or vehicle fuel that could be produced from Alberta biomass resources. We compared these two biomass-based energy scenarios against the Reference scenario to analyze the bioenergy potential.

2.4.1. Reference (BAU) scenario

Current energy supply and demand characteristic for Alberta was considered as a reference scenario to determine the energy substitution and GHG mitigation potential for biomass. The latest detailed report for emissions and primary and secondary energy for Alberta is available for the year 2011 (See Supplementary material: B), which this study took as a base year for energy-use final demand analysis. Using the annual growth rate for the energy sector as estimated by National Energy Board (2013), we projected the final energy demand for the year 2030 (See Supplementary material: C). The calculated emission factor for base scenario is 120 gCO2,eq/MJ energy use (National Energy Board (NEB), 2013).

2.4.2. Case 1 and Case 2

These two biomass-based energy scenarios were formulated in such a way that one is less optimized for energy production than

Please cite this article in press as: Weldemichael, Y., Assefa, G., Assessing the energy production and GHG (greenhouse gas) emissions mitigation potential of biomass resources for Alberta, Journal of Cleaner Production (2015), http://dx.doi.org/10.1016/j.jclepro.2015.08.118