Applied Energy 112 (2013) 257–273

Contents lists available at SciVerse ScienceDirect

Applied Energy

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

# A systematic review of bioenergy life cycle assessments

Stefan Muench [a,b], Edeltraud Guenther [a,*]

[a] Chair of Environmental Management and Accounting, TU Dresden, 01062 Dresden
[b] Boysen-TUD-Graduiertenkolleg, TU Dresden, 01062 Dresden, Germany

## HIGHLIGHTS

- We conducted a systematic literature review of bioenergy LCAs.
- We provide a detailed overview of GWP, AP, and EP for biomass electricity and heat.
- We discuss methodological choices that can lead to variations in results.
- Relevant choices are functional unit, allocation method, system boundary, and carbon modelling.

## ARTICLE INFO

*Article history:*
Received 4 March 2013
Received in revised form 23 May 2013
Accepted 2 June 2013
Available online 6 July 2013

*Keywords:*
Biomass
Electricity
Heat
LCA
Sustainability

## ABSTRACT

On a global scale, bioenergy is highly relevant to renewable energy options. Unlike fossil fuels, bioenergy can be carbon neutral and plays an important role in the reduction of greenhouse gas emissions. Biomass electricity and heat contribute 90% of total final biomass energy consumption, and many reviews of biofuel Life Cycle Assessments (LCAs) have been published. However, only a small number of these reviews are concerned with electricity and heat generation from biomass, and these reviews focus on only a few impact categories. No review of biomass electricity and heat LCAs included a detailed quantitative assessment. The failure to consider heat generation, the insufficient consideration of impact categories, and the missing quantitative overview in bioenergy LCA reviews constitute research gaps. The primary goal of the present review was to give an overview of the environmental impact of biomass electricity and heat. A systematic review was chosen as the research method to achieve a comprehensive and minimally biased overview of biomass electricity and heat LCAs. We conducted a quantitative analysis of the environmental impact of biomass electricity and heat. There is a significant variability in results of biomass electricity and heat LCAs. Assumptions regarding the bioenergy system and methodological choices are likely reasons for extreme values. The secondary goal of this review is to discuss influencing methodological choices. No general consensus has been reached regarding the optimal functional unit, the ideal allocation of environmental impact between co-products, the definition of the system boundary, or how to model the carbon cycle of biomass. We concluded that a higher level of transparency and a harmonisation of the preparation of biomass electricity and heat LCAs are needed to improve the comparability of such evaluations.

© 2013 Elsevier Ltd. All rights reserved.

## Contents



* Corresponding author at: Chair of Environmental Management and Accounting, TU Dresden, Strehlener Strasse 24, 01062 Dresden, Germany. Tel.: +49 351 463 34313.

*E-mail addresses:* stefan.muench@tu-dresden.de (S. Muench), ema@mailbox.tu-dresden.de (E. Guenther).

0306-2619/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.apenergy.2013.06.001

## 1. Introduction

In recent years, the share of renewable energy in the total worldwide energy mix has been steadily increasing. A key advantage of bioenergy is its capability of providing base load energy without any supplementary energy storage facilities. Biomass energy plays a dominant role among the renewable energy options. China has introduced household biogas systems in rural areas as part of its efforts to implement renewable energy [1]. Other Asian countries are also trying to increase the share of renewable energy [2]. Bioenergy is a promising option because of the availability of biomass resources in this region [3,4] and the potential to provide a significant share of the energy consumption [5]. In the 27 countries of the European Union, the contribution of renewable energy to the gross final energy consumption rose significantly in the last years [6]. Energy policies to support bioenergy have been enforced [7] because bioenergy has many advantages over other energy sources, such as the support of regional economic structures [8]. In the United States, the pressure to decrease $CO_2$ emissions from energy generation is increasing [9]. The United States federal government has adopted the Energy Independence and Security Act to promote biofuel production [10]. The production of over 68 billion l of biofuel from agricultural residues is sustainably possible in the United States [11]. It has been predicted that biomass energy will contribute 60% of the total renewable energy to the global final energy consumption in 2020 [12].

Many reviews of bioenergy Life Cycle Assessments (LCAs) are already available, of which most are focused on liquid transportation biofuels. De Boer et al. provided an energetic assessment of microalgae to biodiesel pathways and concluded that thermochemical conversion is the only energetically feasible pathway [13]. Davis, Anderson-Teixeira and DeLucia reviewed GHG emissions and energy efficiency of biofuels and identified assumptions about terms, life-cycle inventory components, and system boundaries as major sources for variation [14]. Gnansounou et al. investigated the influence of modelling choices on energy and GHG balance and concluded that significant bias is inherent in such estimates [15]. Larson compared GHG balances of various biofuel options and found significant differences in GHG estimates due to differing input parameters [16]. Whitaker et al. investigated sources of variability in GHG and energy balances [17]. Yan and Crokes and Farrell et al. concluded that biofuel is significantly less petroleum intensive than fossil fuel [18,19]. The life cycle implications of various fuel types for transportation were reviewed by MacLean and Lave who came to the conclusion that none of the current light duty vehicle fuel/technology options outperforms in all attributes evaluated [20]. Majer et al. found that the inclusion of land use of biodiesel significantly affects GHG balances [21]. The impact of nitrous oxide on biofuel GHG balances was assessed by Mosier et al. who concluded that US biofuel production could lead to a net increase of global warming [22]. Varela et al. found that most biofuels have lower GHG emissions than fossil fuels [23]. Von Blottnitz and Curran and Williams et al. compiled biofuel LCAs and recommend to include a wider range of impact categories [24,25].

Despite the fact that biomass electricity and heat accounted for 90% of the total final biomass energy consumption in 2007 [12], only a few reviews have considered electricity or heat production from biomass. These reviews vary greatly in their scope and level of detail. Varun, Bhat and Prakash and Weisser analysed GHG emissions from several electricity generation technologies, including biomass electricity, in their reviews of energy technology LCAs [26,27]. Fthenakis and Kim compared land use impacts from various renewable electricity generation technologies [28]. A review by Evans, Strezov and Evans had a stronger focus on biomass power analysing GHG emissions, water use, and land use of biomass electricity LCAs [29]. Cherubini and Strømman reviewed various biomass energy chains including liquid fuels, electricity, and heat [30].

To the best of our knowledge, no review to date of electricity or heat production from biomass has included a detailed quantitative

Download English Version:

https://daneshyari.com/en/article/242900

Download Persian Version:

https://daneshyari.com/article/242900

Daneshyari.com