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Use of material flow accounting for assessment of energy savings: A case of biomass in Slovakia and the Czech Republic

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ABSTRACT

Anthropogenic material and energy flows are considered to be the major cause of many environmental problems humans face today. In order to measure material and energy flows, and to mitigate related problems, the technique of material flow and energy flow analysis has been conceived. The aim of this article is to use material and energy flow accounting approaches to quantify the amount of biomass that is available, but that so far has not been used for energy purposes in Slovakia and the Czech Republic and to calculate how much consumed fossil fuels and corresponding CO_2 emissions can be saved by utilising this biomass. Based on the findings presented, 3544 kt/yr of the total unused biomass in Slovakia could replace 53 PJ/yr of energy from fossil fuels and 6294 kt/yr of the total unused biomass in the Czech Republic could replace 91 PJ/yr of energy. Such replacement could contribute to a decrease in total CO_2 emissions by 9.2% in Slovakia and by 5.4% in the Czech Republic and thus contribute to an environmental improvement with respect to climate change.

1. Introduction

A socio-economic system and its natural surroundings are interconnected through material and energy flows. The consumption of materials from the environment is a necessary prerequisite for the production of goods and services and for maintaining and increasing standards of living. In keeping with the laws of thermodynamics, all consumed materials must be turned into waste and emission flows sooner or later and will be released back into the environment. For these reasons, anthropogenic material and energy flows are considered to be the major causes of many environmental problems humans face today (e.g., Fischer-Kowalski and Haberl, 1993; Weizsäcker and Lovins, 1997; van der Voet et al., 2004). These problems include landscape changes, loss of biodiversity, acidification, eutrophication, global climate change and others. Material flow and energy flow analysis has been conceived to measure material and energy flows and to mitigate the related problems. The aim of these approaches is to monitor material and energy flows at various levels and to provide indicators that could contribute to resource management and output emission flows (OECD, 2008).

One of the goals of the material and energy flow indicators is to quantify the total amount of energy needed for the functioning of the human societies. This can be expressed either in mass or energy units and can be further subdivided into fossil fuels and renewable energy sources such as biomass and wind, water or solar energy.

The aim of this article is to quantify the amount of available biomass that has not been used so far for energy purposes in Slovakia and the Czech Republic. A second aim is to assess what portion of the currently consumed fossil fuels and corresponding CO_2 emissions can be saved by utilising this biomass.

To reach the aim, we used approaches of the economy-wide material flow analysis (EW MFA). There are several reasons for using this approach. EW MFA is a method that recognises the increasing importance of environmental issues, material availability and efficiency and the difficulty of adequate management. Contrary to traditional system, EW MFA allows for a comprehensive view into the national economy including relationships between isolated systems or sectors (e.g., the agriculture and energy sectors). EW MFA is an asset for national planning, especially for natural resources, and allows for forecasting of future scenarios. It also allows for assessment of environmental problems caused by the economic activities of a nation and for determining how materially intensive is an economy. In addition, EW MFA mainly uses available statistical data. Eurostat has started to collect necessary data for EW MFA in all EU countries. The existing database is a great advantage because it allows for many calculations (e.g., unused biomass amounts) without additional expenses and data collection. Material flow accounting will be included in

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the regular EU environmental statistics. A proposal is under preparation for regulation by the European Parliament and the Council on European Environmental Economic Accounts. Thus, this common database and methodology will lead to representative and comparable results around the EU and possibly abroad.

The rest of the article is organised as follows: Section 2 describes aims and targets in climate-energy policy. Section 3 describes the methodology (based on EW MFA) that was used for quantification of the excess existing biomass, and the approach by which biomass flows were converted from mass into energy units. Section 4 presents results and Section 5 discusses the results of our calculations and evaluates whether the spare biomass can be a substitute for a significant share of fossil-fuel consumption. The article is concluded in Section 6.

2. Climate-energy policy

The replacement of fossil fuels with renewable energy sources is acknowledged to be beneficial from both environmental and economic points of view and with respect to global climate change. Global climate change is an on-going process that is driven by (among other factors) the CO_2 emissions resulting from the combustion of fossil fuels (IPCC, 2007). The point of departure for a European energy policy is threefold: combating climate change, limiting the EU's external vulnerability to providers of imported fossil energy, and promoting growth and jobs, thereby providing secure and affordable energy to consumers (EC, 2007a). The control of European energy consumption and the increased use of energy from renewable sources, together with energy savings and increased energy efficiency, constitute important components of the package of measures needed to reduce greenhouse gas emissions. Such reduction is necessary to comply with the Kyoto Protocol of the United Nations Framework Convention on Climate Change and with further community and international greenhouse gas emission reduction commitments beyond 2012. Increasing biomass energetic utilisation can be one of the tools for restructuring the energy system of the EU to a low-carbon model; this is one of the critical challenges of the 21st century (EC, 2007b).

In March 2007, EU leaders endorsed an integrated approach to climate and energy policy that aims to combat global climate change and to increase the EU's energy security, while at the same time strengthening its competitiveness. They committed to the concept of Europe transforming itself into a highly energy-efficient, low-carbon economy. The EU Heads of State and Government set a series of demanding climate and energy targets to be met by 2020, known as the "20-20-20" targets. These are:

- A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels.
- Fully 20% of EU energy consumption is to come from renewable resources.
- A 20% reduction in primary energy use compared with projected levels is to be achieved by improving energy efficiency.

The integrated climate-energy package presented by the European Commission in January 2008 is a basic, comprehensive and very ambitious approach to reducing greenhouse gasses emissions, increasing energy efficiency, reducing the consumption of fossil fuels and supporting innovative, low-carbon technologies. The package includes the directives:

1. Directive 2009/28/EC (2009a) establishes a common framework for the production and promotion of energy from renewable sources.
2. Directive 2009/29/EC (2009b) aims to introduce significant reductions in greenhouse gas emissions with a view to reducing the influence of such emissions on the climate. The Directive set out national overall targets for the share of energy from renewable sources in gross final consumption of energy in 2020 (14% for Slovakia and 13% for the Czech Republic).
3. Directive 2009/31/EC (2009c) establishes a legal framework for the environmentally safe geological storage of carbon dioxide (CO_2) to contribute to the fight against climate change.

In 2010, the German Advisory Council on Global Change (WBGU, 2010) recommended that the multilateral climate process be revitalised. According to WBGU, the EU should develop its 20-20-20 Agenda into a 30-20-20 Agenda by committing to reduce greenhouse gas emissions by 30% by 2020. The provision for 100% energy from renewable sources for Europe by the year 2050, combined with a pro-active energy efficiency strategy, could give international climate policy fresh momentum and at the same time put Europe's competitiveness on a sustainable footing.

3. Methods and data

There are various approaches and methods for the energy potential from biomass and efforts also exist to harmonise biomass resource assessment. The tendency is to combine Earth observation-derived data (e.g., Tomppo et al., 2008; Chen et al., 2009) with in-situ measurements based on common agricultural and forestry survey practices. As our aim was to quantify the biomass available for energy for entire countries, without changes in land use and land cover, we used economy-wide material flow analysis and economy-wide energy flow analysis. While the former quantifies material flows in mass units (kilotonnes), the latter transforms the material flows into energy units (Joules) by one specific method: calculating the total theoretical heat that can be produced in combustion, i.e., the gross calorific value of materials (EUROSTAT, 2001; Haberl, 2001a, 2001b). Our goal was to study the amount of energy that can be retrieved from available biomass using thermal conversion. Since thermal conversion usually expresses biomass input in mass units, we used economy-wide material flow analysis as the basis for our calculations.

3.1. Economy-wide material flow analysis

As a follow-up to pilot studies such as Steurer (1992), Adriaanse et al. (1997) and Matthews et al. (2000), EW MFA became the first standardised analysis in the Eurostat methodological guide (EUROSTAT, 2001). Further standardisation was achieved through the Eurostat compilation guide (Weisz et al., 2007) and within the OECD work programme (which operated during 2004–2008) on material flows. Standardisation was finalised with the OECD guide to material flows and resource productivity (OECD, 2008). The aim of EW MFA is to quantify the physical exchange between a national economy, the environment and foreign economies based on the total material mass flowing across the boundaries of the national economy. The ultimate goal of the analysis is to obtain a material balance (Schandl et al., 1999).

The most commonly used indicators that are based on EW MFA are the following: (1) used domestic extraction (DE), which includes all domestically extracted raw materials (such as fossil fuels, metal ores, non-metallic minerals and harvested biomass); (2) imports and exports (IM, EX), which include imports and