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Research paper

Analyzing the potential of domestic biomass resources for the energy transition in Switzerland

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ABSTRACT

Biomass resource assessment constitutes the foundation for integrated bioenergy planning in order to evaluate the sustainable feasibility and to estimate the additional bioenergy potential. Its spatial distribution is an essential criterion to facilitate the exploitation of the untapped bioenergy potential by guiding industry and decision-making processes.

This paper provides regionalized and aggregated estimates of the potentially available resources for bioenergy in Switzerland (10 woody and non-woody biomass types). First, considering the different biomass characteristics and available data, appropriate methods at the finest scale possible were elaborated to estimate the annual domestic biomass amount which could theoretically be collected. Then, explicit and rationale restrictions for sustainable bio-energy production were defined according to the current state of the art. Finally, the additional potential was estimated considering the current bioenergy production. The procedures developed can be transferred to other countries and spatial scales according to the local situation and available data.

The Swiss biomass theoretical primary energy potential was estimated at 209 PJ per year, with the major contributions from forest wood (108 PJ per year) and animal manure (49 PJ per year). Almost half of the theoretical potential can be used for bioenergy in a sustainable way (26 PJ from forest wood and 27 PJ from animal manure yearly). The main restrictions are competing material utilizations, environmental factors, supply costs, as well as scattered distribution and small scale feasibility.

1. Introduction

Sustainable bioenergy can play a decisive role in the transition to a renewable energy system with possible applications in electricity, heat, fuels, and compensation of fluctuant renewable energy sources [1]. Also, the efficient use of locally available biomass resources can strengthen regional and national added values [2–4]. Switzerland has set itself the ambitious target to optimize both material and energy use of domestic biomass resources [5–7]. Similar targets have been set at the European level [2,8].

Previous studies have provided valuable steps towards quantifying the overall national biomass potential on an aggregated level in many countries using various approaches: literature review and projections [9–12], bottom-up calculations on specific biomass e.g. Refs. [13,14]. For Switzerland [15,16], such studies revealed a substantial potentiality from woody biomass, animal manure and waste biomass at national scale. However, these were literature reviews which gathered information from different studies performed at different times with different methods, making comparisons between biomass types difficult. An homogenous approach enables more accurate and comparable results. Moreover, they did not investigate the respective spatial distribution and local biomass supply security which are known to be critical issues for investors in bioenergy facilities [17]. A spatial inventory assessment is required at different geographical scales to i) allow the in-depth availability and sustainability estimation, ii) facilitate the exploitation of untapped bioenergy potentials by guiding industry and policy development strategies [18]. Although a European project has tackled these issues [19], the spatial assessment is missing for Switzerland and also for many other countries, where analyses have been made only aggregated at the national level. The absence of analysis is due to the difficulty to gather data at the regional or lower scales and the lack of methods to use the available data in a meaningful way.

With these premises, the objective here is to demonstrate a method to assess the regionalized potential of biomass for energy in Switzerland with a bottom-up approach using data at the finest available scale. This bridges the gap between previous national aggregated assessments and specific business cases, which is needed to promote biomass uses. The developed procedures can then be transferred to other countries and

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spatial scales according to local situations.

2. Methodology

Exploring the potential of available biomass resources provides the foundation for technology development and integrated bioenergy planning at different local, national and global level. Many approaches are possible depending on data availability and biomass type, such as surveys [20], calculations based on land cover and characteristics [21], calculations based on available national databases [13,14,22] and expert literature studies [16]. In this paper, bottom-up approaches are provided to assess the domestic biomass potentially available for energy production in Switzerland at different spatial scales. Primary energy content was used as it is calculable for all biomass resources and independent from the various processes that are or may be used for conversion into electricity, heat or fuel. The primary energy is the energy physically contained within the resource and means energy which has not undergone any conversion process. Explicit assumptions and the underlying rationale for restrictions were defined to estimate the part of the biomass which is currently usable in a sustainable way. Considering these constraints allow the planning of an energy system in the long term with regards to supply security, sustainability and efficiency. The assessment was done for each of the following biomass types (see more detailed description further below and as overview table in the supplementary material):

- Non-woody biomass: animal manure, agricultural crop by-products, sewage sludge, organic fraction of household garbage, green waste from households and landscape, commercial & industrial organic waste.
- Woody biomass: forest wood, wood from landscape maintenance, wood residues, waste wood.

These 10 types of biomass were chosen following a survey of the available literature [15,16] and discussion with experts to ensure that all significant resources have been estimated here. Due to land limitations and population pressure, the agricultural land use for food and feed production has been given first priority by the national biomass-energy strategy to avoid displacement effects [10]. Therefore the option of domestic production of dedicated energy crops and energy wood plantations were not considered in this study similarly to Panos et al. [18]. The emphasis for sustainable bioenergy is therefore placed on the potential of otherwise available biomass resources as e.g. wastes, animal manure and wood.

The potential assessment is based on the following analytical levels, following the approach of Steubing et al. [16]:

- Theoretical potential (=upper limit): maximum annual biophysical availability of the biomass.
- Sustainable potential: subtraction of environmental, technical, economic and social restrictions from the theoretical potential to mobilize the resources. Our assessment of the sustainable biomass potential was therefore guided by the following criteria regarding the resources mobilization: technico-economic viability, environmental impacts, as well as social and legal constraints. In line with this, we adhered to general environmental principles such as the strategy of biomass cascading use (preferring material over energetic use) and the waste hierarchy (prevention, recycling, energy recovery, and disposal). Assumptions and constraints vary for each biomass type and are detailed in the following chapters.
- Already used potential: amount of biomass already used for energy production.
- Additional potential: difference between sustainable and already used potential.

Firstly the resource amount is estimated according to the typical units used for that biomass type, and this is then converted to dry mass and to organic dry mass. Finally, the primary energy content of the resources is calculated based on dry mass and lower heating value. International average characteristics values are being used, which are comparable to the Swiss case.

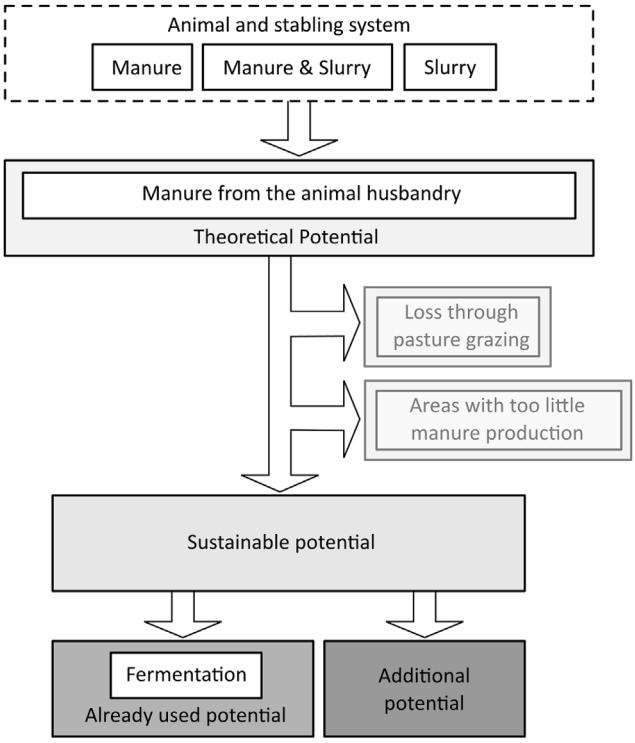

Fig. 1. Potentials assessment: procedure for animal manure.

This study uses spatial analysis techniques to map each biomass type according to the original primary data source which then allow scaling-up at national or regional level. For each biomass type, a spatial estimate for the amounts potentially available is made at the finest spatial resolution possible, using the methods described below. A detailed description can be found in an extensive technical report from the Swiss Forest, Landscape and Snow Federal Research Institute WSL [23] and as DOI data set (http://doi.org/10.16904/18). The procedures for the main biomass types are described below. The most important are illustrated here (Fig. 1–3.) and the other ones as online supplementary material.

2.1. Animal manure

Animal manure refers to all dejections (both liquid and solid forms) from livestock farming. Farm animal excrements and urines form the basic components of this biomass category. Depending on the stable system, they are produced without any additional material (except eventually water) – liquid manure – or they are mixed with bedding material – solid manure.

A bottom up approach at farm level is adopted, based on yearly state surveys of animal count, species and stable system [24,25]. These proprieties affect both generated and usable amounts as well as material characteristics (e.g. whether liquid or solid manure is produced). The following livestock is considered: cattle, pigs, horses, sheep, goats, and poultry. If specified, the animals are classified into appropriate subcategories according to use and age (e.g. cattle: dairy, suckler, calves, other cattle). Other animals (bison, rabbits, camelids …) are neglected due to their low numbers in Switzerland. Reference values to calculate the amount of liquid and/or solid manure generated per animal depending on species, categories and stable system are provided in