Technological Forecasting & Social Change xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage:

Biorefineries' impacts on the Austrian forest sector: A system dynamics approach

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ARTICLE INFO

Article history:
Received 5 December 2013
Received in revised form 31 March 2014
Accepted 2 April 2014
Available online xxxx

Keywords:
Biorefinery
Impact assessment
Forest-based sector
System dynamics model
Wood

ABSTRACT

This paper considers preceding technical research on wood-biorefineries when assessing the potential socio-economic impacts caused by a practical implementation of the developed technologies and products. Four different scenarios were simulated by using a system dynamics-model called FOHOW covering the entire forest based sector in Austria. At first a base scenario (business as usual) was calculated and then three different biorefinery-scenarios were assessed.

By boosting the gross production value the biorefinery-technologies are capable of securing the competitiveness of the European pulp and paper industry. Sawmills profit from biorefineries as they are able to increase their returns from selling sawmill residues, which is securing their entire competitiveness, at the same time sawnwood prices can be held stable or even a little lower. The use of wood for energy would not be negatively impacted by biorefineries in the scenarios, but the average cost of wood for energy can even decrease. Introducing biorefineries may have positive effects on employment, as there are new jobs established, current jobs in pulp, paper and sawmilling business are secured and new jobs in the downstream processing of the biorefinery products are created.

1. Introduction

"A biorefinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, heat, and value-added chemicals from biomass". This definition stems from the National Renewable Energy Laboratory [51] which has identified biorefining to be the most promising route towards creation of a sustainable energy portfolio. Hence, the biorefinery concept is analogous to today's petroleum refinery, which produces multiple fuels and other products from petroleum. Lately the number of scientific papers and patents concerning biorefining increased from less than 5 in 2001 to over 160 in 2008 [97] to over 400 in 2012. Ragauskas et al. [59] outlined their ideas of a research road map for the biorefinery of the 21st century and found that commercialization and policy support of current technologies are required to let the industry grow. Keijsers et al. [37] stated the importance that industries aiming at utilising renewable raw materials are aware of the price and performance value and volumes available. They conclude that such information can speed up new developments and that a suitable match of raw materials with the right industry and application will lead to improvement in the overall sustainability. Chambost and Stuart [10] describe the basis for a systematic product design methodology for Rapid Market Analysis, suitable for evaluating the economic and commercial potential of a biorefinery project,

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http://dx.doi.org/10.1016/j.techfore.2014.04.001

using a set of business tools that includes market and synergy identification. Söderholm and Lundmark [77] investigated the implications of forest biorefineries for market behaviour and policy. They concluded that the advent of new uses of forest-based bio-mass will foster an increased competition for (and thus higher price of) this resource. According to them [77] policy should not directly regulate the allocation of forest resources between different sectors or promote a certain industrial structure. The rationale for policy intervention has been found to lie instead in identifying situations in which essential societal costs and benefits do not enter the private decision-making process. Therefore a need exists to create a better understanding of the linkage between energy and forest products markets, including new co- and by-products. In addition to the issues of commercialisation and policy support the biorefinery concept has also triggered discussions on renewable raw material availability, demand and supply (e.g. [62,90]), energy production and consumption (e.g. [43]), sustainability and greenhouse gas emissions (e.g. [2]). The so called wood- [32] or forest-based biorefinery [91] is one of the basic biorefinery concepts which frequently bases on existing pulp and paper processes ([10,59]). Therefore these forest-based biorefineries seem to be implementable in the mid-term but still need support from the macro-scale environment, particularly from governments, but also the involved industries themselves need to be active [45,52]. Europe traditionally has had a very strong pulp and paper industry. In 2011 it accounted for 27% of the global paper and paperboard production [23]. However, currently the European pulp and paper industry is facing economic challenges which have resulted in shutdowns of mills in e.g. Finland or Norway. The European forest-based industry has to compete with Asia and South America where raw material is cheaper. This is assumed to be the reason for its decreased share in global paper and paperboard production since 2001 (31%).

Therefore the forest-based industry has to seek for a more efficient exploitation of raw materials, new products or even alternative product concepts.

Martino [42] discussed the methodological development in technological forecasting including models and scenarios. Mishra et al. [47] argue that the selection of methods used in technological forecasting needs to be time-, space- and technology-specific. Providing a systematic overview of the methods and tools that has been cited in technology assessment, Tran and Daim [87] mentioned the application of system dynamics models. System dynamics technique has been applied for example to forecast multilevel technological substitution and for incorporating various forms of time dependent parameters in the existing trend extrapolation models [73]. Lately, system dynamics models have been used for example to assess the impact of green economy policies on the Republic of South Africa [50]. An analysis of the forest sector in terms of long-term socio-economic and environmental development under climate stabilization has been presented by Riahi et al. [60]. According to Hurmekoski and Hetemäki [34] the global forest sector faces major structural changes with its operating environment becoming more complex and interlinked with other sectors. Analysing existing forest sector outlook approaches they conclude that those have not been able to sufficiently capture the structural changes (e.g. global paper markets). The renewable energy production in the US was subject to a forecast [14] based upon a literature review and secondary data applying the Pearl growth curve. Näyhä and Pesonen [52,53] started to assess the diffusion of forest biorefineries based on Delphi studies. In contrast to earlier studies this paper will focus on a possible structural change – the implementation of biorefineries – and their potential quantitative impact on the traditional forest sector. This study provides value in providing an assessment for the expected impacts generated by the implementation of biorefineries to the forest based sector by applying a sector specific system dynamics model.

2. Objective

This study aims at assessing the potential socio-economic impacts in terms of international competitiveness, resource efficiency, forest products prices, employment and value added as regards to the forest based sector in Austria caused by the factual implementation of currently developed biorefinery technologies and products.

In order to achieve this goal, promising technologies and concepts developed have been reviewed and chosen as base to derive detailed biorefinery scenarios from projections by a system dynamics (SD) model called FOHOW. FOHOW has the ability to address the potential impacts of biorefineries because it covers the entire forest-based sector, including the use of wood for energy. The resulting new products from forest biorefineries will definitely influence the patterns of wood flows e.g. because of price changes between the various applications/products, including energy use.

3. Methods and materials

3.1. The FOHOW model

In the simulation model FOHOW, the Austrian forest-based sector is modelled as a whole (system), from forest growth to the use of paper (Fig. 1). The simulation model is based on the general market equilibrium theory of demand and supply. Unlike optimisation models such as the GFPM (see [88]), which calculate price and quantity simultaneously (usually by maximising producer and consumer surplus), the used SD simulation does not allow simultaneous equations. Therefore the balance between supply, demand and price cannot be solved simultaneously, but the calculated prices and the quantities oscillate within a certain magnitude around the equilibrium, the scope being determined by the slopes and shifts of the demand and supply curves.[1]

The FOHOW model has already been used to address various forest-based sector-related topics [65,68–70]. It does not intend to deliver exact forecasts but tries to analyse longer-term effects of events ("what-if" questions). Here, the "what-if" questions are related to the impacts of the implementation of biorefinery technology and products.

The current version of FOHOW consists of approx. 1500 equations, of which about 250 are levels, 250 rates, 400 auxiliaries and the rest table functions and constants (cp.

[1] The model's algorithm for calculating the convergence towards market equilibrium is described in detail in Schwarzbauer and Rametsteiner [70].

Please cite this article as: T. Stern, et al., Biorefineries' impacts on the Austrian forest sector: A system dynamics approach, Technol. Forecast. Soc. Change (2014), http://dx.doi.org/10.1016/j.techfore.2014.04.001