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A world model of the pulp and paper industry: Demand, energy consumption and emission scenarios to 2030☆

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ABSTRACT

This article introduces a bottom-up global model of the pulp and paper sector (PULPSIM) with a focus on energy consumption and carbon emissions. It is an annual recursive simulation behavioural model with a 2030 time horizon incorporating several technological details of the industry for 47 world regions. The long time horizon and the modular structure allow the model users to assess the effects of different environmental, energy and climate policies in a scenario comparison setup. In addition to the business as usual developments of the sector, a climate commitment scenario has been analysed, in which the impacts of changing forest management practices are also included. The climate scenario results reveal that there is a significant carbon reduction potential in the pulp and paper making, showing a number of specific features: the central role of the fibrous resource inputs and the potential impact of increased waste wood and black liquor based heat generation.

1. Introduction

Global climate change issues are high on the agenda for both the scientific community and policy makers. According to the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC), significant reduction effort in greenhouse gas (GHG) emissions is needed in order to limit long term global temperature increase. Although most of this temperature rise would take place in the second half of the century, actions should be taken in the near future in order to adopt the necessary steps for the massive infrastructure change required, and to give the right signals to the sectors responsible for most of the anthropogenic GHG emissions.

The pulp and paper sector faces a threefold challenge from the climate change perspective. On the one hand, it is a very energy-intensive sector. Producing 1 tonne of paper requires 5–17 GJ of process heat, depending on the paper type and on the technology applied. Therefore the energy content of the different paper grades is comparable to that of other energy intensive products, such as cement or steel. On the other hand, the most important natural resource for paper-making is biomass, mainly wood and other fibre resources, the use of which is by internationally accepted definitions assumed to be CO_2 neutral. An additional factor – which makes the modelling of the sector even more complex – is that self-generated electricity and heat play an important role in the energy balance of the sector. These three aspects make the sector unique from an energy modelling and climate change perspective, and put it in the focus of attention of the climate research.

According to its relative importance, numerous attempts have been made in the literature to model the pulp and paper market at the global scale and with an outlook to its long term energy consumption and GHG emissions. These global forest sector models are the Global Forest Products Model (see Tomberline et al., 1998) of FAO, the Global Forest Sector Model

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of the European Forest Institute (EFI-GTM) (Kallio et al., 2004), and the World Forest Products Model (WFPM) of JIRACS (2003). While the first two models are based on mathematical programming, the last uses a simulation approach. The EFI-GTM model mainly focuses on the forest industry (Kallio et al., 1987), and is based on the model developed in the IIASA during the late 1980s.

Numerous references in the literature model certain segments of the markets, focusing either on an individual country or on certain characteristics of the sector. Thus national or regional models exist for various countries. The most recent one has been developed for the USA (Ruth et al., 2000; Davidsdottir and Ruth, 2004) and is based on an econometric analysis. It specifies a dynamic model for the paper sector, analysing the impacts of different climate policies (carbon taxation and investment-led policies). Another regional model is NAPAP partial equilibrium economic model of the North American region developed by the USDA Forest Product Laboratory (see e.g. Ince, 1998), that gives long term outlook (till 2050) for the sector based on a price-endogenous linear programming system. Möllersten and Westermark (2003) investigate the CO_2 reduction potential for the Swedish paper industry, based on different carbon emission reducing measures. Farahani et al. (2004) present an article dealing with the techno-economic potential of a new technology – the black liquor gasification-combined cycle (BLG/BLGCC) – on the pulp and paper sector in the US and Sweden. According to their findings, the excess electricity that this new technology can produce may lead to a significant reduction of CO_2 emissions in the sector. Technologically detailed analysis on black liquor gasification can be found in an article by Eriksson and Harvey (2004), in which the performance of the BLG technology is compared in different mill powerhouse configurations.

Another interesting series of publications are activity-based analyses. Farla et al. (1997) make a cross-country, cross-time comparison of energy efficiency developments in the pulp and paper sector in eight OECD countries. They find that energy efficiency improvements played a key role in limiting energy consumption during the 1973–1991 period. The articles of Brännlund et al. (1998) and Bruvoll et al. (2003) implement a nonparametric frontier method (DEA—data envelopment analysis) that allows to measure the effects of environmental regulations on the performance of the individual firms in two Scandinavian countries.

The main purpose of this article is to present a global paper and pulp model (PULPSIM) that attempts to capture both the technological aspects and the market developments of the sector.[1] The overall objective of constructing this model is to synchronize the technological details with an appropriate economic framework on a global level. In particular, in order to analyse specific policies, e.g. in the context of climate change policies, more attention is paid to the detailed modelling of the energy consumption and the GHG emission of the sector.

Therefore in order to overcome some of these boundaries, the specification of the PULPSIM model incorporates the most important market interactions, both on the demand and the supply sides, including the trade issues. Demand for the final paper grades are derived through the 'intensity of use hypothesis' (see e.g. Van Vuuren et al., 1999), according to which the per capita income determines the commodity intensity of the different regions. This dynamic evolution of commodity intensity is essential in long term models, as the relationship between income and consumption is not determined by a single elasticity, but it is redefined over the full time horizon. This provides with a more sensible picture of the commodity demand and, moreover, it allows reflecting the substitution away from the commodity, as the use of alternative materials could take a higher share over a long time scale.

The next element incorporated in the PULSPSIM model is international trade, based on product separation within paper grades. The imported and domestically produced products are differentiated and their demand shares reflect these price differentials. Not only the final products and the forest resources are traded in the model, but many of the intermediate goods, such as sawmill products and chemical pulps as well. Importing and exporting regions are also distinguished according to the past developments of the markets.[2] This approach has its own limitations, mainly that if a region is classified as an importer, it will stay in this group in the whole period. Another method widely used in empirical trade modelling is the product differentiation by origin approach with a constant elasticity of substitution (CES) function, however it still does not solve the small share problem: those countries, which have small shares of imports will continue to have small shares in the future, as it is difficult to drive them out from the CES function corner solution. In order to model the major world trade flows, four regional markets (Africa and Middle East, America, Asia, Europe) were set up. World market prices include distance dependent transport costs, as this cost element could play an important role in some product and market segments. The global trade market is cleared through the allocation of import demand to exporters (see Section 3 for details). These allocation procedures are constructed to check that capacities and the needed resources are available.

The mentioned market modules introduce the economic rationale in the model in a long time scale, with an attempt to provide with a reasonable ground for assessing different policy options or scenarios with long term impacts, such as the carbon constrained future scenarios analysed in this article. It has to be noted however that our approach is still not accounting for the paper-containing products export and import, so it is most probably underestimating the importance of the trade effects in the continuously growing international trade market of the paper products.

This article is structured in five sections. The next section discusses the main features of the pulp and paper sector at the global scale. Section 3 describes the PULPSIM model. In Section 4 the most important features of the reference scenario are introduced concerning the future development of the pulp and

[1] The PULPSIM model has been written in VENSIM 5.4 software. It operates on a year to year recursive simulation basis, running up to the year 2030.

[2] Individual countries, however, could be exporter in one product and importer in another grade according to their past records.