



Comparative environmental assessment of wood transport models A case study of a Swedish pulp mill

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ABSTRACT

Wood transportation from forest landing to forest-based industries uses large amounts of energy. In the case of Sweden, where forest operations are highly and efficiently mechanized, this stage consumes more fossil fuels than other elements of the wood supply chain (such as silviculture and logging operations). This paper intends to compare the environmental burdens associated to different wood transport models considering a Swedish pulp mill as a case study by using Life Cycle Assessment (LCA) as an analytical tool.

Five scenarios (the current one and four alternative reliable scenarios) were proposed and analysed taking into account two variables. On the one hand, the influence of imported pulpwood share from Baltic countries and on the other hand, the use of rail transportation for wood transport. In particular, the following impact categories were assessed: Eutrophication, Global Warming, Photochemical Oxidant Formation, Acidification and Fossil fuel extraction. The environmental results indicate that transport alternatives including electric and diesel trains, as well as the reduction in Baltic wood imports should present better environmental performance than the current scenario in terms of all the impact categories under study. Remarkable differences were identified with regard to energy requirements. This divergence is related to different long-distance transport strategies (lorry, boat and/or train) as well as the relative import of wood selected.

The combination of lorry and train in wood transportation from Southern Sweden plus the reduction of wood imports from 25% to 15% seems to be more favourable from an environmental perspective. The results obtained allow forecasting the importance of the wood transport strategy in the wood supply chain in LCA of forest products and the influence of energy requirements in the results.

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1. Introduction

The European Union (EU-15) is one of the largest producers, traders and consumers of forest products in the world (European Commission, 2007a). The forest sector (forestry, forest-based and related industries) comprises several industrial sectors: woodworking, pulp, paper and paperboard manufacturing and converting, printing industries and furniture. The annual production value of this sector reached 335 billion € in 2001, employing about 3.4 million people (European Commission, 2007b). In addition, EU-15 is a net importer of forest products. Roundwood from Russia and Eastern European countries and pulpwood mainly from North and South America are key imports in the sector.

However, forest-based products consumed in EU-15 are mainly of domestic supply, especially the more highly value-added products, such as quality papers and wood-based panels. EU-15 is even a leading exporter in this kind of products.

Paper is necessary for most human activities (education, communication, business, culture, hygiene, food and beverage packaging,

medicine, ...). Paper is a natural product, manufactured from a renewable raw material: wood. Paper pulp (the basic ingredient for the manufacture of paper and board) is produced from fresh wood, wood chips from sawmills, recovered paper and sometimes, from textiles and agricultural products or industrial crops. Nowadays, wood constitutes the main virgin paper pulp raw material in developed countries (Sigoillot et al., 2005) and pulp manufacture is the largest non-food industrial use of plant biomass (Gutierrez et al., 2001), since virgin fibres are necessary in paper-, pulp- and board products due to quality requirements. The pulp and paper industries are also highly energy and water intensive (EUROSTAT, 2007). However, it is important to remark that the EU pulp, paper and board industry tends to use energy from renewable energy sources. In fact, biomass energy corresponded to half of the thermal energy and electricity consumption in these industries in the year 2000 (European Commission, 2006).

Worldwide consumption of pulp and paper is steadily increasing. The European pulp and paper industry had in the year 2003 a capacity over 41 million metric tonnes¹/year of pulp and 95 million tonnes/year

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¹ All tonnes in this report are metric tonnes hereafter referred as tonne(s).

of paper and cellulose-based products, occupying the second position in world production of pulp and paper after North American countries. In Europe, this industry consists of over 1000 paper mills and 220 pulp mills. Germany is the largest paper producer followed by Finland, Sweden and France. Regarding pulp production, Finland and Sweden are the main pulp-producer countries (European Commission, 2007b). Annual wood pulp production in 2005 was 191 million metric tonnes, including dissolving pulp and other pulps (Skogsstatistisk Årsbok, 2007).

The Swedish pulp and paper industry is organising itself to be globally competitive. It is made up of around 30 paper pulp mills with a total annual pulp production of more than 12 million tonnes (Reciclapapel, 2002; Skogsstatistisk Årsbok, 2007). Approximately 34% of the total wood pulp production is for market pulp. Almost 50% of the wood harvested in Swedish forests is delivered to this sector. In 2006, 5 million tonnes (7% of total use) of wood for forest industries were imported mainly from Baltic countries and Russia (Skogsstatistisk Årsbok, 2007). These imports are relevant for the Swedish industrial sector, especially for the pulp and paper sectors. Exports of secondary products, such as paper, paperboard and wood pulp and recovered paper, were approximately 10.9 million tonnes and 3.6 million metric tonnes, respectively. The resulting net product has a huge surplus, because imports of wood pulp, recovered paper, paper and paperboard accounted for only 2.3 million metric tonnes. The contribution from the forest sector is important for the national economy, the same year 11% of total exports were derived from the forest industry sector.

It is evident that the massive use of wood as a raw material needs an appropriate management in order to reduce the associated environmental impacts. This study aims to complete a previous study where the environmental impacts associated to forest operations for softwood supply to a pulp mill, carried out in Swedish and Baltic stands, were analyzed from stand establishment to wood delivery at mill gate (González-García et al., 2008). In that study, the chain of forest management practices was divided in three main systems: silviculture operations, logging operations and secondary hauling and evaluated according to the Life Cycle Assessment (LCA) methodology (ISO 14040, 2006). According to the results, secondary hauling (transport of wood from forest landing to pulp mill gate) was identified as the main hot-spot for all the environmental impact categories analyzed (Global Warming, Eutrophication, Acidification and Photochemical Oxidant Formation) and energy used by that subsystem was around 60% compared with 37% by logging and only 3% by silviculture. This result fits in with other similar studies carried out mainly in Nordic countries (Schwaiger and Zimmer, 2001; Berg and Karjalainen, 2003; Lindholm and Berg, 2005a,b; Berg and Lindholm, 2005) where energy use associated with timber hauling is 50–65% of total energy requirements in the wood supply chain.

In this study, five reliable scenarios of secondary hauling were analyzed from an environmental point of view. The current scenario was compared with four reliable alternative scenarios in order to identify the best way for pulpwood supply to a specific pulp mill placed in Northern Sweden. For the environmental evaluation, the application of LCA was again considered. There are several LCA studies that have addressed forest systems (Aldentun, 2002; Berg and Karjalainen, 2003; Berg and Lindholm, 2005; White et al., 2005) as well as the Swedish road transport (Eriksson et al., 1996). LCA studies have not only been carried out to compare different products, but also to obtain information about material and energy flows linked to products and systems.

2. Methodology

Life cycle Assessment (LCA) methodology has proved to be a valuable tool for documenting and analysing environmental impacts from product and service systems that need to be part of decision-

making process towards sustainability (Baumann and Tillman, 2004). In addition, LCA may give insight on areas in the forest-wood chain which need improvements, but also show environmental application of wood for industry and consumer markets (González-García et al., 2008, 2009; Karjalainen et al., 2001; Rivela et al., 2006; Werner and Nebel, 2007). The forest sector has environmental relevance not only due to its low fossil fuel use, low emissions to air, water and soil, but also due to its potential as storage for carbon (Goodale et al., 2002; Liski et al., 2001; Lindholm and Berg, 2005b).

LCA is compiled of several interrelated components: goal and scope definition, inventory analysis, impact assessment and interpretation of results (ISO 14040, 2006). SimaPro 7.1 designed by PRé-Consultants was the software used in this study (PRé-Consultants, 2007).

2.1. Goal and scope definition

This study aims to propose alternative scenarios to the current situation of wood supply to a Swedish pulp mill located in Northern Sweden. Secondary hauling (transport of wood from landing to end-point) was identified as the most important hot-spot in Swedish forest operations in a previous study (González-García et al., 2008) and this result is in agreement with other related studies (Berg and Karjalainen, 2003; Berg and Lindholm, 2005; Lindholm and Berg, 2005a,b; Karjalainen et al., 2001).

The study presented here aims to compare several reliable alternative scenarios of wood delivery. Therefore, operations related to forest operations were not included within the system boundaries. Several transport system combinations will be analyzed (lorry, boat and diesel and electric trains), as well as the influence of the amount of wood imported from elsewhere.

The Swedish pulp mill under study can be considered representative of the 'state of art' with an approximate process production of 210,000 tonnes of dissolving cellulose and an annual consumption of 1.30 million m³ of wood.

2.2. Functional unit

The functional unit (FU) provides a reference to which the inputs and outputs are referred (ISO 14040, 2006). In this study, 1 m³ of fresh wood solid under bark (s.u.b.) was selected as the functional unit in order to make a straightforward comparison between scenarios as well as with other related works. This timber has an average basic density of around 400 kg/m³ (Sveriges Skogsvårdsförbund, 1994). The fresh wood contains more water than dry mass. The water content varies with the shipping season. For this study, the average raw weight was, on average, 825 kg/m³.

2.3. Description of the scenarios under study

Currently, there are three main long-distance wood transport strategies to supply wood to wood-based industries in Europe: road, railway and waterway. Road transport is the dominant means of transport used and represents more than 80% of the total wood supplied to wood industries in Europe (Schwaiger and Zimmer, 2001).

The transport work related to wood harvested in the forest and delivery to the pulp mill is extensive. In the case of Sweden, almost 55 million tonnes of roundwood were supplied by lorries in 2005 and the average distance to mill was 94 km. Other means of transport are necessary due to costs, distance, environmental impacts and geography. Average distance by rail is about 290 km. Rail transport is the second most important means of transport. Transport by ship is mainly used for long-distance domestic transport and imported wood (from the Baltic countries and Russia). In waterways there is an important variation in the average distance. The distance considered

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