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# Environmental aspects of Norwegian production of pulp fibres and printing paper

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ABSTRACT

The purpose of this study was to assess the environmental impacts of the Norwegian pulp and paper industry, considering the production of pulp fibres and printing paper. The pulp fibres included in this study are thermo-mechanical pulp and kraft pulp fibres, which differ with respect to the energy consumption and chemicals used during production. The assessed paper grades were super-calendered paper and newsprint. The study was a cradle to gate approach, and corresponds to an attributional life cycle assessment (LCA). The LCA was based on data collected from main pulp and paper producers in Norway. Importantly, aspects related to the increasing use of mineral fillers in the production of newsprints were assessed. The results showed that a reduction of more than 18% climate change impact (kg $CO_2$ eq.) was achieved by increasing the fraction of fillers, in the newsprint furnish. Furthermore, the total climate change impact reduction depended on the applied energy mix. Assuming that the production of printing paper was based only on Norwegian energy mix, yielded a reduction of the climate change impact by more than 44% in 2011, compared to the production based on Scandinavian and European energy mix. Additionally, the input and output transport contributed to more than 20% impact in several cases. We thus concluded that the estimated environmental impacts were affected by; i) the furnish composition of a given paper quality, ii) the input and output transport and iii) the use of different primary grid energy sources.

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## 1. Introduction

To maintain a high environmental performance the pulp and paper industry has made important investments in more efficient production processes, where the reduction of energy consumption has been a main topic. This is caused by increasing energy prices and the necessity to remain competitive in a challenged industry worldwide (see also Gaudreault et al., 2010; Vehniäinen et al., 2010). Considering that the energy consumed in the manufacturing of a given paper quality is a contributor to greenhouse gas (GHG) emissions, opportunities for reducing the corresponding climate change are likely to be found in the paper production processes (Boguski, 2010). The implementation of energy efficiency measures is considered the most cost-effective way to reduce $CO_2$ emissions (Jonsson et al., 2011). Specifically, in a newsprint production process, substitution of thermo-mechanical pulp (TMP) by recycled pulp has yielded a reduction of climate change due to a reduction of electricity consumption (Gaudreault et al., 2010). This is due to the lower amount of energy required for the deinking and cleaning of recovered printing paper, compared to the energy required for producing virgin TMP (Vehniäinen et al., 2010). According to EEA (2006), in most cases recycling of paper is beneficial from a life cycle assessment (LCA) and cost benefit analysis (CBA) point of view. However, differences in geographical aspects are necessary to be taken into consideration. In addition, increased use of recycled paper has been identified as one of the technologies that present top energy savings potential (Xu et al., 2013). Process optimization by reducing the energy consumption is thus considered an important step to mitigate climate change.

Life cycle assessments (LCA) and emission studies regarding the pulp industry have been carried out in several countries, *e.g.* the US, Canada, Portugal, Germany and Sweden (Finnveden and Ekvall, 1998; Miner and Lucier, 2004; Salazar et al., 2006; Dias et al., 2007; Gaudreault et al., 2007, 2010). However, no comprehensive LCA has been reported for the Norwegian pulp and paper industry. Norwegian pulp and paper producers supply various types of pulp and paper grades, including thermo-mechanical pulp (TMP), kraft pulp, newsprint and super-calendered (SC) paper. Norway produces approximately 4.8% of the total pulp produced in Europe.

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### 1.1. Printing paper

The paper production involves several stages, including 1) formation with initial dewatering in a wire section, 2) pressing of the wet web and 3) drying in the dryer section. Water removal is the most energy demanding part of the paper manufacturing process. The cost to remove one unit of moisture at forming, pressing and drying follows the ratio 1:5:220 (McGregor and Knight, 1996).

Newsprint paper is mainly composed of thermo-mechanical pulp (TMP) fibres and recycled paper (Fig. 1, left). In addition, during the last years the content of mineral fillers has increased considerably. The increased amount of fillers improves dewatering during paper formation and pressing (Hii et al., 2012), leading to less energy consumption during drying. SC paper is mainly composed of TMP fibres, clay and a fraction of kraft pulp fibres, which improve the paper strength (Fig. 1, right). In addition, the production of SC paper involves a finishing step (calendering) to smooth the paper surface and thus increase the glossy appearance, as is the case in glossy magazine paper. Newsprints are not super calendered but can be calendered at relatively low intensity. Newsprints have thus a rougher surface and porous bulk structure (Fig. 1, left). For details on the composition, structure and processes involved in the production of TMP, kraft fibres, newsprints and SC paper (Fig. 1), see *e.g.* Chinga-Carrasco (2009).

### 1.2. Motivation

In recent years there has been an increased attention for carbon accounting on harvested wood. Direct emissions from the production of pulp, paper, paperboard and wood products are estimated to be 264 $MtCO_2$/yr (Miner and Lucier, 2004), which is estimated to increase up to 550 $MtCO_2$/yr by 2030 (Kayo et al., 2012). The industry relies heavily on energy from biomass, usually in the pulp producing industry, which uses 49% of the entire biomass fuel (Knight, 2004). According to the Confederation of European Paper Industries (CEPI), over the past two decades the pulp and paper industry has downsized substantially in Europe, especially after 2009 due to the economic crisis and cheaper and massive production in other parts of the globe. However, the global demand of paper is increasing with substantial increase in gross domestic product, particularly in the rapidly increasing economies (Kayo et al., 2012).

The increasing demand of paper in the growing economies also increases the demand of more carbon-intensive energy sources, thus leading to higher emissions (Kayo et al., 2012). Because of increased use of biomass and energy efficiency improvements, the GHG emissions from the pulp and paper industry in Europe have been reduced over time. Since 1990, $CO_2$ emissions of the European paper industry have decreased by approximately 25% (Knight, 2004). With the benefit of cleaner energy and sustainable forestry, the paper industry in Nordic countries can produce printing paper with relatively low environmental impacts.

In this study, the data has been obtained from the leading producers of pulp and paper of Norway, during the years 2008 and 2011. During this period, a Norwegian mill had a major focus on developing a process for producing newsprints, which was more efficient with respect to energy consumption. Low energy consumption was considered crucial for the profitability of the mill. In addition, the reduction of energy consumption in the paper mill would be most positive from an environmental point of view. As part of this strategy, a fraction of the TMP was replaced by a fraction of ash (mineral fillers included in the recycled pulp and virgin ground calcium carbonate). The increased ash content increased the dry content after pressing, which decreased the steam consumption during drying of the paper. In order to verify the environmental impacts affected by the modification of the paper production line, an LCA analysis (cradle to gate) was performed and is reported in this study. In addition to the LCA of newsprint production, an LCA of supercalendered (SC) paper production was performed, thus covering a major part of the pulp and paper industry in Norway. Hence, a comprehensive environmental assessment of the Norwegian pulp and paper industry was performed. The objective of this work was thus to estimate the environmental impacts of relevant pulp and paper products in Norway, including the following pulp and paper products; i) thermo-mechanical pulp, ii) kraft pulp, iii) newsprint and iv) super calendered paper. The study aims at describing the life cycle environmental impacts of the printing paper production (cradle to gate) and is thus considered an attributional LCA.

## 2. Materials and methods

This study uses the fundamentals of LCA methodology to evaluate the environmental performance of part of the pulp and paper industry in Norway. The basics of LCA focus most importantly on defining the system of interest. Determining the system boundary helps to narrow down the prime elements for the inventory. The life cycle inventory consists of the flows in and out of the system boundary. The inventory flows include inputs of water, energy and raw materials as well as releases to air, land and water. The releases to the environment are often environmental emissions or stressors such as carbon emissions, NOx, SOx, nitrogen, ozone and other equivalent emissions. The $CO_2$ eq. includes other contributing stressors towards climate change such as methane and carbon monoxide (*e.g.*, one mol of methane is equivalent to four moles of $CO_2$). This is similar for other stressor equivalents also for various environmental effects.

Accessibility to data for the inputs to the industry is obtained through company production records. Though the accessibility of

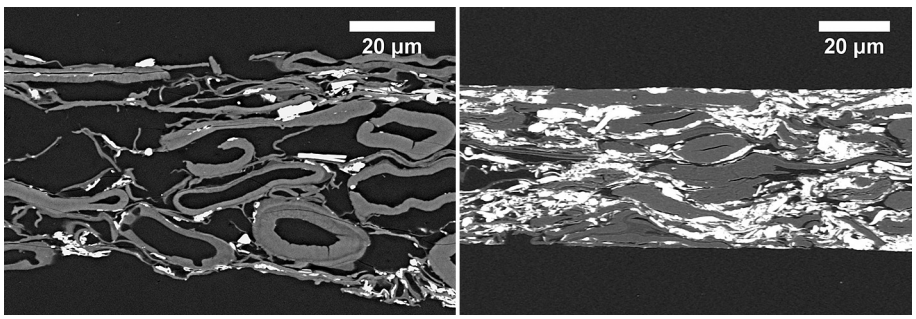


**Fig. 1.** Cross-sections of typical paper structures from newsprint (left) and super calendered (SC) paper (right). The cross-sectional fibre structures are exemplified. The white areas in the images correspond to mineral fillers (*e.g.* $CaCO_3$ and clay). Reproduced from Chinga-Carrasco (2009).

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