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Greenhouse gas and energy based life cycle analysis of products from the Irish wood processing industry

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ABSTRACT

The timber industry in Ireland is an important producer of wood products for export and indigenous use, and supplies significant volumes of sawmill co-products as biomass for energy generation. This research expands existing knowledge on the environmental impacts of wood supply chains in Ireland by widening the analysis to incorporate the wood processing stage. The study determines and analyses energy and material inputs in the production of several timber products; sawnwood, wood chip, wood-based panel (WBP) boards and wood pellets, with an analysis of the resulting greenhouse gas emissions. Forestry operations and transportation make an important contribution to overall emissions. Electricity usage is responsible for the majority of emissions in sawmilling. Integration of combined heat and power (CHP) systems with sawmilling and pellet manufacture reduces greenhouse gas (GHG) emissions. The penetration of renewables in the Irish national grid mix is forecast to increase by 2020 in line with EU renewable energy targets. Analysis shows that the forecast fall in the carbon intensity of the grid will have a positive effect on the reduction of GHG emissions from the wood processing supply chains. Wood energy products compare favourably with other sources of biomass energy and with fossil fuels.

1. Introduction

The timber industry in Ireland is an important aspect of the Irish economy, contributing 3 billion euro of export value in forest products, including sawn timber and wood-based panels, in 2012 (Irish Forestry and Forest Products Association, 2013). There are eight sawmills, three wood-based panel (WBP) mills, and one pellet manufacturer currently operating in the Republic of Ireland. The Irish sawmilling sector provides the primary outlet for indigenous roundwood, utilising 1.75 million m^3 of roundwood to produce 900,000 m^3 of sawn timber in 2012. Additionally, the wood-based panel sector utilised 1.28 million m^3 of wood fibre in the production of 704,000 m^3 of panel, and is a major user of pulpwood, sawmill residues (i.e. sawdust, wood chip and bark) and post-consumer recovered wood.

In Ireland the timber industry supplies significant volumes of sawmill co-products (including bark, sawdust, shavings and wood chip) as biomass for energy generation. Between the years 2000 and 2012, renewable heat generation grew from 2.4% to 5.2% with this growth dominated by biomass (Howley and Holland, 2013). Traditionally, the majority (48%) of biomass-for-energy in Ireland has been consumed by sawmill and WBP industries as feedstock for kilns and process heat generation. However, with the introduction of the EU renewable energy target of 20% of energy from renewables by 2020 (European Commission, 2007), increasing volumes of wood biomass are being utilised by the energy, commercial and domestic heating sectors. For example, in 2012, 152,000 m^3 of roundwood equivalent (RWE) were co-fired with peat at Edenderry power plant (Knaggs and O'Driscoll, 2013). In addition, the production and use of wood pellets and briquettes is gaining prominence, increasing from 82,000 m^3 RWE in 2008 to 144,000 m^3 RWE in 2012.

In order to meet the EU renewable energy targets, it is forecast that the demand for wood biomass on the island of Ireland will increase from 1.589 million m^3 (overbark) to 3.084 million m^3 (overbark) by 2020 (COFORD Roundwood Demand Group, 2011).

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Nomenclature

CHP	combined heat and power
GHG	greenhouse gas
WBP	wood-based panel
RWE	roundwood equivalent
LCA	life cycle assessment
odt	oven-dried tonne
GJ	giga joule
MDF	medium density fibreboard
OSB	oriented strand board
GWP	global warming potential
CED	cumulative energy demand
SC	scenario
SRCW	short rotation coppice willow

This demand increase provides a new market for wood biomass which may be met by roundwood traditionally used in the wood processing sector or by the use of sawmill co-products in the form of chips or pellets. Consequently, competition between the energy and wood processing sectors for biomass will increase.

In addition to the 20% renewable energy target mentioned above, the EU has mandated a 20% reduction in greenhouse gas (GHG) emissions by 2020. Despite the fact that wood biomass contributing to this target is currently considered carbon neutral by the EU, the production and processing of this biomass utilises materials and fossil fuels which results in greenhouse gas emissions along the supply chain. It is important to analyse these wood energy supply chains in order to ensure actual GHG emissions reductions.

Opportunities exist in the wood processing sectors to improve environmental efficiency. In Ireland, the majority of sawmills burn by-products to fulfill their heating requirements, this is supplemented by fossil sources when required, and import electricity from the national grid. By integrating a combined heat and power (CHP) system with an existing sawmill, there is potential to increase energy efficiency and reduce electricity usage from the national grid. In addition, the location of a pellet mill with an existing sawmill allows optimal use of resources (Anderson and Toffolo, 2013).

Life cycle assessment (LCA) is a tool which can be used to assess the environmental impacts and energy requirements of wood processing systems and innovations in these systems from a holistic perspective. LCA allows the evaluation of a product or system over its entire life cycle, from raw material production through processing, to consumption and disposal. The holistic nature of LCA allows the identification of points in the system of critical contributions to key environmental impacts (hotspots). A range of literature exists evaluating the environmental impacts of various wood processing systems. LCA studies have been carried out on the core sawmill products on national scales for Germany (Diederichs, 2014a), Norway (Tellnes et al., 2012) and Australia (Tucker et al., 2009). The production of sawnwood, one sawmill product, has been studied extensively from cradle-to-grave for several regions of the United States (Puettmann et al., 2013b,c,d,e). The functional unit for sawnwood production systems is generally reported as volume of sawnwood produced.

Life cycle assessment studies of medium density fibreboard (MDF) manufacture have been carried out for a number of regions including; the United States (Wilson, 2010), Germany (Diederichs, 2014b), Spain and Chile (Rivela et al., 2007), and Brazil (Silva et al., 2013). The functional unit is consistently reported as 'volume of product at the factory gate' in the reviewed studies with the majority including impacts from cradle-to-gate. Silva et al. (2013) identified the use of urea-formaldehyde resins as an environmental hotspot, with energy use also an important factor (Wilson, 2010). González-García et al. (2009) found that replacing formaldehyde resin in hardboard manufacture with a bio-adhesive (lacasse) results in environmental benefits and reduced energy demand compared to the conventional system.

Oriented strand board (OSB) manufacture has been studied from an LCA perspective in several regions, including the United States (Kline, 2005; Mason Earles et al., 2011; Puettmann et al., 2013a) and Luxembourg (Benetto et al., 2009). Similarly to studies on MDF, the functional unit is expressed on a volume basis and the majority consider upstream impacts from timber production and processing. Mason Earles et al. (2011) investigated co-production of OSB with ethanol and acetic acid with the aim of reducing environmental impacts. Results from the study show a reduction in emission of volatile organic carbon by this method but an overall increase of greenhouse gas emissions and energy requirements. A novel drying technique in OSB manufacture was assessed by Benetto et al. (2009) which lead to a reduction in environmental impacts compared to conventional manufacture.

The use of sawmill co-products for energy generation in power plants has been studied by Mälkki and Virtanen (2003), with the analysis extending from forestry operations to biomass combustion. A number of LCA studies have been carried out on the use of sawmill co-products for pellet production (Hagberg et al., 2009; Magelli et al., 2009; Mani et al., 2005; Pa et al., 2012; Petersen Raymer, 2006; Sikkema et al., 2013; Sjølie and Solberg, 2011). The functional unit used in LCA studies of wood pellet production is primarily 'mass of wood pellets produced', however a functional unit of 'energy contained wood pellets' has also been used to aid comparison with other energy sources. Emissions from wood pellet production are strongly dependent on the fuel used in drying, with emissions increasing when fossil fuels (oil or gas) are used rather than biomass (Hagberg et al., 2009; Magelli et al., 2009). In addition, as wood pellet production is an energy intensive process, the emission intensity of the electricity grid mix has a significant effect on environmental impacts (Hagberg et al., 2009).

In Ireland little research exists on the environmental impacts of the wood processing sector, with only wood production studied from an LCA perspective to date (Murphy et al., 2014b). The aim of this study is to add to the pre-existing LCA knowledge of forest operations in Ireland, by analysing the next step in the timber industry; the wood processing stage. The analysis considers each of the products from sawmilling, WBP manufacture and pellet manufacture from a life cycle point of view.

2. Materials and methods

2.1. Goal and scope

This research endeavours to expand existing knowledge on the environmental impacts of biomass supply chains in Ireland by widening the analysis to incorporate the wood processing supply stage. The study determines and analyses energy and material inputs in the production of several timber products; sawnwood, WBP, wood chip and wood pellets, with an analysis of the resulting greenhouse gas emissions. The study represents a 'cradle-to-gate' LCA and as such the system boundary includes all processes from raw material production to the finished product at the factory gate. It is important to note that the analysis does not consider the embodied carbon in any of the wood products produced.