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Environmental sustainability assessment of using forest wood for heat energy in Ireland

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ABSTRACT

Wood from Irish forestry has potential for sustainably supplying some of Ireland's energy needs. This study used an environmental sustainability assessment methodology to assess how much heat energy could be supplied sustainably and the impacts on the environment in comparison to fossil fuels. Around 11% of the Irish land area is forested and around 31% of harvested forest wood is used for energy. Considering this, the steady-state sustainable supply of fuel wood energy from this area was estimated to be around 8.7% of the Irish heat primary energy demand in 2010. Thus, forest wood fuel is a limited resource and can only sustainably supply a small fraction of demand. Life cycle assessment showed that total environmental impact was about 10% of that for heating oil, although this did not include land requirement which is the dominant impact for wood fuel and limits its supply. Even though forest wood is "greener" than heating oil from a climate change perspective, there are a number of other impacts where it performs worse, in particular, emissions of particulate matter during wood combustion which contributed to the highest emissions impact from the life cycle.

Contents

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1. Introduction

Sustainability can be described as people (globally) being able to "flourish" [1] over a "prolonged" period of time. Flourish could be described as providing at least basic needs, including food, water, sanitation, shelter, health-care and education. Prolonged period could be described as, in human terms, as being many generations, for example thousands of years. The above description of sustainability is relatively easy to grasp, however there are many factors that influence sustainability, which makes the whole area very complex. There are a number of conceptual models relating to sustainability and most of these incorporate the interrelationship between the three domains of environmental, economic and social [2]. It could be argued that environmental sustainability is the foundation to sustainability in the sense that humanity needs the environment to continuously provide natural resources and to deal with its wastes continuously over time for humanity to sustain itself and prosper. Many realise that humanity currently is on an environmentally unsustainable path, with natural resources being gradually used up and harmful emissions building up in the natural environmental, such that nature is becoming less and less able to support large numbers of people [3,4,5]. Considering the above, environmental sustainability has two major components to it, that is, the sustainability of natural resource use and impact on the environment due to emissions/wastes and land use.

In the context of current global energy supply, biofuels have limited supply capability and cannot sustainably supply a major portion of current global energy demand, however they can be part of an overall energy mix, particularly in replacing liquid fossil fuels with second and third generation biofuels [6,7]. Furthermore, the potential uses of biomass may be many and thus biofuels have to compete for available land area with other non-energy applications, especially food, and this could constrain the supply of biofuels.

Silva Lora et al. [8] discusses the concept of sustainability applied to biofuels production, outlining the main issues to be considered. Some biofuel systems have higher life cycle greenhouse gas (GHG) emissions when compared to fossil fuels [9], hence it is necessary to evaluate the life cycle of biofuels. Silva Lora et al. [8] highlight that sustainability assessment of biofuels needs a multicriteria approach to assessment and the following environmental sustainability related issues must be considered and evaluated: Sustainable supply of biomass, productivity and how much biofuel a given amount of land can sustainably supply; Impact on the environment in terms of GHG emissions along the whole life cycle, land use and carbon stock changes, fertiliser uptake efficiency as this influences N_2O emissions, impacts on water resources, soils and biodiversity.

Life cycle assessment (LCA) is an important tool for assessing the impact on the environment of the life cycle of products and services. Cherubini & Strømman [10] performed a review of a large portion of existing scientific literature that explicitly used LCA or a life cycle approach to estimate environmental impacts of biomass energy uses. The review highlighted that even though biofuels had superior performance in terms of GHG emissions, there were a number of categories, such as human and ecosystem toxicity, acidification and eutrophication, where biofuels had increased impacts when compared to many fossil fuels. It also highlighted issues associated with changes in carbon pools due to land-use changes and non-CO_2 GHG emissions.

There are not many published studies providing detailed life cycle assessments of forest wood for energy applications. Ecoinvent provide life cycle inventory (LCI) data for hardwood and softwood production based on central European plantations, in particular Germany [11]. There are a number of studies conducted in Scandinavian countries. Berg et al. [12] provided data for a Swedish study of forestry operations which focused mainly on energy requirements and environmental impacts due to this. The LCI involved mainly diesel use, some petrol and electricity. The average total energy requirement was about 150–200 MJ m^{-3} of wood. About 53% of total energy requirement was transport. Logging accounted for around 40% and silviculture and seeding accounted for 5 and 3%, respectively of total energy requirement. Characterisation was carried out but this was mainly relating energy emissions to a common variety of impact categories, including global warming potential. Michelson et al. [13] provided LCA data for forestry operations in Norway. The major emissions were primarily due to fossil fuel combustion caused by logging operations, transport by forwarder and transport to factory with these three operations accounting respectively for 84% of global warming potential, 85% of acidification and 89% of eutrophication.

Gonzalez-Garcia et al. [14] provided a LCA comparison of the environmental impacts of forest wood production for pulpwood in Spain and Sweden. The LCA included silviculture (including fertiliser and pesticide production), logging and transport. The environmental impacts considered were mainly due to diesel combustion and fertiliser application. Total energy requirements were similar at 395.3 MJ m^{-3} for Spain and 370.2 MJ m^{-3} for Sweden, although the contributions were different with silvicuture, logging and transport accounting for 29.4%, 39.2% and 31.4%, respectively for Spain and 3.1%, 36.7% and 60.2% for Sweden. This is mainly due to different forest management requirements/practices and differing average transport distances. For example, a lot more fertiliser was used in the Spanish case-study. Whittaker et al. [15] provides a recent comprehensive UK study of energy and greenhouse gas emissions of forest systems and this study uses data from a number of other studies performed in the UK. The average total energy requirement was about 695 MJ per oven dried tonne which is somewhat similar to the studies mentioned above, considering the density of oven dried Sitka spruce is about 0.38 t m^{-3}. In relation to GHG emissions, the major contributions were from harvesting (41.7–46.3%), chipping (38.8%–41.6%) and transport (10.6–11.2%) with smaller contributions from site establishment (0.8–7.8%) and road construction (0.1–1.1%). The study also showed that GHG emissions to supply a unit of heat energy from average forest residues of Sitka spruce (at 30% moisture) is 13.3% and 8% of that from natural gas and coal combustion, respectively. Recent studies stress that there is a need to incorporate and further elaborate methodologies for land use change in LCA studies involving forestry operations as these can have a major influence on global warming potential and biodiversity [16,17].

The objective of the study presented in this paper was to assess the environmental sustainability of using forest wood for heat application in Ireland and to compare with fossil fuel. An important aspect of this study is that it explores the environmental sustainability from both the perspective of forest resource supply and impact on the environmental along the life cycle.