Contents lists available at ScienceDirect

Sustainable Production and Consumption

journal homepage: www.elsevier.com/locate/spc

Life cycle assessment of ACQ-treated Veneer Based Composite (VBC) hollow utility poles from hardwood plantation mid-thinning

Hangyong (Ray) Lu[a,*], *Ali El Hanandeh*[b]

[a] *Griffith School of Engineering, Griffith University, Nathan, QLD 4111, Australia*
[b] *Environmental Futures Institute, School of Engineering, Griffith University, Nathan, QLD 4111, Australia*

ABSTRACT

Hardwood plantations are slow to mature with low financial returns in the early stage. Veneer Based Composite (VBC) products developed from mid-thinning may improve the industry's profitability and win new markets. Due to the increasing demand for utility poles and the banning of native forests logging in Australia, VBC poles may become viable alternative to native hardwood poles. Alkaline copper quaternary (ACQ) preservative treated VBC pole was assessed using life cycle assessment (LCA) methodology. The manufacturing processes considered were based on the current technologies in Queensland. VBC pole life cycle stages assessed include mid-thinning, manufacturing, service-life, and disposal. Three end-of-life scenarios were considered: landfilling, incineration for energy recovery and recycling as particleboard. The functional unit used in this assessment is 1-metre-length pole with 115-mm internal-diameter and 15-mm wall-thickness. Global Warming Potential (GWP100), Fossil Depletion Potential (FDP), Acidification Potential (AP), Eutrophication Potential (EP), and Ecological Toxicity Potential (ETP) were quantified. Results indicated that landfilling and incineration outperform the recycling option. Incineration scenario performed slightly better under the GWP100 (0.3659kg-CO_2-Eq), AP (2.12g-SO_2-Eq), FDP (0.360kg-Oil-Eq) and EP (3.81g-PO_4-Eq). Meanwhile, landfilling scenario had slightly less impact in ETP (12.32-CTUe). Despite generating valuable products, the burdens caused by secondary manufacturing and transportation overweighed credits earned from recycling. ACQ treatment, Phenol-formaldehyde (PF) resins production and transportation distances were identified as significant parameters affecting the final result. Sensitivity analysis indicated that EP was sensitive to change in ACQ consumption; ETP was affected by PF resin use while changing distances of transporting product affected GWP100, AP and FDP.

Keywords: Life cycle assessment (LCA); Hardwood thinning; Veneer based composited (VBC); Alkaline copper quaternary (ACQ); Pole

1. Introduction

During the last decade, Australian hardwood plantations have increased by approximately 150%, mainly due to changes in government policies. Currently, Australia has approximately 150 million hectares of forest, dominated by more than 700 different species of Eucalyptus. About two million hectares of these forests are managed as timber plantations; with approximately 49% being hardwood plantations (Australian Government, Department of Agriculture Fisheries and Forestry, 2010). Timber plantations present an opportunity to increase Australian long-term wood supply, while

* *Corresponding author.*
E-mail addresses: hangyong.lu@griffithuni.edu.au (H. Lu), a.elhanandeh@griffith.edu.au (A. El Hanandeh).
Received 2 May 2015; Received in revised form 26 October 2015; Accepted 8 November 2015; Published online 21 November 2015.

http://dx.doi.org/10.1016/j.spc.2015.11.002
2352-5509/

contributing significant social, economic and environmental values (Australian Government, Department of Agriculture Fisheries and Forestry, 2014).

1.1. Background

It is essential to produce high quality logs at an early age (30–35 years). Therefore, pruning and thinning are practised during the early stage of the plantation, in order to increase available light, moisture and nutrients for the rest of trees (McGavin et al., 2006). Approximately, 50% of the trees are typically cut from the third year during the first thinning, with another 30% removed in the second thinning (10–15 years). The removed trees during the second thinning usually have a Diameter at Breast Height Over Bark (DBHOB) of 0.15–0.3 m. However, these thinned logs have low commercial value because they do not have viable markets (Underhill et al., 2014). Veneer Based Composite (VBC) products have been developed as high value applications from plantation second thinning, which can be applied for replacing various engineered wood products (McGavin et al., 2006; Underhill et al., 2014).

Utility pole is defined as a column to support various public utilities, such as cable, fibre optic cable, and related equipment such as streetlights. Utility poles are usually sourced from native forest hardwood species (Gilbert et al., 2014). Hardwood is seen as the most appropriate solution for manufacturing utility poles. Compared to the alternative materials, such as steel and concrete, hardwood has the lowest environmental and economic burdens (Francis and Norton, 2006). However, due to growing environmental awareness and concerns over the sustainability of forestry practices, agreements have been signed in Australia to phase out logging of native forests. Thus, the supply of hardwood utility poles will decrease sharply, while the demand is expected to dramatically increase (Francis and Norton, 2006). Looking for new materials to satisfy the shortage of poles presents a big challenge (Australian Government, Department of Agriculture Fisheries and Forestry, 2014).

1.2. Demand for utility poles in Australia

More than 5 million timber utility poles are currently in-service in Australia, while most of them were produced from native hardwood forest. However, up to 70% of total in service poles are ageing poles and reaching the end of life, which may cause severe consequences in Australian utility system (Francis and Norton, 2006). An investment of approximately 1.75 billion dollars is required to replace these 3.5 million ageing poles. Thus, 175 million dollars is required per annum to achieve this target over the next decade. In addition, new utility poles are also required to satisfy the urban expansion, which will represent an additional cost (Francis and Norton, 2006).

The new developed veneer based composite (VBC) hardwood hollow utility poles may present an alternative to replace traditional hardwood poles, which also could offer positive environmental and economic performances from early stage during hardwood plantation in Queensland. The VBC poles are manufactured from Gympie messmate (Eucalyptus *cloeziana*) plantation mid-thinning, a traditional hardwood species used for manufacturing poles in Australia (Bootle, 1983; Underhill et al., 2014). Nevertheless, the sustainability of the product from life cycle perspective has not been assessed. For this reason, a full LCA is developed to assess the environmental performance of VBC hardwood hollow utility poles from hardwood plantation mid-thinning.

1.3. Timber veneer processing

Veneer is a thin slice of timber with a thickness from 0.3 to 6.0 mm, depending on its natural property and applications (Nolan et al., 2005; Skates et al., 2012). Rotary peeling, slicing and half-round slicing are the three common methods for cutting veneers. The logs need to be preconditioned before cutting, which involves debarking and cutting the log to the certain length. The logs are then pre-softened by immersing in hot steam (Ozarska, 2003). This step controls the moisture content in logs, to ensure the veneers are easily peeled (Skates et al., 2012). Due to the difficulty of using traditional peeling technology for peeling thinned logs with small diameter and low quality, the spindle-less veneer lathe is used to produce unbroken continuous veneers (Underhill et al., 2014).

Timber veneer from hardwood plantation is an innovative solution to satisfy the demand of solid wood product. The suitability of timber from Eucalyptus plantation used for structural laminated veneer lumber (LVL) applications was reported previously by Carrick and Mathieu (2005) and Nolan et al. (2005). More recent research from Queensland Department of Primary Industries (DPI) indicated that they had successfully manufactured and tested engineered wood products such as LVL beams from thinned Eucalyptus trees (McGavin et al., 2006). Skates et al. (2012) explored the potential applications of engineered wood from hardwood mid-thinning. In addition, Underhill et al. (2014) mentioned the suitability for manufacturing utility pole.

1.4. Aims of this study

This paper aims to conduct an LCA study to investigate the environmental performances associated with VBC hardwood hollow utility poles manufactured from Gympie messmate plantation mid-thinning. The environmental burdens of three different disposal scenarios are assessed to determine appropriate end-of-life treatment. Results of this study may have helped hardwood plantation managers and utility companies to facilitate a better sustainable management of plantations and utilities networks.

2. Methods

The goal of this study is to provide a scientifically based and comprehensive assessment of the environmental performance of the VBC hardwood hollow utility pole manufactured from hardwood plantation mid-thinning over its life cycle. The scope of this study includes 'cradle to grave' life cycle inventory of VBC hollow utility poles from hardwood plantation second thinning. The timbers are obtained from the hardwood plantation located in South East Queensland. Primary data was used whenever possible, secondary data on background operations and energy was collected from various sources in the literature as described later in Section 3-Life Cycle Inventory.

For collection of life cycle inventory inputs and outputs, the functional unit is defined as a small diameter pole (1 m in length, with nominal internal diameter of 115 and 15 mm wall-thickness). The VBC utility pole is formed in two half-pole jointed together, while each half pole are compressed by 9 pieces of hardwood veneers.

- Functional unit: one VBC utility pole
- Service life: 25 years
- Geographic boundary: South East Queensland, Australia.