SUSTAINABLE MANUFACTURING OF COMPOSITE PALLET BLOCKS USING WASTE WOOD AND TYRE-DERIVED MATERIALS

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ABSTRACT

An innovative technology is proposed by the Tyre/Wood Block LIFE project for manufacturing of compressed pallet blocks by introducing materials other than virgin timber into the compound: contaminated waste wood and waste tyre-derived materials. The technological, environmental and economical analyses carried out during the project proved the sustainability of this novel solution. A high volume demonstration facility has been set up in Lissarda, Co. Cork, Ireland. Providing that the technology is licensed to other manufacturers across Europe, it has long-term potential: a significant impact on the preservation of trees and absorption of an important quantity of waste tyres. This paper briefly presents the results of an LCA carried out for the pallet block manufacturing activity which proved the environmental benefits of using waste wood and tyre-derived materials over the use of virgin wood.

Keywords: Sustainable, Pallet Block, Waste, Life Cycle Assessment (LCA)

1 INTRODUCTION

The current state-of-the-art in terms of the manufacture of pallet blocks indicates two methods:

- The traditional sawing of timber to the correct shape, and
- The compression of timber materials (such as shavings and sawdust) in combination with glue and heat.

This paper presents a novel approach to the manufacturing of compressed pallet blocks by introducing waste materials other than timber into the compound: waste tyre-derived materials. The innovation consists of combining waste wood and tyre waste in the right proportions to deliver superior performance (compression strength, dimensional stability, resistance to weathering, insulation) through taking advantage of some of the characteristics of the tyre material, such as a greater damping effect, less brittleness and greater durability. At the same time, the result will be a significant reduction (if applied on a large scale) of waste tyres and waste contaminated wood, with a very good impact on the environment.

A full analysis of the innovation was carried out during the 50 month Tyre/Wood Block LIFE project to demonstrate the technical, environmental and economic benefits of the innovative technology.

This paper will be looking at the environmental aspect of the project. Section 2 proves the environmental reasons for choosing waste materials for the manufacture of composite pallet blocks. A Life Cycle Assessment (LCA) was carried out to prove the superiority of the manufacture of composite pallet block using waste wood and waste tyre materials in terms of environmental impact, in comparison with traditional manufacturing methods. Section 3 briefly presents the LCA procedure, which is applied to the manufacturing of pallet blocks in Section 4. The paper concludes with the recommendations made as a result of the LCA and how they were addressed to further improve the environmental impact of the activity.

2 ENVIRONMENTAL ISSUES ADDRESSED BY THE INNOVATIVE TECHNOLOGY USED IN PALLET BLOCK MANUFACTURING

Waste is one of the biggest problems in modern Europe. As European society has grown wealthier, it has created more and more waste. Each year in the European Union alone 1.3 billion tonnes of waste is thrown away – some 40 million tonnes of it hazardous and, according to the OECD estimates, by 2020, we could be generating 45% more waste than we did in 1995 [1].

Contaminated wood coming from construction and demolition, packaging or other sources, and used tyres are a massive problem in Europe.

2.1 Waste Wood

A significant amount of waste sawdust and wood shavings are generated in the timber-processing industry. Additionally, there are millions of tonnes of contaminated wood arising from construction and packaging. In 2004 it was estimated that 70.5

million tonnes of waste from the wood working, construction and demolition, packaging and bulky waste sectors were discarded to landfill in the European Union [2].

In Ireland, the National Waste Database report 2001 shows 236,821 tonnes of waste wood and wood products, of which 10,719 tonnes became disposal and the rest was recovered; 48,626 tonnes of packaging waste wood was generated, of which 15.2% went to landfill [3].

At present there are two pieces of legislation that have an impact on timber disposal and resources available [1]:

- *The Landfill Directive* (1999/31/EC) and subsequent amendments (2003, 2006) restricts the quantity of biodegradable waste entering landfill, as a means to reduce green house gas emissions. Whilst timber is not targeted directly, it is a constituent of household waste, and as such is covered by the directive.
- *The Packaging Directive* (94/62/EC) and subsequent amendments (2004, 2005) restricts the amount of timber used in packaging – for example pallets and packing crates – that can be disposed of either to landfill or incineration without energy recovery. The directive sets recycling and recovery targets for the quantity of wood used for packaging (19.5% in 2006).

Contaminated wood cannot be legally used in any application where its calorific potential is realised (such as wood pellets) or where possible contaminants can leach into the soil (such as horse gallops) or be harmful to animals or humans (such as animal bedding). However, it can be used in the manufacture of composite pallet block.

2.2 Waste Tyres

There is currently in the region of 3.0 million tonnes of waste tyres arising every year in the European Union – see Table 1 for data for each member state in 2004.

Table 1. Tyre Arisings in EU Member States [4]

Member State	Tyre Arisings (tonnes)
Austria	51,000
Belgium	70,000
Denmark	41,200
Finland	32,300
France	401,000
Germany	640,000
Greece	58,500
Ireland	32,000
Italy	434,500
Luxembourg	3,100
Netherlands	67,500
Portugal	52,000
Spain	280,000
Sweden	62,000
UK	435,000
Total EU (2004)	2,659,100

Tyre waste arisings in Ireland are now believed to be in the region of 50,000 tonnes per annum. The figures from the National Waste Database report 2001 is 34,394 tonnes [3].

The EU is aiming for a significant cut in the amount of tyre waste generated through various directives that will impact on the amount of tyres that will have to be reused or recycled over the coming years. Some of the directives and their impact on waste tyre recycling are presented in Table 2.

Table 2. EU Directives targeting recycling of waste tyres [1]

Directive	Impact
Landfill Directive (1999/31/EC) and subsequent amendments (2003, 2006)	• Ban on landfilling whole tyres • Ban on landfilling shredded tyres • **+687,670** additional tonnes
End-of-Life Vehicle Directive (2000/53/EC) and subsequent amendments (2006)	• Tyres from vehicles will have to be treated • **+ 300,000** additional tonnes
Waste Incineration (2000/76/EC) and subsequent amendments (2008)	• Compliance with lower emissions to air standards • Could effectively close ‘wet-kilns’ which treat 20% of the tyres • **+ 111,706** additional tonnes

As a result of these European directives, uses had to be found for tyre-derived materials. Tyres are made up of different materials, of which the greatest quantity is rubber (48%); textiles represent 5% and metal (mainly steel) 15% [4]. The technical capability to shred tyres has been well proven and several facilities are in existence, which supply tyre crumb in various controlled sizes for many applications. There are ready and growing markets for the rubber crumb and the steel, with a significant cost being attached to these. As for the textile waste from tyres, there is no ready market, because of its contamination with rubber dust which makes it unsuitable as a material for recycling into fabric. Significantly, because this material is likely to end up in landfill, it has close to a zero cost value.

Consequently, from an economic, availability and environmental point of view, the tyre textiles make a perfect additive to the waste wood for the manufacturing of composite pallet blocks.

3 LIFE CYCLE ASSESSMENT (LCA)

Life Cycle Assessment (LCA) is one of the most frequently used techniques for evaluating the environmental performance of a product, service or activity either over its total life cycle or over a certain life cycle phase.

The international body that oversees the development of LCA is SETAC (the Society of Environmental Toxicology and Chemistry). The LCA approach developed originally by SETAC [5] has been set down in the ISO 14040 series [6]. Figure 1 presents the Life Cycle Assessment framework as laid down in this standard.

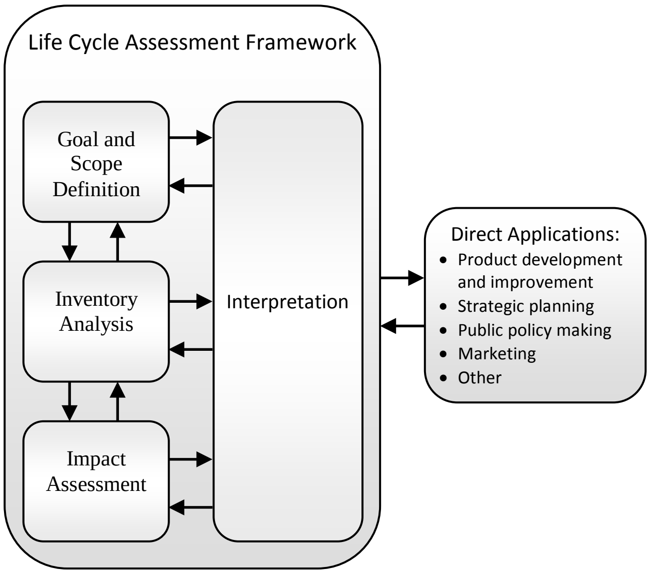

Figure 1. Life Cycle Assessment framework, after [7]

The four phases of Life Cycle Assessment are [8]:

1. *Goal and scope definition* – this stage defines the purpose of the study, the expected outputs of the study, the boundary conditions and the assumptions.
2. *Inventory analysis* – it quantifies the resource use, energy use, and environmental releases associated with the system being evaluated at each stage of the life cycle: acquisition of raw materials and energy resources from the earth; processing of raw materials; manufacturing products and intermediates; transportation of materials to each processing step; manufacture of the product being studied; distribution of the product; use of the product; and final disposition (which may include recycling, reuse, incineration or landfill).
3. *Impact assessment* – conceptually, this consists of three stages: classification, characterisation and valuation. *Classification* is the assignment of inventory inputs and outputs to impact groupings. For example, the use of fossil fuels may be assigned to the impact group 'depletion of finite resources'. *Characterisation* is the process of developing conversion models to translate inventory and supplemental data to impact descriptors. For example, carbon dioxide and methane inventory outputs may be converted to units of global warming potential. *Valuation (Weighting)* is the assignment of relative values or weights to different impacts, allowing integration across all impact categories.
4. *Interpretation or improvement (as named by SETAC)* – the results are reported and the opportunities to reduce the impact of the products or services on the environment are systematically evaluated. It must be mentioned that *LCA doesn't offer solutions*; it is only a support for decision-making.

What is the Eco-indicator 99 method?

The Eco-indicator method is based on the LCA methodology; it is an *extension* of LCA. This is an important point because an analysis using the Eco-indicator method is intended as far as possible to provide the same result as a full LCA [9].

The LCA method has been expanded to include a weighting method. This has enabled one single score to be calculated for the total environmental impact based on the calculated effects. This figure is called *Eco-indicator* (the higher the indicator, the greater the environmental impact), measured in *milli-points (mPt)*. Therefore, the Eco-indicator of a material or process is a number that indicates the environmental impact of a material or process, based on data from a life cycle assessment. Data have been collected in advance for the most common materials and processes. The Eco-indicator has been calculated from this. The materials and processes have been defined such that they fit together like building blocks [9].

4 LCA OF MANUFACTURING OF COMPOSITE PALLET BLOCK USING WASTE WOOD AND TYRE-DERIVED MATERIAL

An abridged quantitative LCA was carried out for pallet block production that uses waste wood and tyre-derived material. The abridged LCA was chosen because it is much quicker and more cost-effective in comparison to a full LCA. The method used is Eco-indicator 99. The study followed all the steps of an LCA: goal and scope definition, inventory analysis, impact assessment and interpretation.

4.1 The Study

The goal of the study was to use Life Cycle Analysis (LCA) to compare the impact on the environment of the production of pallet block in two cases: using a combination of waste wood from construction, demolition or packaging, and waste tyre-derived textiles, or using virgin wood. The results offer a basis for measuring environmental performance and thus can be used to improve the environmental performance of this activity.

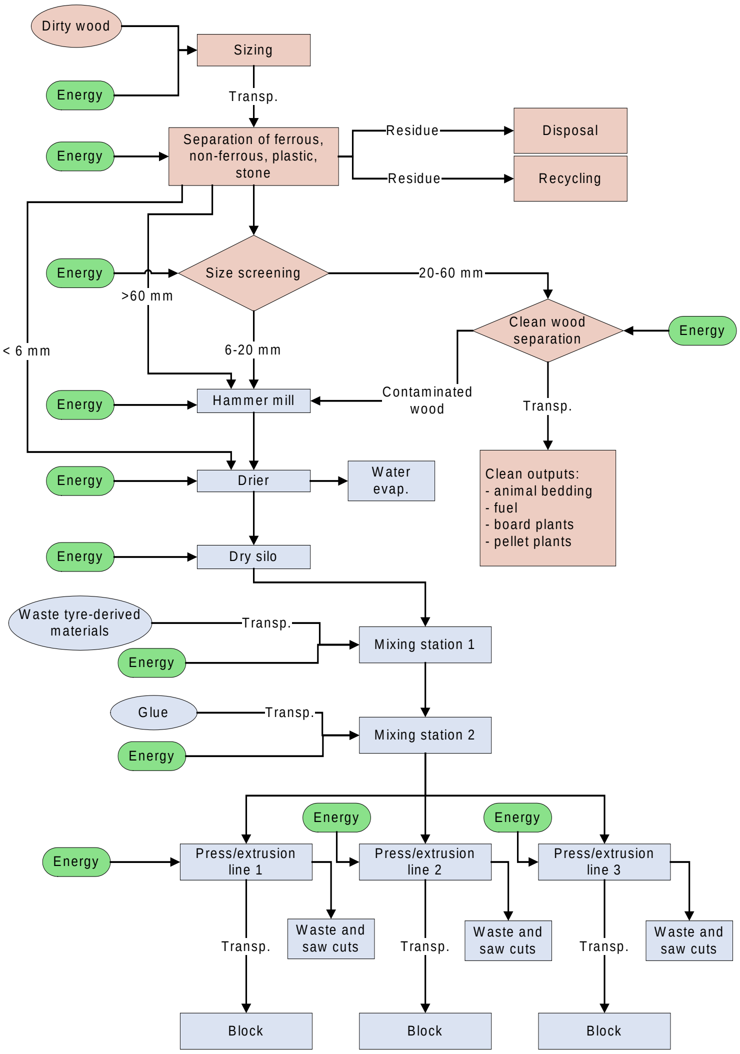

Figure 2. Materials flow diagram for pallet block production using waste wood and tyre-derived material

The activity is meant to mix waste wood from construction and demolition or packaging (pallets) with waste tyre-derived materials and glue to obtain blocks that will be used in pallets manufacturing. The waste wood arrives at the demonstrator facility in chopped-up form. Ferrous and non-ferrous metals, plastics, stones and sand are then separated from the waste wood through a number of processes. A hammer mill breaks the wood into smaller pieces, which are dried to a level of less than 5% moisture content. The dry wood is stored in a silo until it is used in the next process: mixing 1. In the mixing 1 station, the dry wood is mixed with waste tyre-derived materials, which proceeds to mixing station 2 where glue is added. The mixture is then pressed and extruded in a semi-continuous process, with the extrusion being cut to specific block length. There are three press/extrusion lines. The blocks are then automatically inspected and packed for shipment. The whole process is presented for the two scenarios (using waste wood and tyre-derived material and using virgin wood) in Figures 2 and 3.

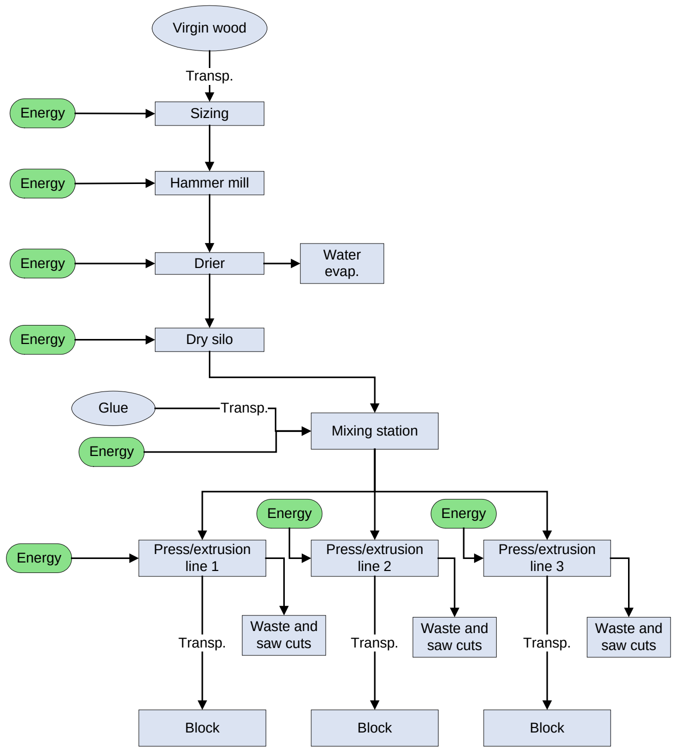

Figure 3. Materials flow diagram for pallet block production using virgin wood

The following phases and products were included in the study:

- Raw material (waste wood) coming from landfill
- All processes necessary to produce the block
- Production of various types of energy necessary for each process
- Distribution/transportation
- By-product handling.

The level of detail in the treatment of the different parts of the study was determined by:

- Availability of data in a useable form
- Significance for the study.

Assumptions and Limitations

The production of capital goods and means of production (e.g., buildings, machinery and transport systems) were not included in the system. Environmental loading caused by the travel, accommodation etc. of personnel was not included in the analysis, either.

Certain material flows into the systems were not followed back to the cradle. Data on these inflows (production of additives and chemicals) were mainly unavailable. These inflows are shown in the inventory results.

Environmental data on the production of the resin, hardener and emulsifier have not been included, because no data was available. Data on the incorporated materials have, however, been included. The list of the materials incorporated into the chemicals has been obtained from the suppliers.

Certain material flows out of the systems were not followed to the grave. Data on these outflows were mainly unavailable. Most of these outflows occur either in small quantities or are not considered to contribute significantly to total environmental effects.

The pallet block was not followed to the grave. The use phase can vary a lot: the final product (the pallet) can be used only on single trips or can be continuously reused; a large majority of pallets leave the country (Ireland) carrying products for export. Separate studies can be carried out for each type of use scenario in order to find the impact on the environment during the use phase. The product can be recycled at the end of its useful life.

When waste wood is used, the raw material (waste wood) is diverted from landfill, thus avoiding landfill. In this case it is not virgin raw material. It is coming from construction and demolition or packaging.

Inventory Analysis and Impact Assessment

The data necessary for this study (quantitative data) were provided by the manufacturer. The company supplied all necessary data regarding raw materials, energy consumption and types of energy, transportation, products and by-products.

The data collection started with a meeting with the manufacturer's representatives. A preliminary materials flow diagram was constructed and system boundaries were set. Primarily, specific data from manufacturer and its suppliers have been used. Where the data was confidential or if the manufacturers or suppliers have not provided the data, data from the Eco-indicator 99 database [9] have been used. A special data gathering template was created to ensure a consistent format of all data.

As the result of several processes is not just one product, but many types of products (co-products), all inputs and outputs of the process were allocated to the co-products.

After all data were collected and the allocation process finished, all inputs and outputs were summarise per functional unit. Then eco-indicators were calculated for both scenarios.

Results

A comparison of the two possible scenarios (using waste wood and tyre-derived material, and using virgin wood) showed that *the first scenario has a lower impact on environment.*

The analysis of the impact on the environment when using virgin wood showed that the quantity of energy consumed to dry the wood was very high. The impact on the environment in the case of using waste wood is reduced by the lower energy consumption for drying and the avoidance of landfill, as well as the recycling of ferrous and non-ferrous metals and the reuse of sand and stone. Recycling of Aluminium is very important. Primary production of Aluminium has a huge impact on the environment, which is avoided by recycling. In both cases there was a large impact of transportation on the environment. The use of waste tyre-derived material contributes to the reduction of impact on the environment of the pallet block manufacturing but the chemicals necessary to glue the two types of material (wood and fabric) increases seriously the impact.

Overall, using waste wood and tyre-related textiles for pallet block manufacturing is better than using virgin wood from an environmental perspective.

4.2 Recommendations

Recommendations were made to improve the overall environmental performance of the composite pallet block process and some actions have been carried out in response:

1. Use waste wood as it has a lower impact on environment than the use of virgin wood.
   Action: The project only uses waste wood. Sawmill residues are used for fuel.
2. As a high impact on the environment is produced during transportation, the company was advised to consider ways of reducing the impact on the

environment produced during transportation of raw materials or finished products.
Action: Raw materials are shredded by the recycling operators in order to reduce volumes and make transport more efficient. Container transport will be used for overseas deliveries.

3. Another area of concern was energy consumption. The impact on environment due to energy consumption is quite high. The manufacturer was already using wood burning for heat generation in some processes but should consider alternative energy sources, which are more environmentally friendly, for more processes.
   Action: The manufacturer is planning to install a combined heat & power (CHP) system, which will be fuelled by biomass from sawmilling residues and forest residues.
4. The separation process is beneficial to the environment. However, PE (polyethylene) goes to landfill. PE recycling should also be considered. That would reduce the environmental impact of the overall activity.
   Action: The overall quantity of PE resulting from the separation of residues is negligible. Nevertheless, this output is stored and given to a plastic recycler.
5. The glue – MUF (melamine-urea-formaldehyde) resin, hardener and emulsifier – have a high contribution to the overall impact on environment. The use of alternative glues, with the same properties but more environmentally friendly, should be considered.
   Action: Currently, MUF resins are graded either as E1, E2 or E3. The company has moved to E1, which has the lowest level of formaldehyde emissions. Tests will also be carried out on MDI resins. However, the economics will also have to be considered.
6. Production of the LDPE (low density polyethylene) used for packaging the final product has a high impact on the environment. The producer should find a ‘greener’ alternative packaging material.
   Action: The company is investigating this area with a view to finding a greener alternative.

5 CONCLUSIONS

Manufacturing of composite pallet blocks using waste wood and tyre-derived materials has proved to be a sustainable activity. The analyses done during the project showed good environmental and economic performance of the activity. This paper briefly presented the results of the LCA carried out during the project which showed the benefits for the environment.

The Tyre/Wood Block partners will, at peak production, produce close to 80,000 tonnes of composite block. This block will include up to 5% waste textiles from tyres, with the remainder being waste wood.

Expanding the methodology through licensing, a wide body of other manufacturers across Europe will be made aware of the benefits of adopting the Tyre/Wood Block approach. This will have a significant impact on preservation of forests and on landfill.

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