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EXECUTIVE SUMMARY –THERMOWOOD®: LIFE CYCLE ASSESSMENT (LCA) OF FINNISH THERMALLY MODIFIED WOOD CLADDING

Contents

1. Overview, Introduction to report, ThermoWood® and LCA

1.1. Report and approach

This executive summary is based on the report 'Greening ThermoWood®[1]: Life Cycle Assessment (LCA) of Finnish Thermally Treated Wood Cladding' by Tho T T Tran[2]. The approach of the executive summary underlines added value to the following readers:

1. Specifiers including architects, orderers of a house/houses, town planning authorities or anyone making decisions of cladding material and solutions.
2. Designers, local house builders and end users.
3. Distributors, wholesalers and builders' merchants.

Regarding added value to the readers, the report emphasizes the documentation of ThermoWood's environmental performance so that energy and environmental

[1] ThermoWood® is a registered trademark owned by the Finnish ThermoWood Association.
[2] Tran, T.T. (2005), Greening ThermoWood®: Life Cycle Assessment (LCA) of Finnish Thermally Treated Wood Cladding, Imperial College London (University of London), MSc in Environmental Technology, Pollution Management Specialist Option, Environmental Technology, A report submitted in partial fulfilment of the requirements for the MSc.

comparisons can be made with other building materials. However, the attempt to compare ThermoWood with other building material is limited because of restrictions of data and approach in the report by T T Tran.

1.2. Concepts of ThermoWood® and LCA

ThermoWood® is thermally modified timber that is made by processing wood in a high (180-230°C) temperature (ThermoWood Handbook 2003). This process has an effect on the biological and chemical composition of wood and therefore also on the quality of wood:
1. Durable solutions. Equilibrium moisture content decreases, moisture shrinkage decreases, greater resistance to rot and mould, better weather resistance.
2. Visual solutions. Wood gets thoroughly colored, resin is evaporated away.
3. Load solutions. Bending strength somewhat decreases, wood gets lighter.

Only high temperature and steam are used in the manufacturing process, and no chemicals or other extraneous constituents are added to wood in the process.

ThermoWood® Concept (ThermoWood 2008) ensures the technical and ecological quality of products sold under the trademark ThermoWood®. Developing the Concept is part of the long term plan of the Finnish ThermoWood Association to promote the use of thermally modified timber. ThermoWood® Concept consists of the following sectors:
1. Patented thermal modification process
2. Registered trademark
3. Audited quality control system
4. Life cycle assessment (LCA)
5. Certified raw material
6. Standardisation
6. Continuous research and development activities

1.2.1. Patented thermal modification process

The industry scale ThermoWood® process was developed and patented by VTT Technical Research Centre of Finland. The patent is administrated by a company called Licentia Oy and it is valid in Austria, Belgium, Switzerland, Germany, Denmark, Spain, France, UK, Greece, Ireland, Italy, Holland, Portugal, Sweden, Japan, Canada, and the USA. The license agreement for exploitation of the patent was signed by the Finnish ThermoWood Association and Licentia Oy.

Valid patents are: EP0695408; JP 3585492; US 5,678,324; CA 2,162,374.

1.2.2. Registered trademark

ThermoWood® trademark is owned by the Finnish ThermoWood Association. The trademark is now registered in EU, Switzerland and Canada. An additional trademark registered in the EU is ThermoHout®. Only the member companies of the Finnish ThermoWood Association have the right to use these registered trademarks. Registered trademarks are ThermoWood® (EU trademark number 000922765) and ThermoHout® (EU trademark number 004296331).

1.2.3. Audited quality control system

The quality control of ThermoWood® production was developed in cooperation with Inspecta Oy. Inspecta Oy is also the third party auditor of the quality control system and issues the right to use an FI inspection mark. All member companies that produce thermally modified timber participated in the preparation of quality control.

The list of ThermoWood® producers that have the right to use the FI inspection mark can be found at Inspecta. The members that have the right to use FI inspection mark with ThermoWood® product have also the right to use the quality stamp of the Finnish ThermoWood Association. Some ThermoWood® producers have the right to use the KOMO certificate of the Dutch testing company SKH.

1.2.4. Life cycle assessment (LCA)

LCA as a concept includes the idea that a product's environmental impact is not to be determined considering only its direct manufacturing process, but the whole supply chain of materials and energy that leads to it. The need to understand how this supply chain of materials and energy works in a system and how it impacts the environment requires the development of Environmental System Analysis tools. These tools study the interactions between the human economic system and its surrounding environment by analysing the materials, energy and waste flows as inputs and outputs from the economic system to the environment (Clift, 2001).

Life Cycle Assessment (LCA) is one of many Environmental System Analysis tools that use this approach. LCA provides a framework for measuring the inputs and outputs of an option, whether a product, a process or an activity, as well as evaluating the environmental impacts and burdens associated with its whole life cycle. Technically, LCA is a systematic approach, where the system of interest comprises the operations that collectively produce the product under examination. Life Cycle Assessment is a process to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying the energy and materials used and the wastes released to the environment; to assess the impact of those energy and materials used and released to the environment; and to identify and evaluate opportunities to affect environmental improvements. The assessment includes the entire life cycle of the product, process or activity, encompassing, extracting and processing raw materials; manufacturing, transportation and distribution; use, re-use, maintenance; recycling, and final disposal.

LCA methodologies are described in the ISO 14040 series of standards developed by the International Organisation for Standardisation (ISO) which issues standardisation of products and activities throughout the world.

1.2.5. Certified raw material

The FFCS (Finnish Forest Certification System) was developed for Finnish circumstances and it demonstrates reliably how the Finnish certified forests are managed and used. The certification system includes all the essential components for forest certification: requirements for forest management and use and chain of custody verification as well as the qualification criteria for external auditing. The FFCS was accepted by PEFC (Programme for the Endorsement of Forest Certification schemes) forest certification system. The Finnish Forest Certification Council issues the PEFC logo use rights in Finland on behalf of the PEFC Council. About 90% of sawn wood that is thermally modified in Finland comes from PEFC certified forests. Regarding other members of Finnish ThermoWood Association outside of Finland, they may use other forest certification systems.

1.2.6. Standardisation

Product classification

ThermoWood® product classification was completed in 2003. Two standard treatment classes were introduced. The classes are called Thermo-S and Thermo-D. Information about ThermoWood® classification can be found in the ThermoWood® handbook, ThermoWood® brochures and the website of the Finnish ThermoWood Association.

CEN/TS 15679:2007 Thermal Modified Timber - Definitions and characteristics

CEN standard for thermally modified timber is now accepted and in national implementation stage. At first the standard status will be Technical Specification.

1.2.7. Continuous research and development activities

Finnish ThermoWood Association annually allocates resources for topical R&D activities.

1.3. Abbreviations

Abbreviations	
KD	Kiln dried to 18%
LCA	Life Cycle Analysis
SimaPro	SimaPro is the most widely used LCA software. It offers ultimate flexibility, parameterized modelling, interactive results analysis and a large included database.
ThermoWood®	Registered trademark owned by Finnish ThermoWood Association
ThermoWood® G	ThermoWood®; online-process in one step
ThermoWood® KD/G	ThermoWood®; prekilned to KD before processing
TMT	Thermally Modified Timber according to CEN/TS 15679:2007

2. Summary

ThermoWood® plays an important role in the quality of the building industry as well as the quality of the environment affected by the use of the material. It is therefore important to understand and foresee the environmental impact of ThermoWood as a new building material which has recently been introduced to the market. Life Cycle Assessment (LCA) method was selected for the investigation as it is a widely recognised tool which evaluates the environmental impact of a product throughout its full life cycle.

LCA results from the study have shown that the environmental impact of ThermoWood® cladding is comparable to that of alternative preservative wood cladding. Both ThermoWood G and ThermoWood KD/G have wished (negative) impact in global warming which is a positive impact on the environment. This is due to characteristic of wood in carbon sequestration as found from previous studies. The largest impact caused by ThermoWood is abiotic depletion which is contributed by the use of natural gas, heat gas and electricity for the intensive heat and steam treatment. The study has also demonstrated potential environmental advantages arising from the use of alternative fuel sources such as biogas and wood energy. Paint coating, maintenance interval and disposal of ThermoWood have a non-negligible impact in this study and should be considered for the overall environmental performance.

Overall, ThermoWood® has a potential of being a green building material if consideration is made to the production as well as the use and disposal at the end of its life cycle using best available techniques. The study also recognised that LCA has limitations in its methodology and is highly dependent on data quality. In consequence, recommendations for further research are made to update and produce more accurate data for energy inputs and emission outputs and ThermoWood® performance to provide innovation for cleaner production. Nevertheless, ThermoWood has a significant environmental potential.

3. LCA of ThermoWood®

3.1. Goal, scope and limitations

The overall goal of the study was to conduct a LCA of Finnish ThermoWood® cladding to assess the potential life cycle environmental impacts associated with using the product in the UK from 2005 over the next 30 years when it reaches its end of life. The goal of the study has been split into the following objectives:

- To compile a detailed life cycle inventory of the material and resource consumption and emissions associated with the production, use and disposal of ThermoWood cladding produced from either green timber (i.e. no kiln drying) or previously kiln-dried (KD) timber based on available information from companies behind the study and considering various scenarios for different energy sources and disposal options.
- To use the life cycle inventory to evaluate the eco-profile of ThermoWood and indicate areas where opportunities exist to improve its overall environmental impacts.
- To help benchmark ThermoWood against existing data for conventional wood building material on the same functional unit basis.
- To achieve a first LCA examination of ThermoWood.

Regarding the scope, the study is based on existing products, wood cladding produced in two mills in Finland by using technology patented by VTT Finland (see Figure 1). Production and disposal scenarios are considered as well as transportation from production sites to an application in central London. Since ThermoWood is a real life product that has been produced commercially, two materials used for ThermoWood production are considered here, collectively modified as softwood: 1) Thermally modified pine, and 2) Thermally modified spruce. The scope of this ThermoWood LCA study addresses the following items:

- The functions of the product systems and the functional unit
- The product system and its boundaries
- Allocation procedures as well as types of impact and methodology of impact assessment, and subsequent interpretation to be used
- Data requirement, assumptions, limitation, initial data requirements and type and format of the report required for the study.

The limitations are:

- Regarding the functional unit for the study, it has been defined as the construction, use, maintenance and disposal of 10m2 of building cladding in ThermoWood produced by two companies in Finland with 125mm × 25mm dimension and used in the Greater London area.

- According to BS 8417:2003, the minimum requirements for use as cladding in UK is that the material should be of a natural durability of at least class 3. With a durability rating of class 3, the material should be capable of satisfying performance requirements for 30 years service life as a cladding.
- In order to ensure the lifetime guarantee against weather and biological conditions, ThermoWood is examined including a protective surface coating.
    - A water-based white paint is used for all the ThermoWood alternatives. The paint is assumed to be initially factory applied followed by regular on-site maintenance re-coating.
    - In this study, 4 year and 8 year intervals for maintenance coatings are considered to compare the impacts of surface treatment on the environment.

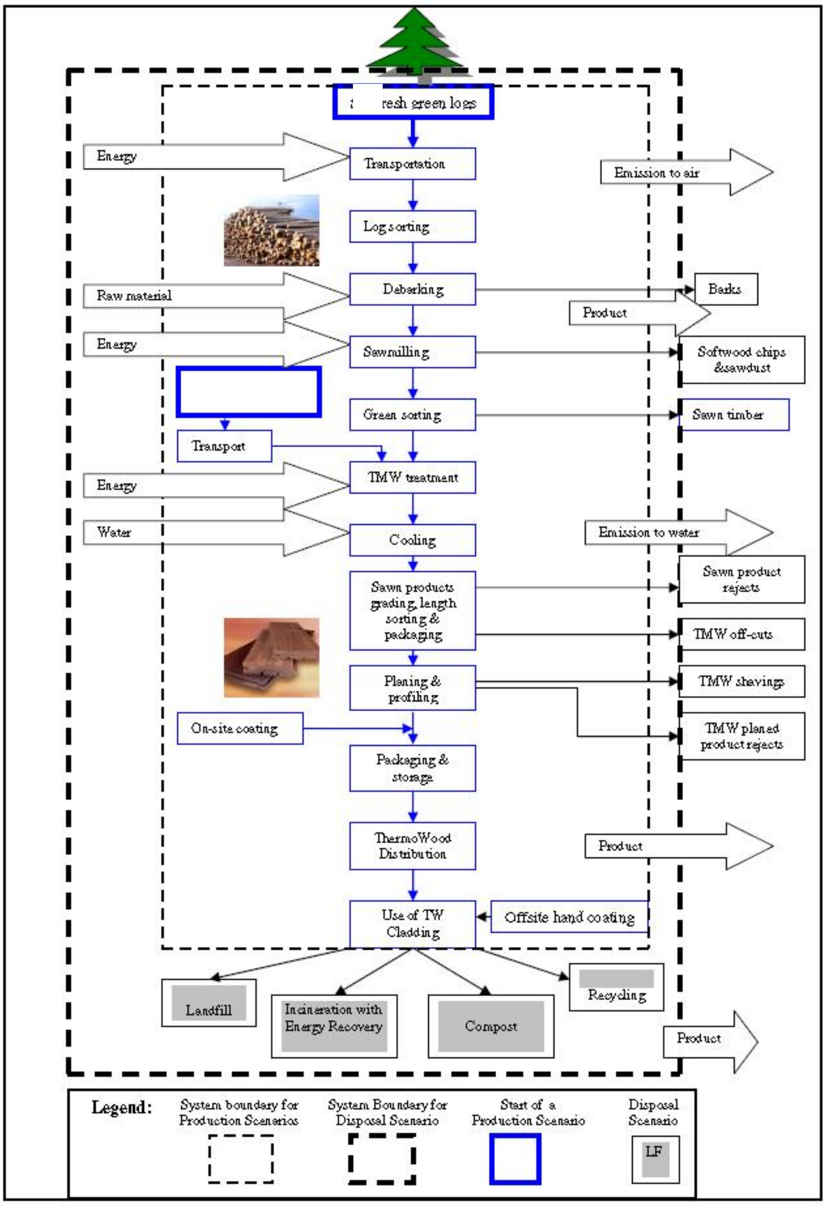

Figure 1. LCA System Boundaries for ThermoWood cladding production.

3.2. Inventory analysis

This section will describe the data collection and calculation procedures to quantify the relevant inputs and outputs of a product system. For each of the ThermoWood claddings assessed, including two scenarios - ThermoWood G and ThermoWood KD/G and preservative wood cladding as an alternative, inventories of significant environmental flows to and from the environment, and internal material and energy flows, have been produced. This has been achieved through the collection of data specific to the processes of each product system.

Data used in the study have been obtained from a number of sources. Primary data regarding the foreground processes have been collected from members of Finnish ThermoWood Association. Secondary data from background processes have been collected from indirect sources such as literature and the already existing database in SimaPro 6.0. These include:

- Ecoinvent: Both unit and system processes databases are used. These two substantial databases were developed by the Swiss Centre for Life Cycle Inventories to provide a set of unified and generic LCI data of high quality. The database contains 2500 datasets of products and services and include data related to this project e.g. energy, transport, building materials, chemical, waste treatment.
- BUWAL 250: This database was selected for its inventory of packaging materials that includes emissions from raw material production, energy production, production of semi-manufactures and auxiliary materials, transports and the production process of the materials. It provides data for the analysis of PVC film and nylon bands for ThermoWood packaging.
- ETH-ESU 1996: Both unit and system processes databases are used. These databases contain inventory data on the Swiss and Western European energy supply chain. Data from these databases are used for the analysis of energy use for ThermoWood treatment process (see Table 1).

Table 1. Material and Process Input Data for ThermoWood production scenarios. This table was evolved by interviews of Finnish ThermoWood association experts in 2008.

Material	ThermoWood G Scenario 1	ThermoWood KD/G Scenario 2	Data source
Wood planks	1,08	1,17	SimaPro6
Electricity (kWh) 1)	150	106,6	ETH-ESU
Gas B250 (kWh) 2)	480	350	ETH-ESU
PVC film	0,4	0,4	BUWAL 250
Nylon	0,05	0,05	BUWAL 250

1) Finland B250.
2) In Scandinavia, it is common to use bark and/or other wood residuals as a source of energy instead of gas.

In order to be able to benchmark the ThermoWood cladding with preservative wood cladding production, a simple production scenario of preservative wood cladding board on the same functional unit bases was developed. It was assumed that the wood cladding is made from softwood, based on spruce with a dimension of 25 × 125 mm. The summary of materials used for production, use and maintenance are summarised in Table 2.

Table 2. Material Input Data for Preservative Wood Cladding Production (per functional unit).

Material	Amount	Data source
Sawn timber, softwood, planed, kiln-dried	im^3	Ecoinvent
Wood preservative, organic salt, Cr free	0,6 kg	Ecoinvent
PVC film (kg)	0,4	BUWAL 250
Nylon (kg)	0,05	BUWAL 250

3.3. Impact assessment

Characterisation and classification are mandatory elements of a LCA study. To understand how data are characterised in impact categories in SimaPro 6, the following definitions of these impacts provide an insight of how impact assessment makes sense of the inventory results (see also Figure 2):

- Abiotic resource depletion: Non-living resources like minerals, coal or crude oil. The debate on the characterisation of depletion categories is not yet settled. In this method, characterisation is based on ultimate reserves and extraction rates. The unit of indicator result is kg of antimony equivalent.
- Global warming: This category refers to the impact of emissions on the atmosphere radiation heat adsorption, also known as greenhouse effect. Emissions are characterised as the global warming potential for a 100-year horizon. The units of indicator result for this method are kg CO_2 equivalent.
- Stratospheric ozone depletion: This refers to the deterioration of the stratospheric ozone layer that stops solar UV-B radiation from entering the atmosphere. The units of indicator result are kg of CFC-11 equivalent.
- Human toxicity: This category is related to the harmful effects of substances on human health. Emissions are characterised as human toxicity potential in an infinite time horizon, in kg 1,4-dichlorobenzene equivalent.
- Ecotoxicity: The following three impact categories all refer to the potential toxic effects of substances in the natural environment. Ecotoxicity potential is considered to happen on a global scale and in an infinite time horizon. Results are expressed in kg 1,4-dichlorobenzene equivalent. Ecotoxicity is divided into three categories depending on the environmental sub-compartment. 1. Freshwater aquatic ecotoxicity; 2. Marine aquatic ecotoxicity. 3. Terrestrial ecotoxicity.
- Photochemical oxidation: Also known as photo-oxidant formation. Sunlight causes some emissions like VOCs and CO, in the presence of NO_x to form chemical oxidising compounds such as ozone. Photo-oxidant formation is also known as summer smog. Characterisation results are expressed in kg ethylene equivalent.
- Acidification: This category is related to the acidification of the environment by pollutants such as SO_2, NO_x and NH_x. These emissions react with water in the atmosphere and form acids that have several effects on the natural and man-made environment. Emissions are characterised as the acidification potential in kg SO_2 equivalent.
- Eutrophication: When there is an excess of nutrients in the environment, shifts on species distribution and excessive production of biomass may happen. This category characterises emissions of nutrients such as N and P into kg PO_4 equivalent.

Characterisation results for ThermoWood G using method CML baseline are displayed in Figure 2 where the contribution of individual unit process can be identified. As can be seen from the figure, for all impact categories, sawn timber and electricity Finland are the major contributors. However, sawn timber is the main contributor resulting in wished (negative) impact in global warming which is a positive impact on the environment.

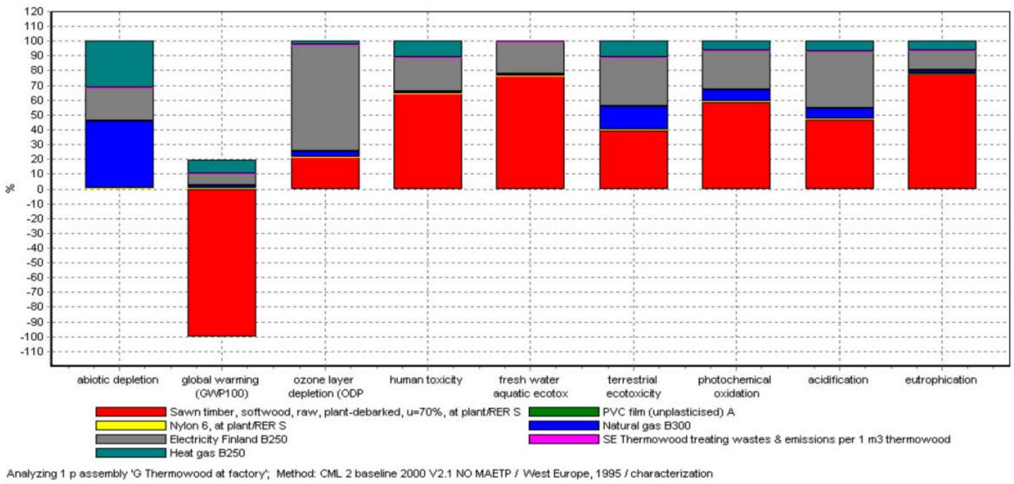

Figure 2. Impact assessment characterisation by process of the production of ThermoWood G.

In order to benchmark ThermoWood cladding products against an alternative wood cladding material, a Life Cycle Inventory for preservative wood cladding based on previous study on the same functional unit bases was developed and Life Cycle Inventory Assessment was carried out using the same standard methodology as that for ThermoWood scenarios. The original focus of the study was based on ThermoWood made by heat treatment for cladding purpose and that made without heat treatment. The illustrations in the following section show the comparison of environmental impact between three production scenarios: ThermoWood G, ThermoWood KD/G and preservative wood cladding. However, it should be noted that this comparison should be used carefully as data for ThermoWood G and ThermoWood KD/G are specific processes while the preservative wood cladding data are only a secondary source and come from existing databases and describe generic processes. This observation should be taken into consideration as such.

Both the previous and the next figures demonstrate the global warming benefit of wood-based materials in sequestering carbon from atmosphere - this is apparent even though energy from fossil fuels is used in wood transport, milling, ThermoWood treatment and preservative treatment processes. It also indicates that the more significant categories after normalisation are Global Warming potential, Abiotic Depletion potential, Acidification potential and Freshwater Aquatic Ecotoxicity potential. Meanwhile, Ozone Layer Depletion potential and Photochemical Oxidation potential are less significant in normalised scores. ThermoWood treatment has a higher impact on resource depletion than preservative wood, primarily due to the demand for natural gas and the energy consumptions in production. However, in several other environmental impact categories e.g. toxicity, ThermoWood, especially ThermoWood G, is comparable or superior to preservative wood. The fact that ThermoWood KD/G seems to perform ‘better’ in Abiotic Depletion and Global Warming than the ThermoWood G is unexpected and may be related to possibly missing data from the KD/G dataset (see Figure 3).

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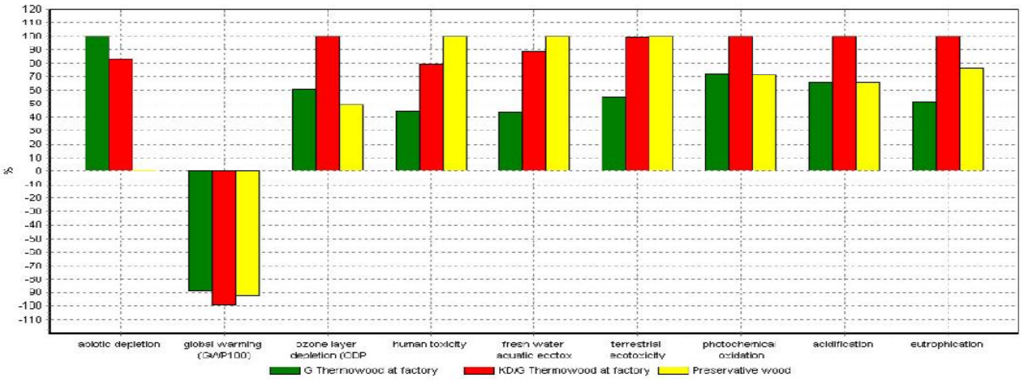

Figure 3. Comparison of classification and characterisation of ThermoWood (G and KD/G) and Preservative wood produced at factory gate - not whole life cycle.

3.4. Interpretation

The following analysis is done for comparison purposes and to detect inconsistencies in the methodology. It should not be seen as the definitive environmental profile for ThermoWood. Characterisation is performed using the Eco-indicator 99 method and comparing with findings from the impact assessment phase.

Figure 4 makes clear that Eco-indicator 99 works with a different set of impact categories. The three ecotoxicity damage categories handled by the CML method are here grouped into a single impact category in this method. Acidification and eutrophication are aggregated as a single impact category. Human toxicity is divided into two separate impact categories, and so is abiotic resources depletion. Carcinogens, radiation and land use are not explicitly mentioned in the CML method. The characterisation results, however, are not much different from the ones obtained with the CML method before.

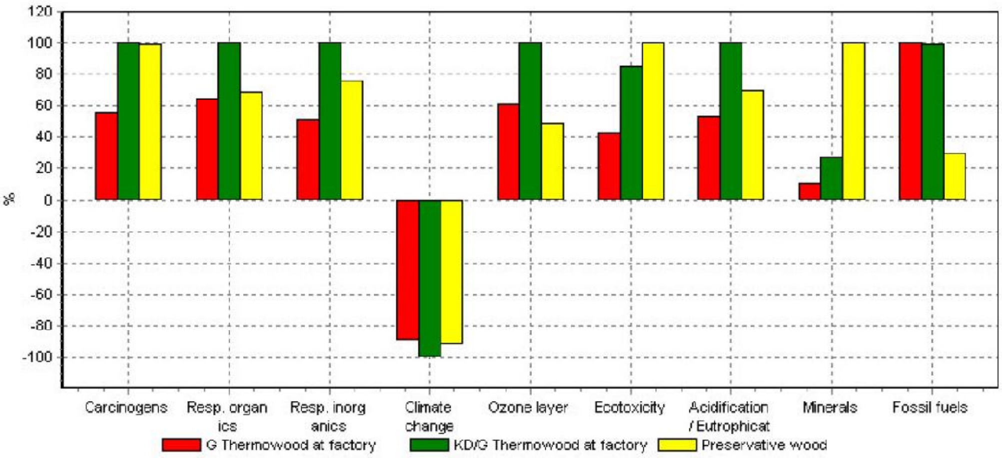

Figure 4. Characterisation comparison of ThermoWood (G and KD/G) and preservative wood produced at Factory using the Eco-Indicator method

4. Conclusions and recommendations

The environmental impact from the production of ThermoWood® cladding is comparable to that of alternative preservative wood cladding as well as other building materials (see Table 3 and Figure 5). Further information on ThermoWood® production and its use, maintenance and disposal at the end of its life should be used to update the results of the present study when available.

Table 3. Methods for improving ThermoWood® environmental performance when using G ThermoWood® or KD/G Thermowood as cladding material.

Reduction of climate change	Improvement of healthiness
+ Using wood and ThermoWood creates a significant opportunity to reduce climate change. + Using local, sustainable raw materials like bark or wood residuals as a source of heating energy instead of fossil fuels (gas, oil or coal). + Due to ThermoWood's greater resistance to rot and mould, it can be assumed to improve more durable and lasting building solutions.	+ Opportunity to reduce carcinogens and ecotoxicity. + ThermoWood has greater resistance to rot and mould. + With ThermoWood, moisture shrinkage decreases. Therefore, it can be assumed that ThermoWood improves some building solutions, quality of life and healthiness.

The use of energy for ThermoWood® treatment and maintenance of paint coatings have non-negligible impacts in this analysis. In cases where mechanical or physical damage is the most significant factor limiting the actual service life of ThermoWood®, reductions in natural gas consumption may be possible by reducing the level of treatment to the minimum needed for biological durability for that life duration only. Consumption of natural gas for ThermoWood® treatment causes impacts, especially in abiotic (resource) depletion. It is important to identify opportunities to substitute this fuel used mainly for flaring VOCs from ThermoWood® treatment plants with e.g. biogas from anaerobic digesters, or to capture or destroy VOCs by other means.

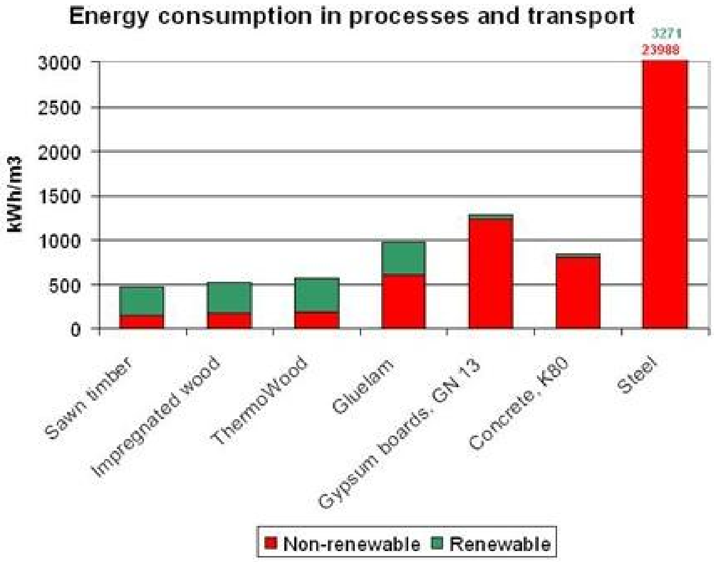

Figure 5. Energy consumption of some building materials in processes and transportation. The sources of energy are divided into renewable (bio-energy, wind, solar and water power) and non-renewable (fossil fuel) sources.

ThermoWood® is a promising building product with a significant potential in environmental performance. However, it is recommended that

- ThermoWood® environmental performance documentation will be further developed so that energy and environmental performance comparisons can be more clearly made with all relevant building materials.
- Communication of benefits of ThermoWood® will be developed. **When compared with most other building materials, use of ThermoWood® has likely positive environmental benefits in the areas of climate change and human toxicity.** Yet it is possible to discover many other ThermoWood® benefits in the area of material properties, new applications and changing legislation. **To link measurable environmental benefits with ThermoWood® is a very promising opportunity to both producers and all user groups.**
- Solutions including ThermoWood® components will be addressed instead of focusing mainly on ThermoWood products and their properties. These solutions must be developed with attention to the known and anticipated needs of specifiers (including architects and town planning authorities), distributors, home builders and other target groups.
- The carbon footprint of ThermoWood® will be carefully examined in the future. Despite lack of sufficient information of ThermoWood®'s carbon footprint at the moment of publishing this report, **it is likely that ThermoWood® has a promising carbon footprint and influence on current environmental issues** (Carbon footprint 2008). A Carbon Footprint is a measure of the impact our activities have on the environment in terms of the amount of greenhouse gases we produce. It is measured in units of carbon dioxide (CO_2).

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