International Joint Conference on Environmental and Light Industry Technologies

18-19 November 2010, Budapest, Hungary

Óbuda University

THE CONNECTION OF ECO-DESIGN AND THE CARBON SEQUESTRATION OF WOOD-BASED PRODUCTS

Ágnes LAKATOS [1]

[1] Institute of Product Development and Manufacturing
Faculty of Wood Sciences
University of West Hungary

Abstract:

In the course of its growth most of the carbon accumulated in a tree originates from the CO_2 content of air. In this sense, by using wood products, it is possible to store stocks of carbon extracted from the air. Applying the whole life cycle concept for the design of durable products made to a large extent of wood and manufactured by professional technologies support the sequestration of large carbon quantities for longer periods, contributing to the protection of climate.

This paper demonstrates that the use of wood as renewable raw material results in a lower environmental impact of the product. Movements of wood volumes related to a given product as well as the corresponding changes in carbon sequestration are shown as a result of evaluations based on plant surveys. Since the investigations extended to all elements of the technology comprising the consumption of auxiliary materials, use of energy and the production of wastes and secondary raw materials, the results will contribute to the life cycle analysis of wood products.

Keywords: carbon sequestration, product design, life cycle analysis, wood product

INTRODUCTION

The role of wood as renewable material has been significantly up-graded from the climate change's point of view. It is especially worth of attention that carbon sequestrated in wood as a result of photosynthesis from the carbon dioxide of the air makes around 50% of the mass of wood. As a world-wide tendency today, an important part of wood removed from forests is burnt (in Hungary this part amounts to 53%), which emits carbon, even if not of fossil origin, but sequestered in former times, back to the atmosphere, increasing thereby its CO_2 concentration and promoting climate change. Whereas, if we manufacture products of wood, the carbon stored in those products will be excluded for a shorter or longer period from the carbon cycle [1]. Carbon storing capacity of wood products depend on two factors: the mass of wood built in the product and the life of the given product.

For determining, the mass of wood built into the product it is important to know the processing technology of wood. For the subject of our investigation we chose building joinery, as one of the determinant segments of woodworking industry. The structure of woodworking industry in Hungary is illustrated in Figure 1 below.

The second influencing factor of carbon storage by wood is the life of products made of wood that is in principle defined in the course of product design already. The process of product design can be considered as a clean process from the environment's point of view, but it may decisively influence the environmental impacts by the product in the course of its entire life cycle and if of important role in elongating its life.

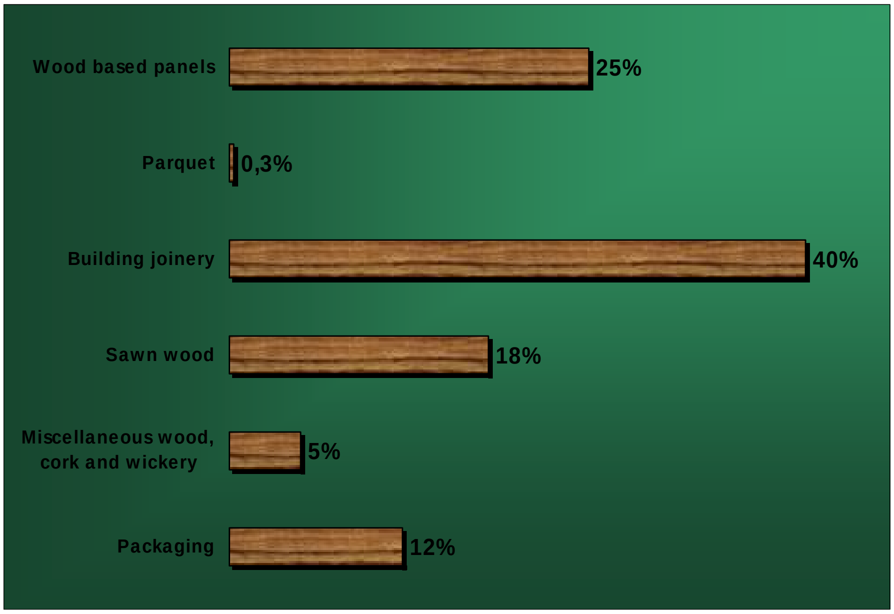

Figure 1: Weight of the different segments of wood-working industry in Hungary, 2009 (Source: HCSO)

As a consequence of the changed ecologic and economic conditions of the existence of humans there is a need of radical change of approach in the world of products with the ecology coming to the fore [2]. A general change in the approach to the environment is fortified by the directives of the European Union that appear in our national regulations as well. A number of decisions under elaboration also touch upon the issue of ecological design and the necessity of using appropriate methods aiming at its implementation. The immediate objective of eco-design or environmental conscious design is to help sustainable development to come reality by creating the equilibrium of economic, social and environmental interests; in other words it is a taking social responsibility [3]. Its direct purpose is to minimise the undesirable environmental effects of products that is enhance their environmental performance. One of the possible means for this latter is extending the life of products by improving their durability.

These objectives can be met by applying the approach of entire life cycle, the essence of which is to follow the product in the course of its life from the acquisition of the raw material up to its final disposal and study its environmental impacts over the whole life cycle. This approach is also referred to as “from cradle to coffin”, but today, with the spread of recycling the wording “from cradle to cradle” is more used. The most commonly used method applying life cycle impact assessment over the whole life span of products is Life Cycle Analysis (LCA), which can be regarded as the indicator of sustainable development and a supporting tool of environmentally conscious design [4]. By applying LCA one may make decisions on the directions of development at the individual stages of product design by considering environmental aspects, producing thereby products of better environmental performance, i.e. of longer life [5].

EXPERIMENTAL

The small size company studied produces windows of laminated wooden frame with factory finish, satisfying the requirements of air tightness resistance to water, thermal and sound insulation. Besides, windows complying with exclusive recommendations on thermal and acoustic performance by using triple glazing and increased profile depth are manufactured, along with products of aluminium-wood frame combining the natural warmth of wood with high-tech solutions.

The exceptionally high useful life of the products is guaranteed by the premium quality raw materials, manufacturing experience of the company and the continuously developing technological conditions.

The plant produces some 6000 units annually, 65% of which is windows of 90 mm profile depth, the rest being of the more common 68 mm thick wooden frame. Not more than 3% of the production is exported. The plant consumes about 37 800 m raw profile of six different depths yearly. Raw material storing is illustrated in Figure 2.

Figure 2: Raw material store

The study was focussed to the glazed units of a semi-detached house comprising an entrance door, four French windows and three windows of different operation style. These products all are of 68 mm deep frame made of three-layer laminations of first class, defect-free end-jointed Scots pine. The glued-laminated raw material had an average moisture content of u=12%. The insulating panel used in the entrance door leaf is a 24 mm thick sandwich with polyurethane foam core and faces of 4 mm plywood and 0.6 mm thick sliced Scots pine veneer respectively on the two sides. The frame members are jointed with double fork joints in the corners.

Measurements of masses were made using digital balance of 10 g precision (Figure 3). Among the individual processing steps, those resulting in change of the mass of material were taken into consideration.

It can be generally stated that in the plant there exists no complete and explicit report of the incoming and outgoing materials. The situation is even more complicated by the fact that the different materials are kept record of in varying units (kg, tons, m^3, m^2, piece, litre etc.). In several cases the incoming and outgoing quantities of the same material are not recorded in the same units; for example the incoming wood is recorded in m^3, while the outgoing product just in pieces, the waste is given in tons, the hardware, when bought, in pieces, when scrap, in tons. Unit conversion in the case of materials orb parts of different density and size is only possible approximately; the difficulty is further grown by the varying moisture content, hence density of wood [6].

Figure 3: Measurement of mass after cutting to length

The central processing unit in the plant is a Weinig Conturex C124 window-manufacturing CNC automat; a full exploitation of the same is contemplated and the whole manufacturing process is optimised on that criterion. Figure 4 illustrates the state of window frame parts after profile machining. Despite the optimisation efforts buffers of work pieces are produced between the individual phases of processing, the handling of which is solved by hand-pulled staring carriages.

Figure 4: Frame parts after profile machining

The glue contained by the laminated raw material delivered into the plant could be considered unimportant. The insulating panels of the door leaves were sanded using wide-belt contact sanding machine; however it was noted that they were prepared by an improper routing pattern, that is why they had to be re-done on the CNC centre then sanded again. The plant is producing for individual orders, the respective products are manufactured in batches. It may occur that due to customer needs, minor manufacturing defects or shortage of raw material or bought parts the original production sequence is changed.

Rejects after profiling are recycled and stored in the raw material store; glass beads and other battens are made of them for the next series. Normally produced glass beads are hand-sanded and stored together with those coming from reject then built into the product. Glazing blocks are manufactured from the wastes of a previous series. Wastes of cut to length of the laminated raw material is stored then sold out. One of the development objectives of the company is to cease cutting to length of the raw material by procuring lengths of laminated material just 10 mm more than the final dimension. The raw material shipped in such form would be stored on pallets which in turn on shelves.

RESULTS, DISCUSSION

Movement of the raw material of wooden process frames in the course of the manufacturing is summarised in Figure 5. On the basis of our measurements we received a complex picture of the movements of wood related to the product group studied. In the process diagram, quantitative data in kg-s appear in connection with all the technological phases influencing the quantity and movement of wood.

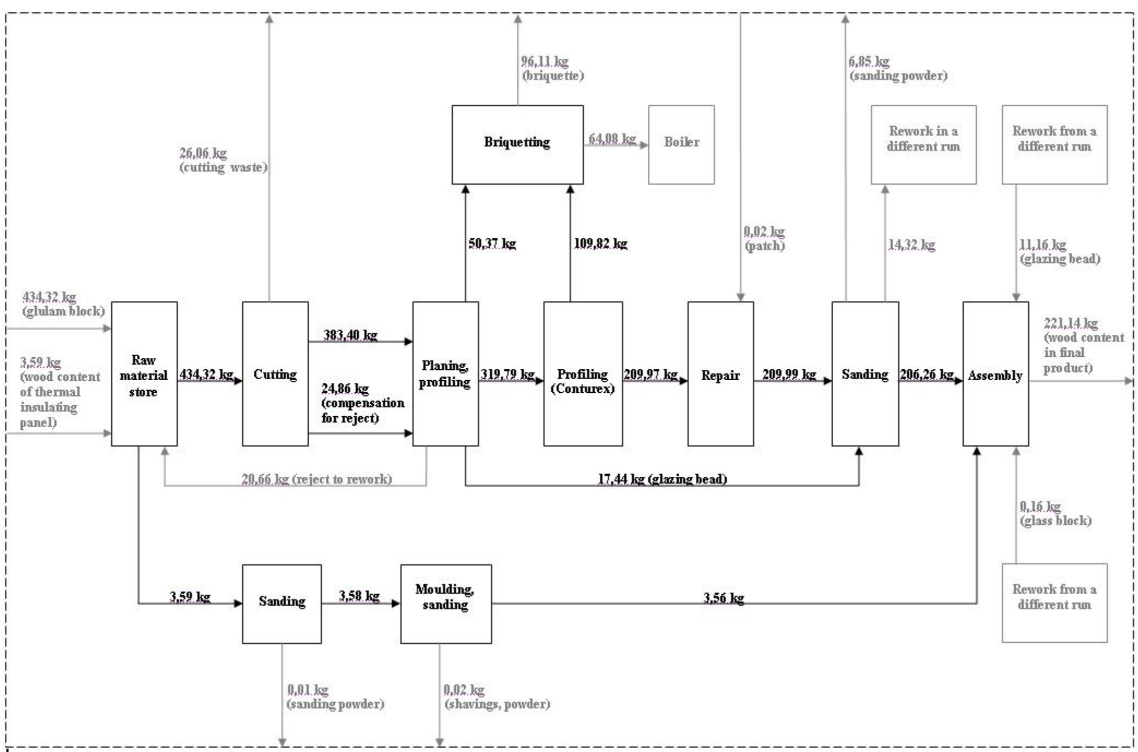

Figure 5: Movements of wood

On the basis of the flows of wood quantities illustrated in the diagram we can summarise the destiny of the quantities of wood used in the plant for the manufacture of products. Considering the laminated raw material, the wood-content of door-leaf panels and the defect-mending patches all together as raw material we may draw our conclusions.

Incoming and outgoing masses of wood are summarized in Table 1.

Table 1: Wood-content of the series of products studied

Input		
Designation	**Weight [kg]**	**In terms of %**
Raw materials	437,93	97,48
Rework (from different run)	11,32	2,52
Total:	**449,25**	**100**
Output		
Designation	**Weight [kg]**	**In terms of %**
Reject to rework	20,66	7,79
Rework (in different run)	14,32	
Waste (cut wood)	26,06	28,73
Waste (shavings, powder)	6,88	
Waste (briquette)	96,11	
Utilize for fuel	64,08	14,26
Final product	221,14	49,22
Total:	**449,25**	**100**

As much as 49.22 % of the raw material used for manufacturing was built into the final products, some 7.79 % was recycled, 14.26 % utilised as fuel within the plant. The remaining 28.73 % is leaving the plant sold as utilisable waste.

The investigations extended to all elements of the manufacturing technology, including the use of auxiliary materials, energy consumption, production and handling of secondary products and wastes, creating the possibility of conducting a whole life cycle analysis with respect to wooden products. Because of space limitations this is not part of the present paper.

On the basis of the findings in our investigations the interrelationship of ecology-driven product design and the carbon-sequestration of wood products can be determined, the central element of which is the use of life cycle analysis, including the definition of carbon dioxide as reference quantity. Behind the application of LCA there exist preferences of natural sciences; it is worth studying one of its phase, the impact assessment. In this phase of the analysis the material, energy, and emission (e.g. CO_2) inventory data touching upon wood are associated with impact categories (such as climate change). Inventory data belonging to a given impact category can be converted to a common measure on the basis of their relative weights. In the case of climate change one of these common measures is the Global Warming Potential (GWP), which relates to each other the greenhouse effect potential of the different greenhouse gases. In the case of all such characterizing factors a reference material is defined with the value of characterizing factor being 1, and all data are related to it. The reference material in the case of gases of greenhouse effect is carbon dioxide being one of the most important one of such gases. GWP is expressed then as kg CO_2-equivalent.

CONCLUSIONS

The study presented verifies that the raw material cycle of wood products can be relatively precisely determined. These calculations, when conducted to other types of wood products will give a more comprehensive picture on the carbon cycle. The carbon sequestration of wood products is a strong argument for designing them for longer useful lives. The method of life cycle analysis used in ecologically conscious design summarises the carbon cycles of raw material flows and emissions. It expresses the environmental impact of products in equivalent values, that may make the comparison of quantities of carbon released and sequestered in the course of the whole life of a product possible. That is, in the design process one has to take into consideration not only the environmental impacts but the quantities of carbon sequestrated in the wood.

REFERENCES

[1] TONN, B., MARLAND, G. *Carbon sequestration in wood products: a method for attribution to multiple parties.* Environmental Science & Policy 10(2) April 2007, pp. 162-168
[2] HEGEDŰS, J., KŐ, F. *Az értékelemzésre alapozott terméktervezés módszertana* (Value analysis-based product development*, in Hungarian*) Kecskeméti Főiskola Kecskemét, 2001
[3] GIUDICE, F. et al. *Product Design for the Environment: a Life Cycle Approach.* Taylor&Francis Group, Boca Raton, USA, 2006
[4] TÓTHNÉ SZITA, K. *Életciklus-elemzés, életciklus hatásértékelés* (Life Cycle Analysis, Life Cycle Impact Assessment, *in Hungarian)* Miskolci Egyetem Miskolc, 2008
[5] ABELE, E. et al. *Environmentally-Friendly Product Development: Methods and Tools.* Springer London, UK, 2005
[6] BORONKAI, L. *NKFP Erdő-fa hasznosítás Magyarországon 7.6 alprogram. Egyetemi kutatás.* (National Research Development Programme: Forest and Wood Utilisation in Hungary, *in Hungarian*) Nyugat-Magyarországi Egyetem Sopron, 2004

Corresponding author:

Ágnes LAKATOS
Institute of Product Development and Manufacturing
Faculty of Wood Sciences
University of West Hungary
Bajcsy-Zs. u. 4.
9400, Sopron
Hungary
Phone: +36 99 518 638, fax: +36 99 518 231, e-mail: lagi@fmk.nyme.hu