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COMPARISION OF WOOD PRODUCTS AND MAJOR SUBSTITUTES WITH RESPECT TO ENVIRONMENTAL AND ENERGY BALANCES

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ABSTRACT

Wood is a renewable material and energy source with a very long history. Wood utilisation for material purposes and energy uses has increased during the last decades due to growing world population and "poor man`s energy crisis" respectively. Destruction of forests has led to a world-wide discussion about the use of wood and the management of forests.
Sustainable energy supply is one of the mayor factors for mankind's development. Renewable energy sources gain importance as well as low energy consuming technologies.
Wood is a renewable material with a long-term perspective. Wood production in the forests requires little energy only (~ 1% of the energy content of wood). Manufacturing of wood-based semi-finished and finished products as well requires little energy; in almost all cases much less than the energy content of the wood employed for the manufacturing of the products. Wooden houses, furniture etc. need less energy for manufacturing than the energy that - considering the whole life cycle - can be provided by burning residues occurring during processing or by utilising the energy contained in the wooden product itself at the end of the life cycle.
Wood is a material for at least two or three cycles of utilisation.: First it is used as a product (i.e. timber, panels, building component, furniture), secondly it is used in a material recycling process (i.e. wood-based panels partially produced from recycled wood), and thirdly it is used for energy generation. No other renewable material can meet these advantages in terms of volume and economy.
Materials competing with wood are numerous: PVC for windows, steel and concrete for large constructions, bricks for wall in houses, plastics for windows and furniture, etc. There may be some (technical) advantages of these competing materials, but the energy balance and the environmental balance (i.e. based on LCA criteria) are dramatically worse compared to wood. Wood products require very little energy for their manufacture compared to other products based

on competing materials and for this reason the LCA-profile for wood products is of clear advantage. Wood processing has, in addition to a low energy consumption, clear advantages expressed in terms of environmental indicators like acidification, ozone formation, toxicity potential and, above all, the global warming potential.
The paper provides basic data and examples for wood-based and non-wood-based products.

Key words : wood products, LCA, energy balance, building sector

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INTRODUCTION

Over centuries, but especially during the last decades, wood and wood-based products had to face strong competition from substitute materials, such as plastics, concrete, steel glass or aluminium, as these material appear to offer wider options to the customers. Some factors that can influence customer's decisions on what kind of end products to acquire include marketing efforts, product prices, quality, durability and image.

Conflicting and often opposing views exist about the environmental consequences of using wood products. On the one hand, environmental concerns related to deforestation, forest degradation and loss of bio-diversity lead to a negative image of wood products, in particular when the products are manufactured from wood from the tropics. On the other hand, a wide range of producers and consumers are aware of the positive environmental aspects of using wood. However, it should be noted that many environmental advantages of wood products had not been scientifically evaluated and proved until the early 1990s, when the life cycle assessment (LCA) approach was developed.

This paper tries to provide some factual information on the environmental and energy balances of wood in certain products compared to mayor substitutes, applying the LCA methodology. It intends to assist policy-makers, producers, consumers and other interest groups to better understand the environmental benefits of using wood instead of non-renewable raw materials. Results presented refer to houses, sheds, window frames and flooring.

ENVIRONMENTAL IMPACTS AND ENERGY BALANCES OF WOOD PRODUCTS AND MAJOR SUBSTITUTES

LCA comparison was developed for the following product groups:

- Single-family bouses (raw construction only, all of approximately the same k-value)
    - a) Blockhouse
    - b) Timberframe house
    - c) Conventional brick house
- Simple three-storey building
    - a) Building 1 made of 1000 tonnes of wood and 60 tonnes of steel
    - b) Building 2 made of steel only
- Window frames (lifetime 30 years)

  a) Wood
  b) PVC
  c) Aluminium
- Flooring materials
  a) Wood flooring
  b) PVC flooring
  c) Linoleum

Single-family houses (raw construction)

Three different types of single-family houses with approximately the same heat transition coefficient (k-value) were compared: a) timber-frame house, b) blockhouse and c) conventional brick house. The analysis was conducted for two cases, Case A: No thermal utilisation of waste wood and Case B: Thermal utilisation of waste wood.

Case A: No thermal utilisation of waste wood

In case A, the potential of energy generated by thermal utilisation of waste wood recovered during demolition of the house at the end of the life cycle was not considered in the LCA study. The potentials of the impact categories regarding global warming, acidification, eutrophication and photochemical ozone creation were calculated on the basis of energy consumed for production of building materials and construction of the single-family houses concerned. The results obtained can be summarised as follows:

- The house with the lowest share of wood-based building materials (brick house) shows the most unfavourable impact assessment results in comparison with the other two house types.

- Despite the highest amount of wood and wood-based materials, the blockhouse seems to be environmentally less favourable than the timber-frame house.

Case B: Thermal utilisation of waste wood

At the end of life cycle, the C02-neutral waste wood substitutes the fossil fuels as biomass for energy generation. The analysis of the environmental impact is based on the net energy consumption which is the difference between the energy input and the energy generated by the thermal utilisation of renewable waste. The results obtained lead to the following conclusions:

- The real environmental impacts of the three house types are in this case notably lower than in Case A.
- The blockhouse is environmentally the most favourable family house followed by the timber-frame house and the brick house.

Table 1: Life cycle impact assessment without considering the wood based waste

House type	Impact potential	Unit	Production	Construction	Total Case A	Total Case B
Framework house	GWP100	kg CO_2 eq.*)	70100.00	24752.00	94852.00	79248.00
	AP	kg SO_2 eq.	156.37	55.2	211.58	176.78
	EP	kg phosphate eq.	13.32	4.	18.02	15.05
	POCP	kg ethene eq.	4.03	1.	5.46	4.56
Blockhouse	GWP100	kg CO_2 eq.	71546.00	24752.00	96298.00	52957.00
	AP	kg SO_2 eq.	159.59	55.21	214.81	118.13
	EP	kg phosphate eq.	13.59	4.70	18.30	10.06
	POCP	kg ethene eq.	4.12	1.42	5.54	3.05
Brick house	GWP100	kg CO_2 eq.	85277.00	29702.00	114980.00	108400.00
	AP	kg SO_2 eq.	190.22	66.26	256.48	241.81
	EP	kg phosphate eq.	16.20	5.64	21.844	20.60
	POCP	kg ethene eq.	4.91	1.71	6.616	6.24

*) eq. = equivalent

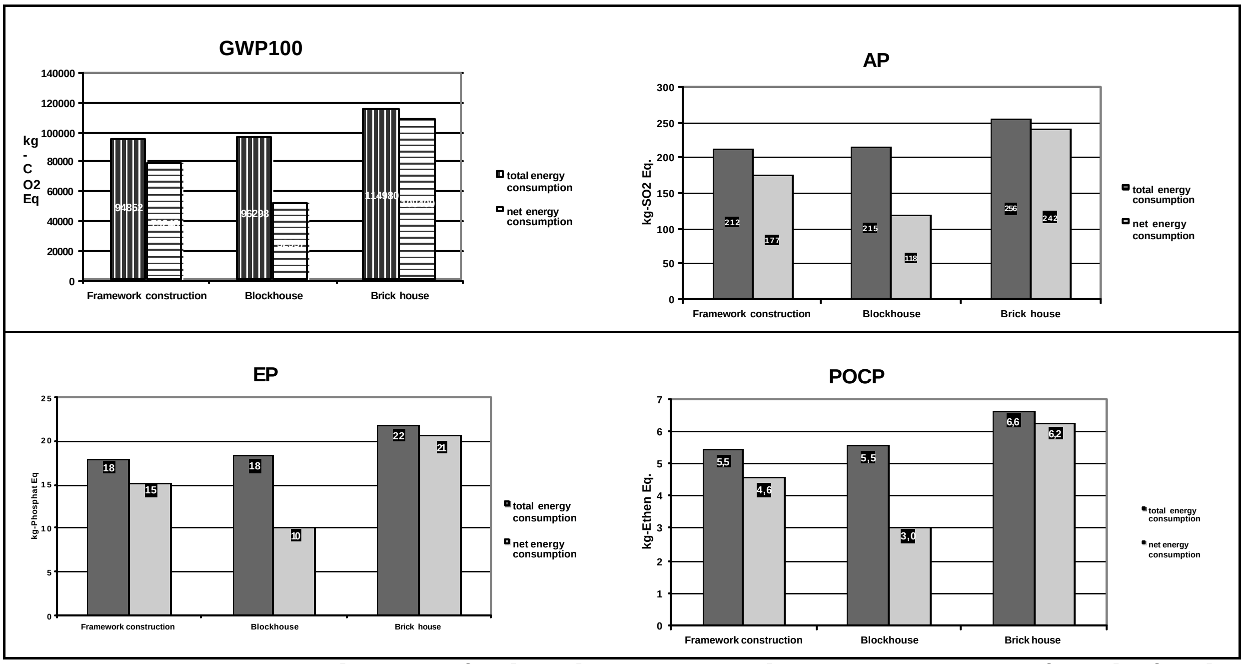


Fig.1: Comparative visualisation of selected environmental impact categories of single-family houses, Case A (total energy) and Case B (net energy consumption)

Simple (three-storey) buildings

Two buildings are compared, Building 1 consisting of 1000 tonnes of wood and 60 tonnes of steel and Building 2 only of steel. Two cases are analysed, Case A: Total energy consumption excluding the thermal utilisation of waste wood and Case B: Net energy consumption including the thermal utilisation of waste wood.

Case A: Total energy consumption

The total energy inputs for Building 1 and Building 2 are 5 460 GJ and 17 000 GJ, respectively. Even without thermal utilisation of waste wood, the wood building shows significant advantages which indicates the dominance of wood as an environmentally sound building material. The results obtained show that compared to Building 1 the environmental burdens caused by Building 2 are more than three times higher.

Case B: Net energy consumption

At the end of life cycle, the waste wood from Building 1 is considered as a C02-neutral energy source which provides an additional 7 290 GJ of energy and replaces fossil energy of the same amount. The substitution of fossil fuel results in the reduction of the corresponding amount of emissions in the atmosphere. Therefore, in Table 2, the figures for impact potentials have negative values and show the importance of timber as an environmentally sound building material. The energy input for Building 2, however, remains at the high level of 17 000 GL.

Table 2: Environmental impact resulting from simple three-story industrial buildings (hall)

	Building made from :	Case A (Total energy consumption)		Case B (net energy consumption)	
Impact	Unit	Building 1 (from wood & steel)	Building 2 (from steel)	Building 1 (from wood & steel)	Building 2 (from steel)
GWP100	kg CO2-eq.	1,096,000	3,410,000	-1,463,000	3,410,000
AP	kg SO2-eq.	2,445	7,613	-3,264	7,613
EP	Kg phosphate-eq.	208	648	-278	648
POCP	kg ethene-eq.	63	196	-84	196

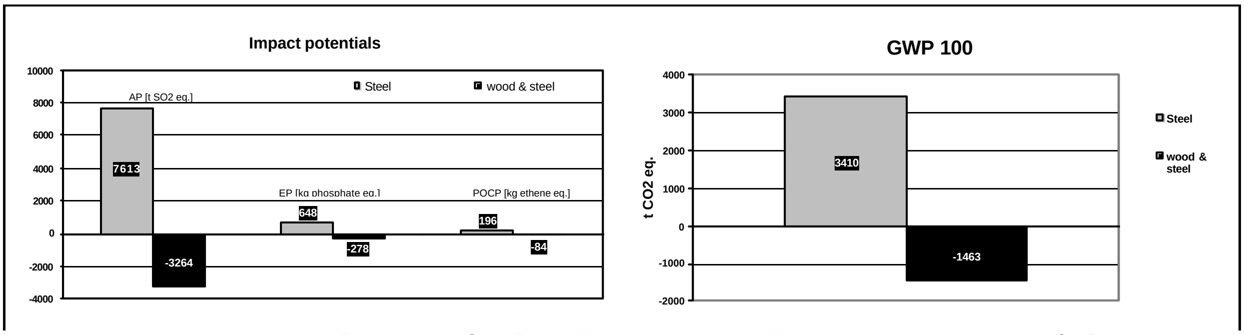


Fig.2: Comparative visualisation of selected environmental impact categories of three-storey building, Case B (net energy consumption)

The subjects of investigation were windows made from aluminium, PVC and wood. It is assumed that the glazing is the same for all three frame types and, therefore, the glass is not included in the analysis of impact assessment. The functional unit is a two-wing window of 1650 mm * 1300 mm. The window frames have a lifetime of 30 years; maintenance during the use phase is included.

The results achieved lead to the following conclusions:

- For all impact categories concerned the environmental burden of wooden windows is the lowest.
- Regarding the wooden window, waste wood can replace fossil fuel so that the environmental impact is reduced.
- Acidification potential (AP) of the wooden window amounts to only 40 percent to 47 percent of that of aluminium and PVC windows.
- Concerning the eutrophication potential (EP) and the photochemical ozone creation potential (POCP), the results for the wooden window are around two-thirds of that for other windows.

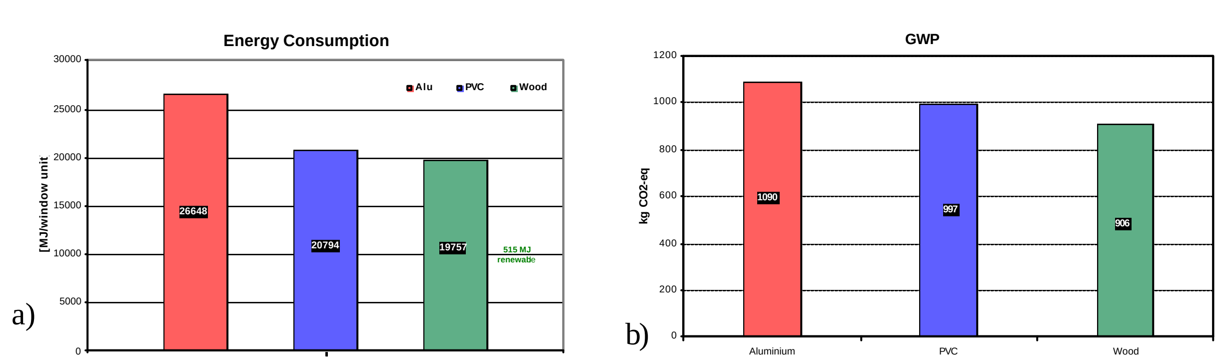
The following are differences in the impact potentials for various modules:

Concerning the global warming, the lifetime impact of a windows is high. Due to the periodical treatment with paint, lacquer or other chemicals, the wooden window results in having the highest GWP impact followed by PVC and aluminium. However, when the entire life cycle is considered, the wooden window is the most favourable product and the PVC and aluminium windows are placed second and third, respectively.

With regards to AP and EP, the effect resulting from window transport is almost the same for aluminium and PVC as frame material and considerably higher than for the wooden window. In the case of POCP, the transport effect is again for the wooden window the lowest followed by aluminium and PVC windows.

From the viewpoint of frame material, the wooden window shows the lowest AP, EP and POCP. Aluminium and PVC are alternately placed second and third.

Concerning the environmental impact of **lifetime, AP, EP and POCP** are for the three window types almost the same. However, the wooden window shows a slightly higher potentials than the other window types.



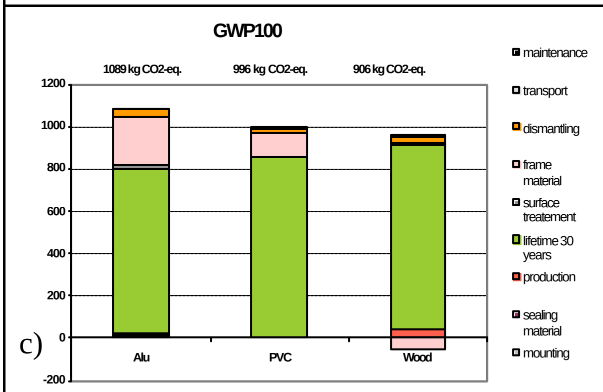


Fig. 3: Environmental impact of windows

a) Energy consumption
b) Global warming potential (GWP)
c) GWP split up into different phases of the life cycle, showing the very significant contribution of the use phase

Flooring materials

The analysis of flooring materials includes the ecological comparison between wood, PVC and linoleum. Basic data used in the study were taken from Äsa Jönsson (1995). Whereas the methods applied by Jönsson for comparing wood, PVC and linoleum flooring materials differ from the LCA method, the resulting impact assessment within the framework of this study based on Jönsson's data was conducted according to ISO 14042.

The analysis includes the importance of wood as substitute for fossil fuels as well as the environmental impacts of different flooring materials. The results obtained lead to the following conclusions:

- Pinewood as flooring material consumes the lowest amount of energy (electricity and fossil) followed by linoleum and PVC.
- Burning wood at the end of life cycle has no negative effects, because the CO_2 released was removed from the atmosphere by photosynthesis.
- Non-renewable materials as components of linoleum and PVC cause negative effects due to the additional CO_2 released to the atmosphere.
- Besides the CO_2-neutrality, the renewable waste can substitute equivalent amount of fossil fuels leading to the reduction of CO_2 in the surrounding atmosphere.
- PVC shows the highest GWP (4.2 kg/M2) which is 2.5 times more than that of linoleum (1.6 kg/m2), while the effect of wood is very small (0.42 kg/m2) and can be more or less neglected.

- With regard to AP, PVC again shows the worst record followed by wood and linoleum, and the fact that wood shows higher potential than linoleum might be related to the incineration process.
- The ecologically most unfavourable result for wood flooring is the relatively high EP, whereas PVC flooring shows the lowest ER concerning POCP, however, wood as flooring material is the best, whereas PVC and linoleum are placed second and last respectively.

CONCLUSIONS

Wood is an environmentally friendly building material. It is CO_2-neutral and it is produced in a sustainable way, at least in Europe. But, the subjective impression that with respect to environmental aspects wood products are superior than the competing products can also be proved by hard facts. The results of the comparative LCA studies clearly indicate that wooden products and products systems based on wood show advantages in most environmental impact categories. This rather positive result is not surprising for wood technologists and LCA experts with timber related background.

In decision making processes environmental aspects have become more important during the last decade. The question which can be raised in this contexts is: Why do wooden products still have to face such strong substitution pressure?

There are many reasons. First of all, the environmental behaviour is not the only aspect that influences the decision in favour or against a product. Other features, such as technical behaviour, regulatory affairs (standards, building codes, fire protection directives, etc.), durability, image, habits and, last but not least, the costs of the product, heavily effect the decision. We all know that wood based products also have some disadvantages. Wood shrinks and swells, it is prone to biological attack which may end in total deterioration, it needs continuous attention and maintenance, it can burn, etc.. Customers may rate such behaviour very differently. In addition, cost effects should not be forgotten.

In order to better understand why wooden products still have to face substitution one should consider the following list of preferences in decision making process of many customers.

1) Regulatory affairs often direct the decision in a certain direction. This can hardly be influenced by the customer. An example for such an obstacle are the fire hazard regulations in many countries, which prohibit or restrict the use of wood in many building types.

Necessary measures: Work towards wood friendly building codes, where ever this is necessary and reasonable!

2) Technical superiority is very important when it comes to decision making. Customers tend to chose the technically best and most durable solution when ever the costs for this solution are still reasonable.

Necessary measures: Design wooden products and product systems technically sound so that they will stay in service for a long time! Low durability and high maintenance efforts will negatively effect the image of wood and the customers perception on the long term.

3) Wooden products and product systems must be cost effective and competitive! Higher prices for wooden products compared to competing products can only be justified if there are other features, such as very positive image, aesthetics, technical superiority (e.g. better insulation properties), which are rated high by the customers.

Necessary measures: Produce wooden products cost effective in order to be competitive!

4) The knowledge about the advantages of using wood in constructions is rather limited. This is not only the case for architects, also the end users often do not know enough about wood. This limited knowledge often leads to wrong utilisation of wood and consequently to problems which negatively affect the image of wood.

Necessary measures: Provide easy to use and understandable technical information to architects and end users! Advertise the advantages of wood in an appropriate way!

5) Many environmentalists still believe that trees should stay is the forest in order to preserve nature. Certainly environmental preservation is an important task, but there are environmentally sound forest management systems which secure sustained utilisation of forests without endangering the nature.

Necessary measures: Inform environmentalists and politicians about environmentally sound forest management systems and possibilities for sustained utilisation of renewable resources!

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