Industrially manufactured nature-based building products

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Summary

The Nature CO2 project carried out a preliminary study on nature-based building (NBB) products and their potential use in Finland. The manufacture and use of these low-carbon products has rapidly increased in Central Europe, and there is a desire to bring information about these products to the Finnish building materials industry as well. The main tasks of the project were the survey of building products, the calculation and comparison of carbon contents, and the study of the potential use of the products. At the same time, the aim was to investigate the research and development needs of products and structures and to outline the lower limit of carbon foot print for the use of the coming Finnish climate declaration of construction projects.

1. Introduction

NBB products consist of renewable and common raw materials from agriculture, forestry and excavation (Figure 1) and can be produced without high temperatures.

Figure 1. The raw materials of NBB products.

NBB products are part of low-carbon construction products, and they have similarities with construction products that are made from bio-based and circular economy materials as well as industrial side streams (Figure 2).

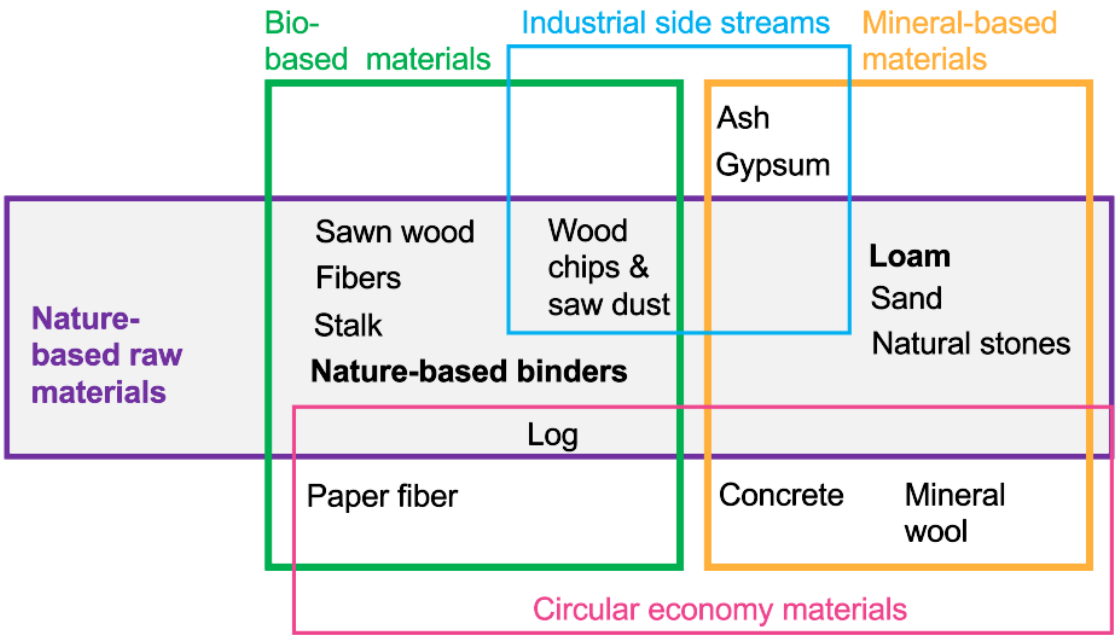


Figure 2. The raw materials of NBB products in ratio to other low-carbon raw materials.

In three decades, the manufacture and use of NBB products has expanded rapidly in Central Europe, and today there are dozens of products and extensive product families available. This preliminary study on NBB products, funded by the Ministry of the Environment and companies, was carried out between 1.5.-31.12.2022 and was divided into the following 3 work packages.

2. Survey of nature-based building products

The main task of the project was to map European industrially manufactured NBB products, for which product cards were prepared in the final report. According to the methods of manufacture and application as well as technical characteristics of the products, the products were divided into 11 product groups (Table 1). Each manufacturer has its own version of the product, and thus the compositions and properties of the products also vary.

Table 1. Groups of NBB products.

1. Straw elements

Raw materials: Wheat or oat straw, Wooden frame.

The straw is installed on a wooden frame to the desired density, the straw surfaces are cut flat, and the sides or ends are closed with plywood or glulam, depending on the product. The wind protection is a membrane permeable to water vapour, which can also be used to protect the inner surface of the element during installation.

The elements can be used to build heat-insulating and load-bearing external walls up to six floors, and they are also used for additional insulation of old buildings or, for example, for insulation. as an insulating layer of solid wood elements.

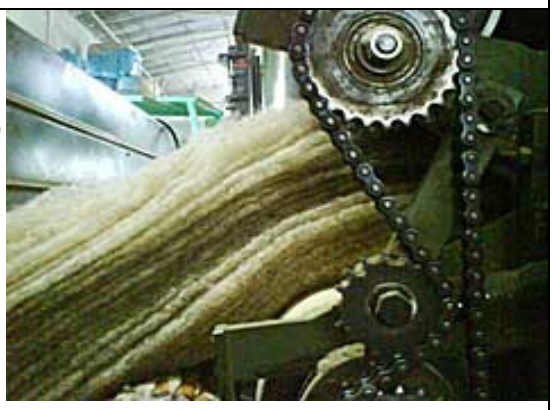
2. Plant-based insulation wools

Raw materials: Hemp, flax, jute, cotton, peat, polyester, flame and mould retardants.

For the production of plant-based insulation boards and wool, short fibers of plants are used, which are not utilized by the textile industry. The fibres are carded into overlapping layers, which are bonded together, e.g., by carding. polyester fibre obtained by melting from recycled bottles. The insulation thus obtained is then treated with a flame and mould retardant and packaged in rolls or semi-rigid boards.

Insulation up to 250 mm thick can be made with the binder, but thinner mats or strips can also be made without binders.

3. Sheep's wool insulation



Raw materials: Sheep's wool, polyester.

The wool of free-grazing sheep is mostly thick and durable fibre, which is not suitable for textile production, but is nevertheless excellent for producing wool insulation. The shorn wool is sorted, washed, dried and carded into thin gauzes that can be joined together mechanically by needling or glued together with melted polyester.

Light sheep wool insulation is normally used for insulation, and a denser carpet is used as an underlay felt for parquet.

4. Blow insulators

Raw materials: Cutter chips, straw, hemp, flame retardant.

The cutter chips are sifted out of the finest ingredient and the straw ingredients are shredded before packaging. The flame retardant used is ammonium phosphate, which is considered environmentally friendly and has no health hazards.

The insulation is blown by a purpose-built machine between horizontal beams or into an enclosure consisting of air barrier paper, boards and a wooden frame. Planed chips as thermal insulation are currently being studied in the Ecosafe project carried out in Tampere University [1].

5. Compressed stalk boards

Raw materials: Straw, hemp, polyester, resin, lime.

The manufacture of the boards includes pressure and heat, after which the boards are cut to measure and dried.

The main application of the boards in Central Europe is additional thermal insulation and plastering substrate on the exterior side of the masonry. Being well permeable to water vapor, they are well suited as a substrate for lime plaster and provide better impact resistance than mineral wool. Boards are also used as a substrate for clay plastering on the interior surface and as additional heat insulation, especially in the repair of historic houses.

6. Reed boards and mats

Raw materials: Reed, galvanized steel wire.

Lake reed does not need to be sown or fertilized, so the cost of the product comes mainly from winter cutting, transportation and preparation. Reed mats tied with galvanised iron wire and reed boards consisting of several layers of reed are made from reeds of uniform thickness. Fastening to the wooden structure is carried out with galvanized nails or clasps.

Reed board has been used as thermal insulation for facades and as a plastering substrate, as well as reed mat. It can also be used for sound insulation for intermediate floors.

7. Clay mortars

Raw materials: Clay, sand, straw, hemp shives, wood fiber, pigments.

The clay mortar ingredients are mixed dry in the mill using multi-axis mixers, after which the mortar is bagged.

Clay plasters are suitable for new and renovation construction of interiors, and they can also be used as fire protection and sound insulation of log structures and other wooden structures. Plaster mortar can be mixed and sprayed using conventional construction site machines or applied traditionally with hand tools. Clay mortar does not harden when wet, which is why plaster residues can be reused. Clay mortars are also used for masonry of furnaces.

8. Clay boards

Raw materials: Clay, sand, perlite, wood fiber, hemp fiber and shives, straw, hay, jute fabric, fiberglass mesh, reed mat.

Clay boards are pressed into the mold from a moist clay mass. Surface reinforcement mesh and heating or cooling piping can be integrated into the board by rolling the clay mass, or products can also be manufactured by striking from very dry mass to avoid drying shrinkage and cracking and save on drying costs. Fireproof clay boards are screwed into framed walls and suspended ceilings, where they balance heat and moisture and insulate sound. The boards are overplastered with fine plaster, and painted with clay paint.

9. Clay masses and elements

Raw materials: Clay, sand, gravel, straw, hemp hurd, cutter shaving.

The clay masses are mixed dry, bagged, and delivered to builders. The builders use a pneumatic impactor to ram the heavy mass into wall formwork or to make floor covering. Wall elements can also be made from masses using industrial methods, and conventional casting and spraying methods can be used in construction. In addition, structures can be 3D printed from fine clay mass. Biomaterials give the light clay mass thermal insulation and, e.g. cutter shaving can be clayed to improve its moisture capacity.

10. Clay bricks and tiles

Raw materials: Clay, sand, perlite, crushed brick, straw, wood fiber, sawdust, hemp fiber and hurd.

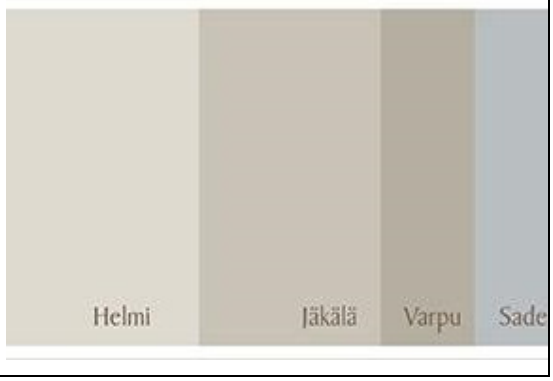
Clay bricks and boards are mold pressed and extruded from a moist clay mass or manufactured by striking from a very dry mass, such as clay boards. They are not burned, but waste heat of brick factories can be used to dry products.

In Central Europe, clay bricks are used primarily in the restoration of the walls of historic half-timbered houses as a filling for the load-bearing wooden frame. Dense bricks can also be used to build load-bearing walls in new construction. The floor tiles are laid as soundproofing mass on the wooden intermediate floors, on top of which e.g., a parquet can be installed.

11. Paints and coatings

Ingredients: Starch, linseed oil, tar, clay, milk, egg, pigments.

Natural paints and coatings are made using a paint mixing mill, mixing bio- and mineral-based binders with pigments, after which the paints are canned. Earth colours extracted from the ground, such as ocher, sienna, umbra and also carbon are the longest used pigments. Nowadays iron oxide is the most common ingredient for the pigments. Among natural paints and coatings, there is a product for all surfaces in buildings.



The thermal conductivity of products developed as heat insulators is at best in the class of mineral wool, but the selling point of most products is good sound insulation, which increases with density. The frequently cited beneficial effects of NBB products on indoor air conditions are largely based on their building physical and chemical properties and can be classified into the following 5 groups:

- Humidity balancing ability of room air
- Room temperature balancing ability
- Fault tolerance and moisture safety of structures
- Low chemical emissions and non-toxicity
- Odor elimination

These positive effects on indoor air conditions and the health of building users strongly support the use of NBB products.

Conventional wood products are well known and are already manufactured in Finland, so there was no need to make their own product cards for them. In addition to vertical loads, wood is able to absorb well horizontal loads due to its high bending strength and act as a beam. NBB products have been successfully used in various wood structures, such as log walls, solid wood panel structures, vertical and horizontal frames and column-beam structures.

3. Calculation of carbon content

Based on the available Environmental Product Declarations, NBB products could currently reduce the carbon footprint of conventional wood structures by an estimated 10–15%. In the future, investment and production volumes as well as renewable energy sources will have a major impact on the production costs and carbon footprint of NBB products. However, due to the constantly growing wind power capacity and good raw material availability, Finland has excellent starting points for the manufacture of nature-based and low-emission building products. One of the biggest sources of the carbon footprint of bio-based products are fertilizers made from fossil materials. Replacing these with bio-based fertilizers would reduce the carbon footprint of bio-based products significantly.

The project also proposes a method to take into account the carbon handprint of products by using carbon capture from bio-based construction demolition waste (Figure 3). For example, pyrolysis would leave about half of the carbon stored in structures unreturned to the atmosphere. By using stalk and other annual crops as raw material for building products, the carbon sink does not disappear either.

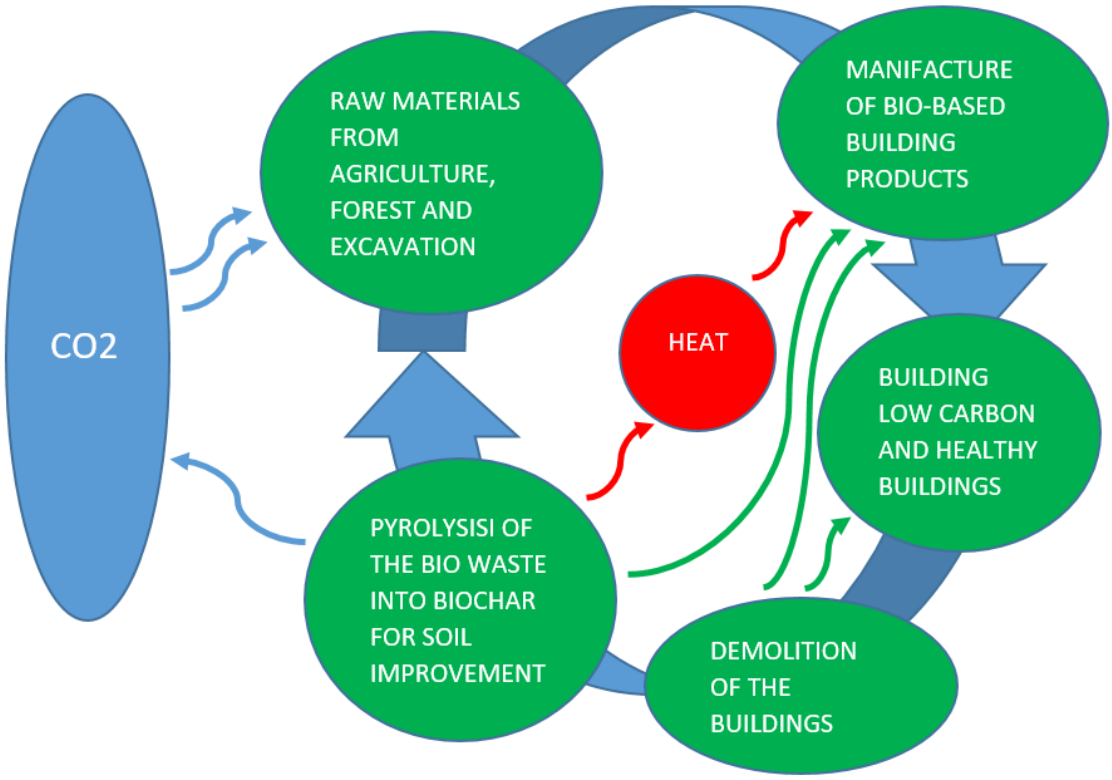


Figure 3. Proposal on the capture and use of bio-based carbon in building products as biochar.

Carbon dioxide can also be filtered from combustion gases in the manufacture of bio-based building products and the incineration of demolition waste. However, it must be possible to store this liquefied carbon dioxide for a long time in order to be taken into account in the climate declaration of the construction project [2-4].

4. Application potential

The potential for using NBB products in Finland was investigated in a workshop and product exhibition (Figure 4) as well as with the help of a subsequent internet survey. Products that are already used in Finland fared best in the product survey, and the respondents would accept prices on average 15–20% higher than conventional building products.

Figure 4. In connection with the workshop, a product exhibition of NBB products was organised.

5. Summary

A survey of NBB products manufactured industrially in Europe found a large number of products that were made into 11 product cards based on methods of manufacture and application as well as technical characteristics of the products. The surveyed products would be well suited to complement the wooden structures used in Finland, and several building construction concepts could be innovated from their combinations. The health effects of NBB products are largely based on their building-physical and chemical properties, such as the ability to balance humidity and temperature in indoor air, moisture security, and the avoidance of microbial problems, chemical emissions and odours in structures. The health effects strongly support the use of NBB products. Based on the available EPDs, NBB products could currently reduce the carbon footprint of conventional wood structures by an estimated 10–15%. In the future, investment and production volumes as well as renewable energy sources and the type of fertilizer will have a major impact on the production costs and carbon footprint of NBB products. In the product survey, products that are already used in Finland fared best, and the respondents would accept prices on average 15–20% higher than conventional building products.

The final report of the project can be downloaded from: https://urn.fi/URN:ISBN:978-952-03-2835-1 and more information obtained from: Mikael.Westermarck@tuni.fi

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